Alien terrestrial arthropods of Europe

Edited by

Alain ROQUES, Marc KENIS, David LEES,
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Jean-Yves RASPLUS and David B. ROY

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EDITORIAL

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DAISIE and arthropod invasions in Europe

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A milestone in the knowledge of alien species in Europe has been achieved by the DAISIE (Delivering Alien Invasive Species Inventories for Europe) project. Through the Sixth Framework Programme of the European Union, DAISIE has delivered a major portal for information on biological invasions that is publicly available at http://www.europe-aliens.org. The rationale was to develop a pan-European inventory of invasive alien species by integrating existing databases, to describe patterns and evaluate trends in biological invasions in Europe, identify priority species and assess their ecological, economic and health risks and impacts. Although an on-going process, the foundation, scope, and technological architecture of DAISIE was established through a consortium of leading researchers of biological invasions in Europe from 19 institutions across 15 countries and delivered through the cooperation of experts in ecology and taxonomy from throughout Europe that in total amounted to 182 contributors. The inventory, accounts, and distribution maps today provide the first qualified reference system on invasive alien species for the European region. The information presents an outstanding resource to synthesise current knowledge and trends in biological invasions in Europe. The data will help identify the scale and spatial pattern of invasive alien species in Europe, understand the environmental, social, economic and other factors involved in invasions, and can be used as a framework for considering indicators for early warning.

A key component of DAISIE is *The European Alien Species Database*, an inventory of all alien species in Europe, and resulted from compiling and peer-reviewing national and regional lists of alien fungi, bryophytes, vascular plants, invertebrates, fish, amphibians, reptiles, birds and mammals. Data were collated for all 27 European Union member states (and separately for their significant island regions), other European states (Andorra, Iceland, Liechtenstein, Moldova, Monaco, Norway, the European

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part of Russia, Switzerland, Ukraine, former Yugoslavia states) and Israel. Marine lists are referenced to the appropriate political region with administrative responsibility. To have full coverage of the European marine area, the data for countries bordering the Mediterranean Sea in North African and Near East countries are included. By November 2008, records of 10,771 alien species, were included in the database, belonging to 4492 genera and 1267 families. Both species of exotic origin and species of European origin introduced in European regions outside their native range were considered. Plants are most represented accounting for 55% of all taxa (5789 species), terrestrial invertebrates 23% (2477 species), followed by vertebrates (6%), fungi (5%), molluscs (4%), Annelida (1%) and Rhodophyta (1%). In total, the database includes records of 45,211 introduction events to particular regions (plants: 28,093; terrestrial invertebrates: 11,776; aquatic marine species: 2777, terrestrial vertebrates: 1478; aquatic inland species: 1087). Due to unprecedentedly thorough assessment, DAISIE substantially improved the accuracy of estimates of alien species numbers derived from previous datasets.

The information accumulated by DAISIE has been summarized in the *Handbook of Alien Species in Europe* (DAISIE 2009), which contains analytical chapters on each taxonomic group, and fact sheets of the 100 most invasive alien species in Europe with distribution maps and images. The book also lists all alien species recorded, ranked taxonomically; this list can be used as a reference for future assessment of trends in biological invasions in Europe. The current volume "*Alien terrestrial arthropods of Europe*" largely follows the lead set by the *Handbook of Alien Species in Europe* but provides much needed detail on one of the largest and most complex taxonomic groups, the arthropods.

Unlike other groups of animals and plants, no checklist of alien terrestrial invertebrates was available in any of the European countries until the beginning of this century. Thus more than any other taxonomic group, creating an inventory of invasive alien arthropods in Europe proved to be a major challenge. Consequently, an estimate of the importance of terrestrial alien invertebrates at the European level remained impossible, largely due to the limited taxonomic knowledge regarding several major arthropod groups. As a result, the initial analyses in DAISIE were drawn from the most reliably studies group, the insects. Even with such a partial picture, the new evidence emphasised the need for more detailed assessment of alien arthropods. For example, the initial work in DAISIE has shown that approximately 90% of terrestrial insects having arrived into Europe unintentionally (75% associated with a commodity, 15% as stowaways). The highest numbers of insects occur in human-made habitats (ruderal, cultivated land, parks and gardens) and invasions are concentrated to these few highly invaded habitats. Not surprisingly insects are one of the taxonomic groups with the most species causing impacts in Europe, and most of these impacts are on the economic rather than environmental sectors. In this regard, *Alien terrestrial arthropods of Europe* extends the initial work in DAISIE and develops a clearer picture of arthropod invasions across a much larger taxonomic range than insects. This substantial work will set the benchmark for authoritative assessments of invasive terrestrial invertebrates.

Through DAISIE, Europe is today the continent with the most complete information on its alien biota. The continent has been working towards implementing an effective strategy on invasive alien species and DAISIE is considered as one of the major instruments towards achieving this goal. An internet-accessible knowledge base, such as DAISIE, can provide crucial information for the early detection, eradication, and containment of invasive aliens —which is most achievable for species that have just arrived. As a result of DAISIE, managers and policy-makers addressing the invasive alien species challenge can easily obtain data on which species are invasive or potentially invasive in particular habitats, and use this information in their planning efforts. Agencies responsible for pest control can quickly determine if a species of interest has been invasive elsewhere in Europe. Importers of new alien species can access data to make responsible business choices. Land managers can learn about control methods that have been useful in other areas, reducing the need to commit resources for experimentation and increasing the speed at which control efforts can begin. DAISIE is potentially a model for other continents which currently have much less detailed information on their alien biota.

References

DAISIE (2009) *Handbook of Alien Species in Europe*. Dordrecht: Springer.

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RESEARCH ARTICLE

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Introduction
Chapter 1

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Dispersal of organisms is among the most important conditions that has enabled the development of life on earth and the high diversity of species we encounter today. This natural process is guided by biogeographical barriers which subdivide the accessible space of the Earth into compartments: species are limited to islands, summits, lakes, or oceans and shorelines, mountain ridges or climate zones. Such natural boundaries reduce competition, create conditions for speciation, and form the basis for the evolutionary centre where a given species has originated. This species is then **native** (indigenous) to this area.

These natural biogeographical barriers have increasingly been overcome by human dispersal and humans now inhabit all parts of the world. This process of human dispersal started in Africa more than 100,000 years ago, and is an intrinsic part of human history. At first, this slow but continuous conquest was performed by walking, at the natural speed of humans, and was limited by the physical condition of individuals. The speed of movements increased in the last centuries and today, we can reach virtually any spot on earth by airplane within 24 h. The turning point was certainly, when sailing ships circumnavigated the world and connected continents. With such big carriers, mass transportation of materials, animals and plants over large distances was also possible.

Christopher Columbus was the second European in the New World (the first discovery of North America by the Vikings some 500 years earlier had no long-lasting consequence, other than the introduction of the North American bivalve *Mya arenaria*

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to Scandinavia in the 1200s (Petersen 1992), and with him the global race duel to connect all parts of the world faster and tighter began. Thus, the year 1492, when Columbus set foot on the first Caribbean island was the starting point of this self-accelerating process later called globalisation.

This process had serious consequences because man did not travel alone. His entourage comprised crop plants and domesticated animals and pets, including all the pests, pathogens and parasites which usually adhere to them. In other words: in the last 500 years hundreds and thousands of species have been spread worldwide both intentionally and unintentionally. Through this human aided spread the biogeographical barriers have become more and more permeable and more and more species are no longer restricted to their native areas.

Species living outside of their natural range and outside of their natural dispersal potential are **alien species**. Their presence in the new habitat is due to intentional or unintentional human activities and without this human support they would never have reached their new area. Thus, there is an important difference between natural dispersal of species that, e.g., allows Mediterranean species to spread north of the Alps because the summers are becoming warmer and man-mediated transport of American, African, Asian or Australian species which then suddenly show up in European harbours or airports and disperse into the hinterland. These last species are called **alien *to* Europe**. Obviously, species of European origin may also be translocated by man outside of their natural range, e.g. Mediterranean species to Northern Europe or species of continental Europe to Atlantic and Mediterranean islands. In this case, they are called **alien *in* Europe**. However, in many cases it appears highly difficult to disentangle the effect of human-mediated transport from that of natural dispersion when a native European species is suddenly found outside its range.

But why is it disadvantageous to increase the number of naturally occurring species (the native fauna and flora) by some alien species? In most (if not all) natural ecosystems the given set of species is the result of a long adaptation and co-evolution to the physical and biotic environment. The higher the natural biological diversity is, the greater the biotic resistance is against additional, foreign species. If ecosystems are disturbed (e.g. by fire, flooding or erosion) or are artificial ecosystems (such as agricultural habitats or urban areas), alien species have a much higher chance to establish.

An alien species will interact with resident species or the abiotic environment in a different manner than a native species and therefore such an additional species is usually neither an enrichment of the ecosystem nor any amelioration of a process. Alien species are usually somehow different from the resident species since they have evolved in a different environment. They may represent a new type of predator, they may have novel weapons, or they may have other new properties which may enable them to alter habitats or even ecosystem functioning. They can fill hitherto empty niches, they may change matter flux or impact energy flow. Such changes affect the resident species most often in a negative way and native species may become less common or even disappear. At this stage, the alien species impacts the invaded ecosystem and becomes an **invasive**

species. Usually the term “alien” is used in the sense of “not wanted here” but calling it invasive is a clearly negative attribute.

The consequences of an alien species can be manifold: Most obvious is direct competition with native species, an increasing abundance in the new environment until a complete replacement of native residents occurs. Alien species may be associated with pathogens and parasites or they are pathogens and parasites, which may transfer onto and affect a new host. If the new host is susceptible to the new pathogen or parasite, a strong reduction in the population of this native species will result or even local extinction is possible: The alien species has thus caused a loss of biodiversity.

Further consequences of an alien and invasive species may concern water flux, e.g. by increasing consumption or contamination. Matter flux (primarily carbon or nitrogen) may be influenced by an altered decomposition of plant litter and wood or via nitrogen-fixating symbionts.

Besides such environmental impacts many alien species cause enormous economic impacts or directly influence human or animal health. Many alien invertebrates, especially insects, cause great damage to agriculture and forestry. Many protozoans and “worms” are human parasites and many insects are vectors of bacteria and viruses which cause numerous serious diseases. Today, such super-pests are cosmopolitan but this term camouflages that in most parts of the world, where they occur today, they are alien and invasive species. In the case of humans and on a global scale, they cause millions of fatalities each year.

Not all alien species are invasive and it is in fact strange to observe some aliens for years and decades at a given location that show no signs of obvious spread. The process from the first introduction of an alien species into a new environment until aggressive invasiveness is characterised by several steps and an alien species may fail at each of these steps. After a first introduction, it is decisive if the new environment fits the need of this species. Usually, if the number of individuals is low, the species has a rather small chance of establishing reproducing populations. But the higher this number is or the longer the introduction process lasts, the better the chances are of the new species establishing. Establishment means survival and reproducing viable populations on the spot, which is called the lag phase. The next step is when the alien species produces a surplus reproduction which allows modest migration. In this period an alien species may adapt in some way to its new environment and this phase is often called bottleneck with a transition from the lag phase to the log phase. In the log phase, the alien species reaches more suitable habitats which allow a higher reproduction. By continuous population growth, the population pressure on adjacent areas is increased and impacts on the ecosystem also become evident and increase: now the alien has become invasive. Observing an alien in a non-invasive status does not mean that it will not become invasive (and thus can be tolerated as harmless), it rather means that it is not (yet) invasive but it could be just a matter of time until it becomes invasive. Changes in land use or climate can also enable previously harmless alien species to begin to spread uncontrollably and become invasive.

Roughly 50 years ago, the British ecologist Charles Elton published his *Ecology of invasions by animals and plants*, already then warning of the danger arising from alien and invasive species: "The whole matter goes far wider than any technological discussion of pest control, though many of the examples are taken from applied ecology. The real thing is that we are living in a period of the world's history when the mingling of thousands of kinds of organisms from different parts of the world is setting up terrific dislocations in nature. We are seeing huge changes in the natural population balance of the world" (Elton 1958). Elton was among the first to describe the typical pattern of an alien species establishment. That what he called "biological explosion" is today known as biological invasion (Nentwig 2008). He was also among the first to investigate why and how species were dispersed by human activities and he analysed even then the negative impacts of species in a new environment. He was among the first to ask how this could be prevented.

Astonishingly, the hazards provoked by alien species did not cause that much concern among scientists, nor did it attract public awareness as much as would have been expected (Hulme et al. 2009). However, the ultimate reason for the loss of more than 5% of the world GNP, one main reason for the loss of biodiversity, for millions of human deaths, and for the loss of more than 20% of the world's food production cannot be ignored.

Prevention has multiple faces leading from raising awareness in the public to better scientific knowledge and documentation. More regulations and guidelines must to be put into place and existing regulations must be applied more consequently and carefully. Further import of aliens should be avoided; current aliens should be confined, controlled and even eradicated. We must face this challenge through changes in world trade, adoption of regional strategies and regulations, improved national legislation and better administration, but also through improvements in general education and awareness and the improved spread of information through the media.

Science is also absolutely required in order to manage the problems that alien species may cause. How can they be detected and identified? What is their population development and habitat requirement? What is their impact in the invaded area? How can they be controlled, reduced, or eradicated? How can we predict which species that may become invasive and how can we manage the risks? For most alien species there are yet no answers to most of these questions. Even the seemingly simple question on the number of alien species in Europe could not been answered a few years ago.

Therefore, the European Commission, in its Sixth Framework Programme, launched a call for an inventory of alien invasive species. The successful application was awarded to a consortium of leading researchers of biological invasions in Europe, drawn from 19 institutions across 15 countries. The resulting project, DAISIE (Delivering Alien Invasive Species Inventories for Europe), was launched in February 2005 and ran for three years, until the end of January 2008.

The main objectives of DAISIE were (1) the creation of an inventory of all known alien species in the European terrestrial, freshwater and marine environments; (2) to describe the worst alien and invasive species in Europe and to describe their environmental, economic and health risks impacts; and (3) to compile a directory of experts on alien species. Since February 2008, the DAISIE information system is freely available at http://www.europe-aliens.org. In 2009 a condensed version of the DAISIE information system was published in a Handbook of Alien Species in Europe (DAISIE 2009).

Invertebrates, and among them arthropods, comprise the largest proportion of alien animals and are of pronounced importance, e.g. in agriculture, horticulture and forestry, the cultural environment and for human and animal health. Despite the far reaching and serious effects that alien invertebrate species have on biological diversity, health and society, knowledge of their effects and potential risks is still insufficient. This knowledge is crucial for managing the risks involved with the transfer of species both intentionally and unintentionally. Based on the expert knowledge of 78 scientists from 25 European countries, this book will present for the first time in a comprehensive way the alien arthropods having established in Europe, including detailed information on taxonomy, pathways, invaded habitats, impacts and trends. The book will focus on the 1590 terrestrial arthropod species presently identified as aliens *to* Europe. They will be presented by taxonomic rank. For each group, additional information will be provided about the species alien *in* Europe whenever the actual status of such species can be considered as ascertained with regard to the difficulties mentioned above. Moreover, the 80 most important alien invasive species are presented in factsheets in more detail in order to raise awareness and provide information upon which to base measures to prevent and control these species.

References

DAISIE (2009) *Handbook of alien species in Europe*. Dordrecht: Springer. 399 pp.

Elton CS (1958) The ecology of invasions by plants and animals. London: Methuen & Co. Ltd. 181 pp.

Hulme PE, Pyšek P, Nentwig W, Vilà M (2009) Will threat of biological invasions unite the European Union? *Science* 324: 40–41.

Nentwig W (Ed) (2008) *Biological Invasions. Ecological Studies* 193. Heidelberg: Springer. 441 pp.

Petersen KS, Rasmussen KL, Heinemeier J, Rud N (1992) Clams before Columbus? *Nature* 359: 679.

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Taxonomy, time and geographic patterns
Chapter 2

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Abstract

A total of 1590 species of arthropods alien to Europe have already established on the continent, including 226 more or less cosmopolitan species of uncertain origin (cryptogenic). These alien species are dispersed across 33 taxonomic orders, including crustaceans, chilopods, diplopods, pauropods, Symphyla, mites, arachnids, and insects. However, insects largely dominate, accounting for more than 87% of the species, far in excess of mites (6.4%). Three of the insect orders, namely Coleoptera, Hemiptera and Hymenoptera, overall account for nearly 65 % of the total. The alien fauna seems to be highly diverse with a total of 257 families involved, of which 30 have no native representatives. However, just 11 families contribute more than 30 species, mainly aphids, scales and hymenopteran chalcids. For a number of families, the arrival of alien species has significantly modified the composition of the fauna in Europe. Examples are given. The number of new records of aliens per year has increased exponentially since the 16th century, but a significant acceleration was observed since the second half of the 20th century, with an average of 19.6 alien species newly reported per year in Europe between 2000 and 2008. This acceleration appears to be mainly related to the arrival of phytophagous species, probably with the plant trade, whereas the contribution of detritivores, parasitoids and predators has decreased. Some taxa have not shown any acceleration in the rate of arrivals. Asia has supplied the largest number of alien arthropods occurring in Europe (26.7 %), followed by North America (21.9%) but large differences in the region of origin are apparent between taxa. Once established, most alien species have not spread throughout Europe, at least yet, with 43.6 % of the species only present in one or two countries, and less than 1% present in more than 40 countries. Large differences also exist between European countries in the total number of alien arthropods recorded per country. Italy (700 species) and France (690 species), followed by Great Britain (533 species), host many more species than other countries. The number of alien species per country is significantly correlated with socioeconomic and demographic variables.

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Keywords

aliens, arthropods, Europe, globalization, taxonomy, Asia, drivers of biological invasion

Introduction

Expanding world-wide trade, globalisation of economies and climate change are all factors that contribute to an accelerated international movement and establishment of alien organisms, allowing them to overcome geographic barriers (Hulme et al. 2008, Hulme 2009, Walther et al. 2009, Roques 2010). These alien species have already been shown to impose enormous costs on agriculture, forestry as well as to threaten human health and biodiversity (Williamson 1996, Wittenberg and Cock 2001, Pimentel et al. 2002, 2005, Vilá et al. 2009). Although terrestrial arthropods, and particularly insects, represent a large part of the alien species problem, they appear to have received disproportionately less attention compared to plants, vertebrates, and aquatic organisms, especially regarding their possible ecological impact (Kenis et al. 2009). Most of the works concerning alien terrestrial invertebrates have dealt with case studies of pests having a high economic or sanitary impact, such as gypsy moth (*Lymantria dispar* (L.)) in North America (Liebhold et al. 1992), Asian long-horned beetles (*Anoplophora* spp.; Haack et al. 2010), or Asian tiger mosquito (*Aedes albopictus* (Skuse)*;* Eritja et al. 2005). More synthetic studies have been carried out at guild level (e.g., bark beetles; Brockerhoff et al. 2005) or at ecosystem level, especially for forest insects (Liebhold et al. 1995, Mattson et al. 1996, 2007, Niemelä and Mattson 1996, Langor et al. 2009). However, continental inventories of alien arthropod species, or even of alien insects, are still lacking in most regions, although such studies are needed to assess which taxonomic or bio-ecological groups of alien species are better invaders or more harmful to the economy or environment, and which ecosystems or habitats are at greater risk (Mondor et al., 2007).

In Europe, the potential problems caused by alien arthropods have traditionally been considered as less severe than in North America, Australasia or South Africa (Niemelä and Mattson 1996). As a result, unlike other groups of animals and plants, no checklist of alien terrestrial arthropods was available in any of the European countries until the early 2000s. However, in the last 20 years, several exotic pests of economic concern, to name a few, the western corn rootworm (*Diabrotica virgifera virgifera* LeConte), the red palm weevil (*Rhynchophorus ferrugineus* (Olivier)), the harlequin labybeetle (*Harmonia axyridis* (Pallas)), or the chestnut gall maker (*Dryocosmus kuriphilus* (Yasumatsu)), have invaded Europe, inducing more interest in the issue of alien arthropods. The horse-chestnut leaf miner, *Cameraria ohridella* Deschka and Dimić, an alien in Europe originating from the Balkans, has also raised much public concern because of its spectacular damage to urban trees in invaded areas of Central and Western Europe (Valade et al. 2009).

Thus, checklists of alien arthropods began to be compiled from 2002 onwards, successively covering Austria (Essl and Rabitsch 2002), Germany (Geiter et al. 2002), the Netherlands (Reemer 2003), the Czech Republic (Šefrová and Laštůvka 2005), Scandinavia (Nobanis 2005), the United Kingdom (Hill et al. 2005, Smith et al. 2007), Italy (Pellizzari et al. 2005), Serbia and Montenegro (Glavendekić et al. 2005), Switzerland (Kenis 2005), Israel (Roll et al. 2007), Albania, Bulgaria and Macedonia (Tomov et al. 2009), and Hungary (Ripka 2010). However, a major advance in the knowledge of alien arthropod species established in Europe was the European project DAISIE (*Delivering Alien Invasive Species Inventories for Europe*) in 2008. Besides furnishing national and regional lists, this project provided for the first time an overview of the alien fauna of arthropods that has established on the continent. DAISIE identified a total of 1517 alien terrestrial invertebrates, of which 1424 arthropods. However, limited expertise in some taxa during the DAISIE project meant full coverage of all the terrestrial arthropods could not be achieved with the same level of precision. The working group formed on this occasion therefore decided to continue its activity over the next two years, enlarging its taxonomic scope and competencies, in order to provide the most exhaustive list of the alien terrestrial arthropods of Europe as possible, with detailed information about each species.

The update of the DAISIE list revealed in this book accounts for 1590 arthropod species alien to Europe, i.e. 166 more species, including both additions and deletions from the former list, and a much better coverage of taxonomic groups other than insects and spiders (i.e., mites, myriapods and crustaceans). In order to allow a comparison of their invasive patterns, the different taxonomic groups are presented separately in 21 chapters which have the same format. Because of the large number of species in some groups, these have been divided into several distinct chapters; i.e., four chapters for Hemiptera and five chapters for Coleoptera. Each chapter successively analyzes the taxonomy of the alien species component compared to that of the native fauna, the temporal trends of introduction, the biogeographic patterns, including both details of the region of origin and the distribution of the species in Europe, the pathways of introduction, the ecosystems and habitats which are invaded, and the economic and ecological impact of the biological invaders. At the end of each chapter, a table summarizes key information regarding all species in the taxa which are alien *to* Europe; i.e. of ascertained exotic origin or cryptogenic (see Chapter 1 for definitions): family, feeding regime, date and country of first record in Europe, invaded countries, habitats, plant or animal host, and one reference at least (usually that of the first record). In a number of cases, a second table includes a list and similar information for the species considered as alien *in* Europe; i.e. spreading to new countries within Europe, especially for species of Mediterranean origin recorded in more northern areas and species of continental Europe which have colonized islands. We did not provide such tables systematically. Indeed, it was difficult to ascertain for a lot of these species whether they have been introduced in other parts of Europe through direct or indirect human activity - and thus meet our definition of aliens (see Chapter I) - or they are naturally expanding, e.g. with global warming, or even if their native distribution range was incompletely known before their ''discovery' in these new areas.

The geographic range covered in this book is primarily Europe in geographic sense, with the main Mediterranean islands and archipelagos (Balearic Islands, Corsica, Sardinia, Sicily, Malta, Crete, and the Ionian, North Aegean and South Aegean islands) and those of the North Sea (Aland, Svalbard) which are considered separately from the associated continental countries. Ireland was considered as a single biogeographic entity (i.e., Republic of Ireland plus Northern Ireland). Because of their possible importance as a first step for the invasion of continental Europe, the islands of the Altantic Ocean (Madeira, the Canary Islands, The Azores Archipelgao), were also included in the analysis but they may also correspond to a source of aliens of Macaronesian origin colonizing the European continent.

This substantial work allowed us to figure out the relative importance of the different taxa of alien arthropods in a standardized fashion to other groups as well as to compare their respective habitats (Pyšek et al. 2009), and environmental and economic impacts (Vilá et al. 2009). The present chapter presents the most important patterns exhibited by the terrestrial arthropods alien *to* Europe.

2.2 Taxonomy of arthropods alien *to* Europe

Alien terrestrial arthropods represent the second most numerous group of organisms introduced to Europe (Roques et al. 2009). A total of 1364 species originating from other continents have established so far, to which we add 226 more or less cosmopolitan species of uncertain origin (cryptogenic) for a total of 1590 species. Insects largely dominate this list, accounting for more than 87%, far in excess of mites (6.4%) (Figure 2.1). These alien species are dispersed across 33 taxonomic orders, including two orders of crustaceans, 10 of myriapods (three of chilopods, five of diplopods, one of pauropods and one of Symphyla), four of mites, one of arachnids, and 16 of insects. However, the relative importance of each order is highly variable (Figure 2.2). Three of the insect orders, namely Coleoptera, Hemiptera and Hymenoptera, overall account for nearly 65 % of total alien arthropods, representing 25.0%, 20.0% and 18.7%, respectively. The number of alien Hymenoptera established in Europe is thus much higher than previously considered (Daisie 2009). Diptera (6.2 %), Lepidoptera (6.1 %) Thysanoptera (3.3 %) and Psocoptera (3.1 %) have much lower importance as do Prostigmata mites (4.9 %- see Chapter 7.4) and Aranea (3.0 %), the only non-insect orders to exhibit more than 45 alien species. The other orders are anecdotal. It should be noted that some orders show no alien species whereas there are important components of the native fauna such as Trichoptera. More generally, at the order level, the taxonomic composition of the alien fauna significantly differs from that of the native European arthropod fauna. Calculations done on insects have revealed that establishment patterns differ between orders (Roques et al. 2009). Hemiptera are nearly three times better represented in the alien fauna than in the native fauna (20.0% vs. 8.0%). The alien entomofauna also includes proportionally more thrips (3.3 vs 0.6%), psocids (3.1 vs. 0.3%) and cockroaches (1.1 vs. 0.2%) than the native fauna, but much fewer dipterans (6.2 vs. 21%) and hymenopterans (18.7 vs. 25%). Differences are less pronounced for Coleoptera (25.0 vs. 30.0%) and Lepidoptera (6.1 vs. 10%).

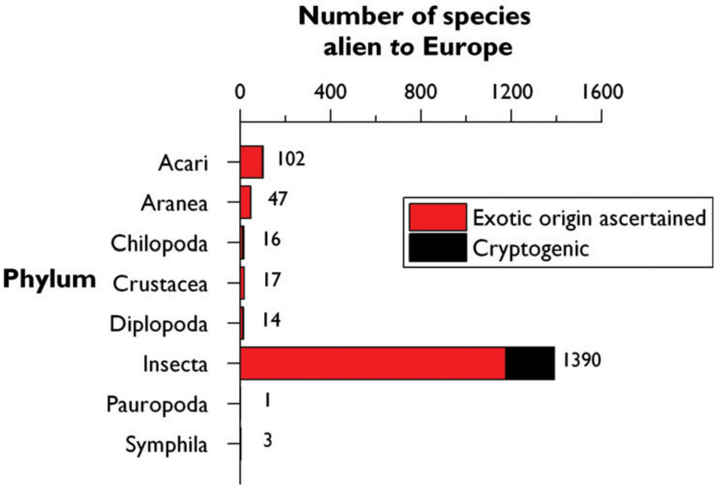

Figure 2.1. Relative importance of the different phyla in the 1590 species of arthropods alien to Europe. Species of ascertained exotic origin and cryptogenic species are presented separately. The number to the right of each bar indicates the total number of alien species observed per phylum.

The alien fauna seems to be highly diverse with a total of 257 families involved. However, only 38 of these families contribute 10 and more alien species, while 11 families more than 30 species (Figure 2.3). These 11 families mostly include hemipterans comprising aphids (Aphididae with the highest number of alien species - 102 spp.) and scales (Diaspididae and Pseudococcidae), as well as hymenopteran chalcids used for biological control such as Aphelinidae (63 spp.) and Encyrtidae (55 spp.), mites (Eriophyidae), and thrips (Thripidae). All of these except snout beetles (Curculionidae) and ants (Formicidae) are tiny arthropods. Noticeably, whilst these families dominate the alien fauna of arthropods, they are less intercepted by the phytosanitary quarantine services at European borders. A comparison done by Roques (2010) between interceptions and establishments of alien species in Europe during the period 1995 – 2005 for the alien insects and mites associated with woody plants in Europe has revealed that the major families of invaders were largely undetected (e.g. aphids, midges, scales, leafhoppers and psyllids). In contrast, the groups which were predominantly intercepted (e.g. long-horned and bark-beetles), actually made little contribution to the established alien entomofauna. Similar results were obtained at country level for Austria, the Czech Republic, and Switzerland (Kenis et al. 2007).

For a number of families, the arrival of alien species has significantly modified the composition of the fauna presently observed in Europe. First, a total of 30 families had no representatives in Europe before the arrival of aliens. These include seven families of myriapods (Henicopiidae - 5 spp., Haplodesmidae, Rhinicricidae, Oryidae, Siphonotidae, Oniscodesmidae, Pseudospirobolellidae, Spirobolellidae, Trigoniulidae - 1 sp. each), four mite families (Listrophoridae - 4 spp., Myocoptidae, Pyroglyphidae and Varroidae - 1 sp. each), and one spider family (Sicariidae - 2 spp.). For insects, no native species existed for three alien families of psocids (Lepidopsocidae - 5 spp., Psyl-

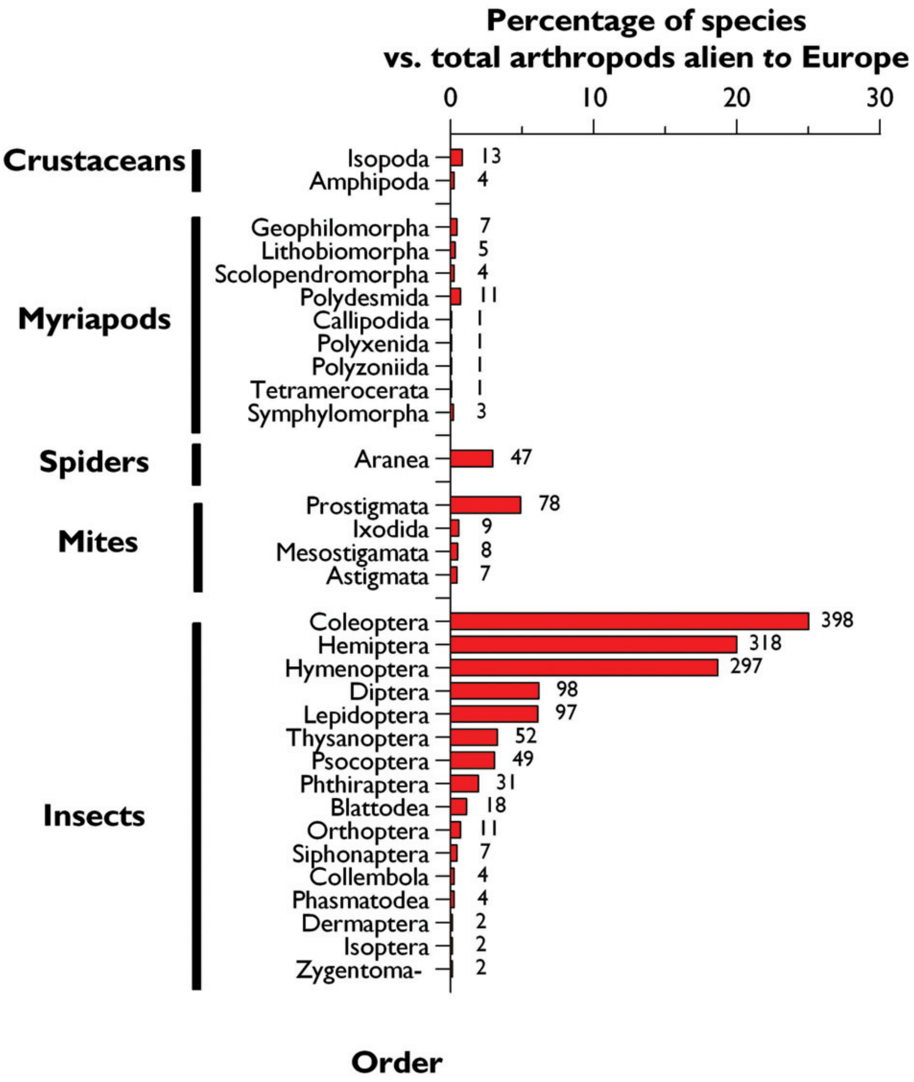

Figure 2.2. Relative importance of the different taxonomic orders in the 1590 species of arthropods alien to Europe. Species of ascertained exotic origin and cryptogenic species are summed. The number to the right of each bar indicates the total number of alien species observed per order.

lopsocidae - 5 spp., and Psoquillidae - 3 spp.), three lice families (Gliricolidae - 2 spp., Gyropidae and Trimenopidae - 1 sp. each), two Blattodea families (Blaberidae - 10 spp., and Blattidae - 6 spp.), two scale families (Phoenicococcidae and Dactylopiidae - 1 sp. each), two beetles families (Ptylodactylidae or little ash beetles - 2 spp. and Acanthonemidae or toe-winged beetles - 1 sp.), one lepidopteran family (Castniidae - 1 sp., the palm moth *Paysandisia archon* (Burmister)), one Phasmatodea family (Phasmatidae - 4 spp.), one family of Hemiptera Auchenorrhyncha (Acanaloniidae - 1 spp.), and one thrips family (Merothripidae - 1 sp.).

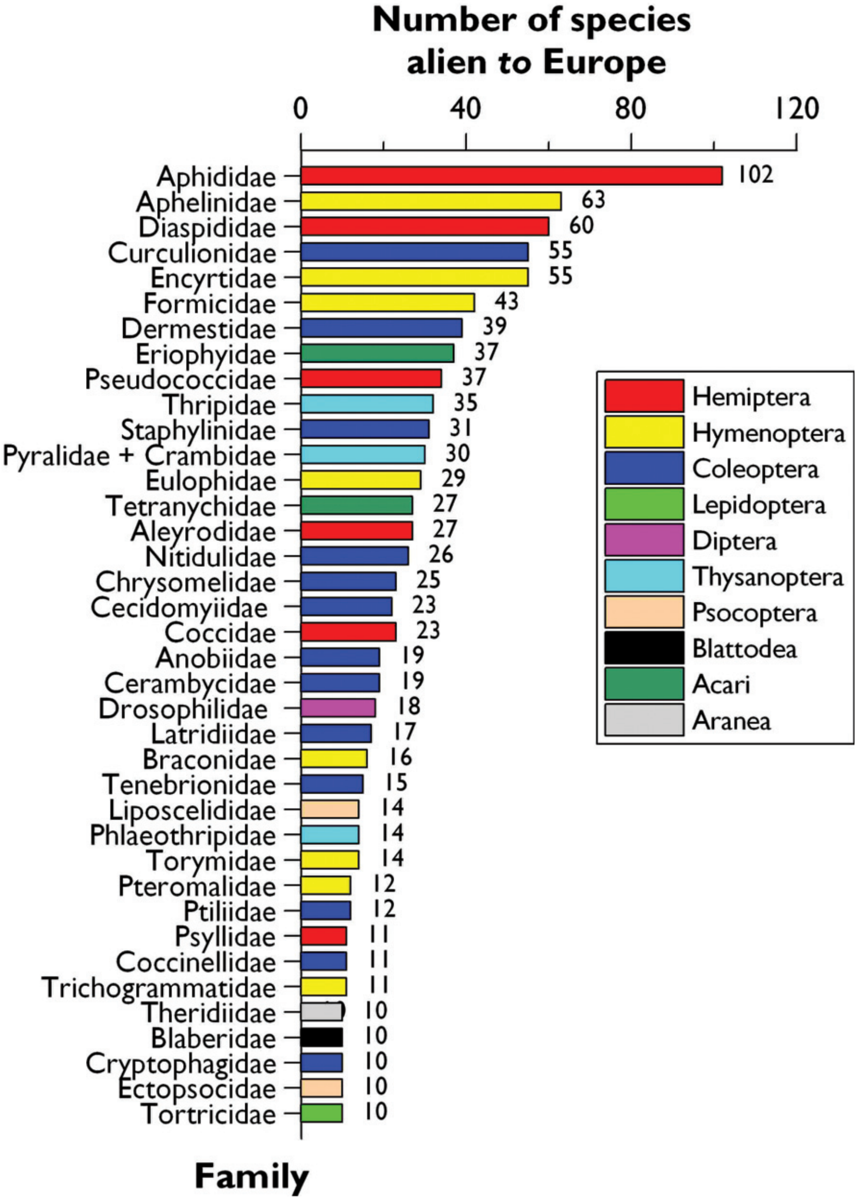

Figure 2.3. Families of arthropods contributing most to the fauna alien *to* Europe. Only the families with numbers of alien species equal to 10 or more are shown. Corresponding taxonomic orders are indicated by different colors. The number to the right of each bar indicates the total number of alien species observed per family.

In some other families, alien species could be over-represented. This is especially true for scales, where aliens now represent nearly half of the total Diaspididae fauna observed in Europe (60 out of 130 species - 44.6 %), a third of the Coccidae fauna (23 out of 70 species - 32.3 %), and a fourth of the Pseudococcidae fauna (37 out of 141 species

- 25.7 %). Similar high proportions of aliens are observed for psocids (Pachytroctidae - 66.7%, Ectopsocidae - 57%, and Liposcelidae - 26.4 %), hemipterans (Aleyrodidae - 39.1 % and Adelgidae - 36.0 %), hymenopterans (Agaonidae - 40.0 %, Apheliniidae 24.2 %, and Siricidae - 23.8%), and saturnid lepidopterans (30.0 %). Even if the relative proportions are lower, the arrival of a large number of alien species has also largely modified the faunal taxonomic structure in dermestid beetles (21.9 % of aliens), tetranychid mites (15.1 %), drosophilid flies (14.8 %), and encyrtid chalcids (7.2 %).

2.3 Temporal trends of arrival in Europe of alien arthropods

Some alien arthropods were introduced to Europe long ago accompanying human movements. For instance, a number of ectoparasites of humans and early-domesticated animals such the head louse (*Pediculus capitis* De Geer), the crab louse (*Phtirus pubis* (L.)), the cat flea (*Ctenocephalides felis felis* (Bouché)), the rat flea (*Xenopsylla cheopis* (Rothschild)) or the human flea (*Pulex irritans* L). are probably allochtonous in Europe, having arrived in ancient times with their hosts (Mey 1988; Beaucournu and Launay, 1990). Thus, *Pulex irritans* was shown to have been present in Europe since the Bronze Age at least, having been found in remains of lake dwellings in the French Jura, dating back to 3100 B.C. (Yvinec et al. 2000). Fragments of insects related to stored products were also found in Roman and Viking graves (e.g., *Sitophilus granarius*; Levinson and Levinson 1994). However, unlike plants and other animal groups, a clear identification of the *archaeozoans** has appeared difficult for arthropods. Therefore, we only qualified as aliens the *neozoan** species, i.e. those having likely been introduced after 1500.

The introduction of alien arthropods is usually accidental, the release of biological control agents remaining limited, as well as the escape of arthropod 'pets' from captivity (see Chapter 3). Thus, the introduction phase is rarely observed and pathways of introduction are poorly known. Consequently, an alien arthropod is usually discovered when it is already established, spreading and causing damage. The precise date of arrival in Europe is not known for most species. Even conspicuous species, such as the Asian long-horned beetle, *Anoplophora glabripennis* (Motschulsky), have been reported with a delay of at least 3–5 years since establishment (Herard et al. 2006). However, taking into account these caveats, the date of first record in Europe- the single temporal datapoint usually obtainable- may be used as a proxy for the date of first arrival.

The date of first record in Europe, relying on published papers, could be obtained for 1421 of the 1590 alien species (89.4%). The number of new records per year appears to have increased exponentially since the 16th century, but a significant acceleration was observed during the second half of the 20th century (Figure 2.4a). As a probable result of globalization, this trend is still increasing with an average of 19.6 alien species newly reported per year in Europe between 2000 and 2008; i.e., a value nearly double the 10.9 species that were observed per year during the period 1950- 1974.

In order to understand better this process, we decompose the values according to the feeding regime of the alien species (Figure 2.4b). Fluctuations in the number of

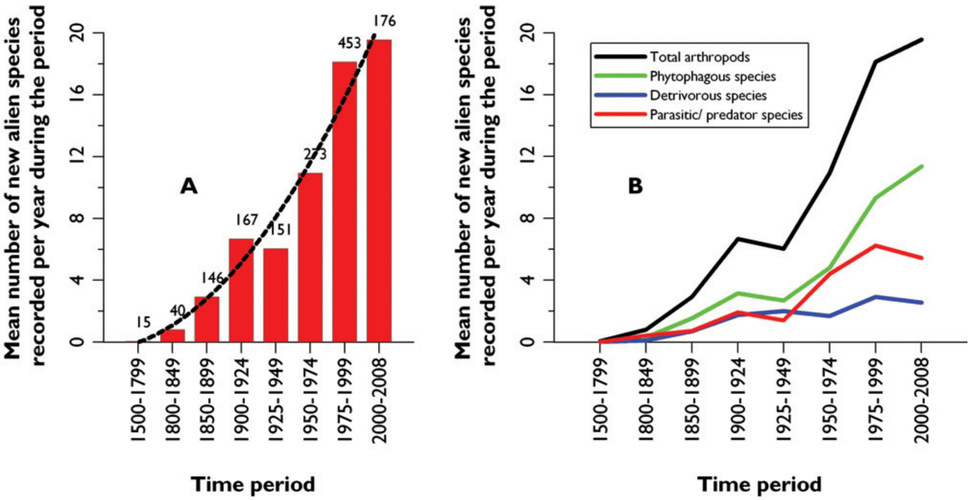

Figure 2.4. Temporal changes in the mean number of new records per year of arthropod species alien *to* Europe from 1500 to 2008. **A** Total arthropods (Best fit: $y= -0.411- 0.407x + 0.304 x^2$; $r^2 = 0.965$) **B** Detail per feeding regime.

total arthropods newly arriving per year in Europe appear to be strongly dependent on the increasing arrival of phytophagous species, especially during the last ten years. In contrast, the number of detritivores and parasitoids/ predators has appeared to decrease during this last decade, and contributed much less to the overall increase, whereas these three feeding guilds had contributed more or less equally during the first half of the 20th century. After the period 1950- 2000 when alien parasitoids and predators markedly increased probably in relation with the wave of releases of biological control agents, the explosion of ornamental trade since the 1990s is likely to have triggered the arrival of alien phytophagous arthropods, as has been shown for insects related to woody plants (Roques 2010). Specific analyses per taxa have confirmed these tendencies. Whereas the arrival of mites (see Figure 7.4.2), scales (see Figure 9.3.2.), flies (see Figure 10.2) or lepidopterans (see Figure 11.2), which are mainly phytophagous groups, has revealed a similar acceleration in the number of newly recorded aliens during the last period, no such trend has been observed for the parasitic lice and fleas (see Chapter 13.4), nor for the detritivorous Blattodea (see Chapter 13.3).

2.4 Biogeographic patterns of arthropod species alien *to* Europe

Origin of the species alien to Europe

A precise region of origin was ascertained for 1271 species (79.9%) of the 1590 alien arthropod species, while 93 species were only known to be native to tropical or subtropical regions. The remaining 226 cryptogenic invertebrates are mostly cosmopolitan species for which there is no agreement regarding their area of origin. This is particularly true for stored products pests and for some ectoparasites on cattle and pets that occur on other continents. A few other cryptogenic species have appeared in Europe without having been detected elsewhere. However, data on their phylogeography, population ecology, parasitoids and dispersal biology strongly suggest that they originate from another continent. The horse-chestnut leaf miner, *Cameraria ohridella*, is illustrative of the difficulty in identifying the native range of such species. Whereas this leaf miner was previously considered as an extra- European alien, recent genetic studies indicate that it originates from the southern Balkans (Valade et al. 2009).

Asia has supplied the major part of the alien arthropods occurring in Europe (26.7 %) followed by North America (21.9%) (Figure 2.5). Analysing specifically insect data per time unit has revealed that the relative contribution of Asia and North America was stable over time (Roques et al. 2009). During the periods 1950–1989 and 1990–2007, 29% and 21% of the established insects were of Asian and North American origin respectively. The contribution of tropical and subtropical areas is surprisingly important. The overall contribution of species from Australasia, Africa, Central and South America in combination with species of undefined tropical areas represents 37% of all alien insects in Europe. While we agree that insect species coming from these areas are not just native to tropical ecosystems, this proportion is nevertheless outstanding.

Unlike the temporal trends, the regions of origin do not differ significantly between feeding regimes. Asia is the main region of origin for alien phytophages, parasitoids/ predators and detrivorous species although a bit less important for the latter group (Figure 2.5).

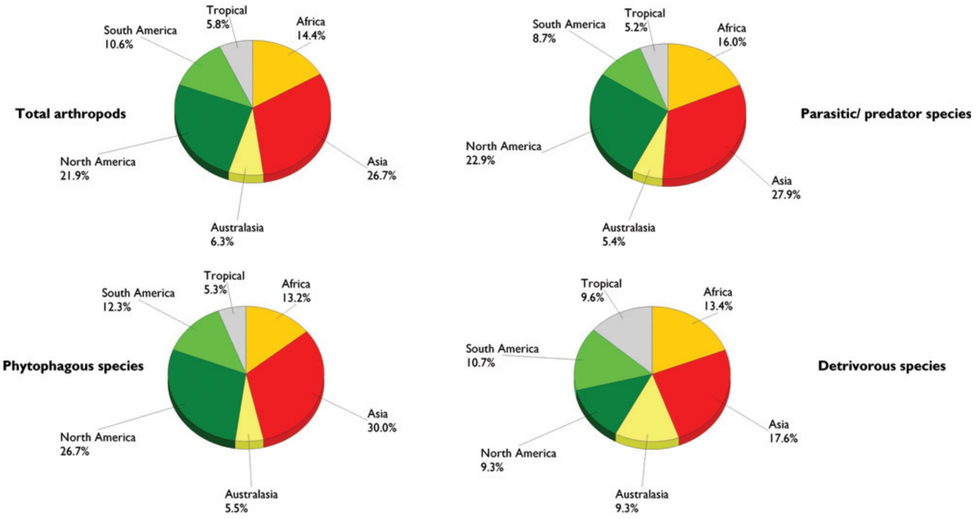

Figure 2.5. Region of origin of the 1590 arthropod species alien *to* Europe. Total arthropods and breakdown per feeding regime are presented. Percentages of the total per category are shown under each region.

However, a comparison of the native range of species from the different orders revealed significant differences (χ_2= 388.26; P=0.0000). Most mites (51.5% - see Figure 7.4.3), hymenopterans (32.3 % - see Figure 12.3), and dipterans (30.6 %- see Figure 10.3) have arrived from North America whilst 37.2 % of lepidopterans (see Figure 11.3) and 31.5 % of hemipterans have originated from Asia. Coleoptera have come from various regions, including a significant component from Australasia (9.5%) mostly linked to the introduction of *Eucalyptus* and *Acacia* spp. in the Mediterranean regions of Europe. Coleoptera also represent a large proportion of the cosmopolitan stored product pests that are predominantly of tropical or subtropical origin.

Patterns of spread

Once established, most alien species have not spread throughout Europe, at least yet. We used the presence in a country as a proxy of the invaded range because it appeared impossible to get sufficient data for a quantitative assessment of this invaded range area for most alien species. A total of 694 species (i.e., 43.6 %) have not invaded more than one country/ island additional to the one where they arrived, and 63.6 % are present only in five European countries (Figure 2.6). Less than 1% (12 out of 1590) of the alien arthropods are present in more than 40 countries; among these are the melon and cotton aphid, *Aphis gossypii* Glover, and several beetles associated with stored products especially seed bruchids (e.g.,. *Callosobruchus chinensis* (L)). Detritivorous species appeared to have dispersed significantly more (8.5±0.5 countries) than phytophagous species (7.1±0.3) and parasitoids/ predators (5.5±0.3) (Krsukall-Wallis test. $F_{2,1598}$= 10.97; P=0.0000).

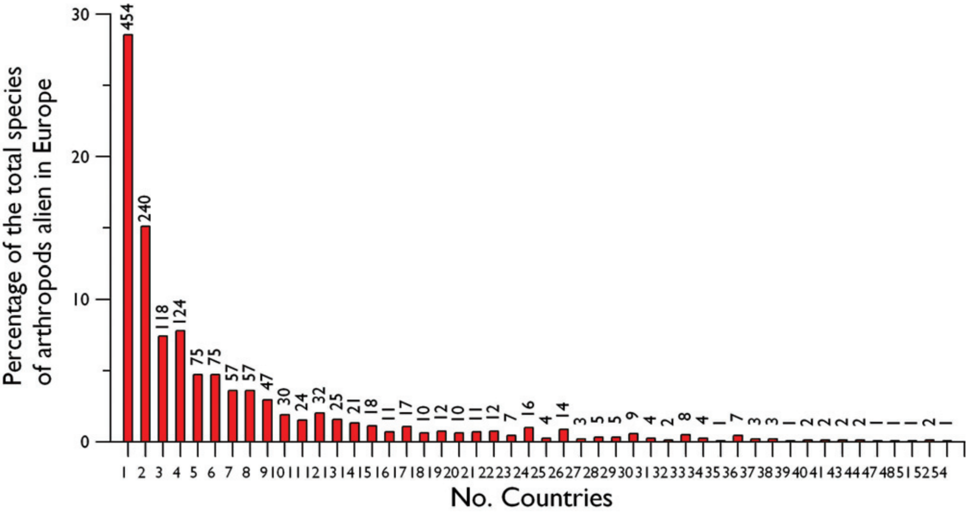

Figure 2.6. Geographic spread of the arthropod species alien to Europe expressed as the number of countries colonized by these species and their frequency.

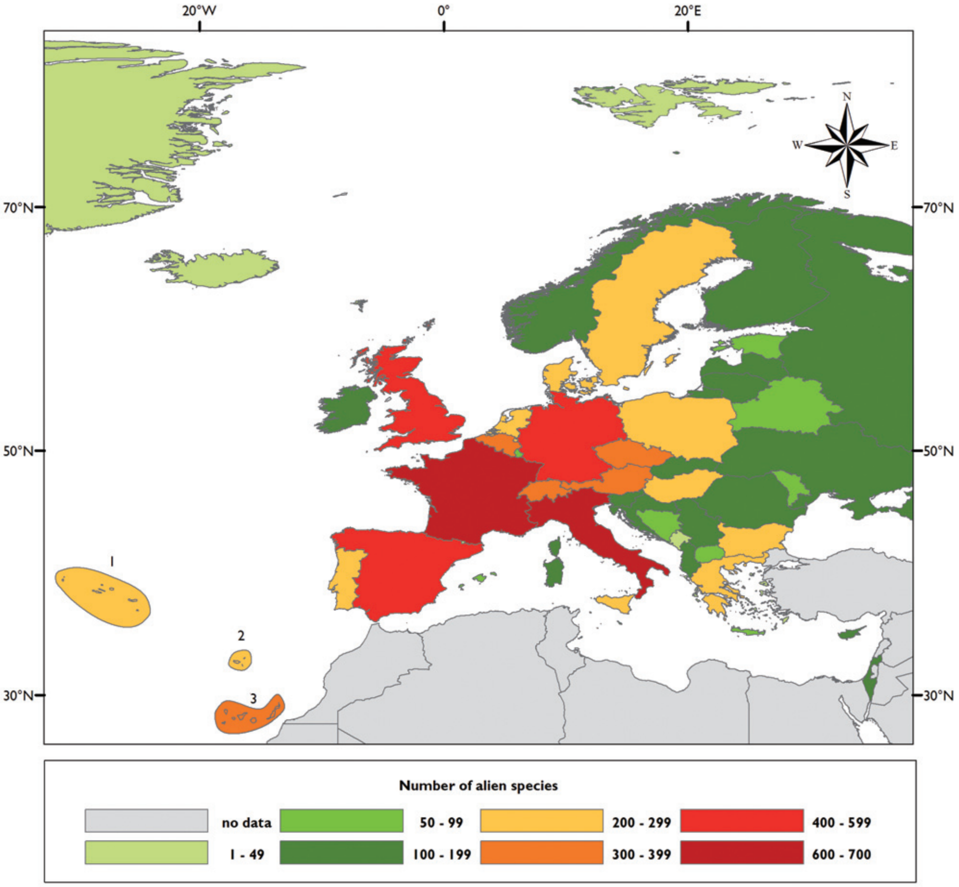

Figure 2.7. Comparative colonization of continental European countries and islands by dipteran species alien *to* Europe. Archipelagos: **1** Azores **2** Madeira **3** Canary islands.

Large differences also exist between European countries in the total number of alien arthropods recorded per country (Figure 2.7 and 2.8). Italy (700 species) and France (690 species), followed by Great Britain (533 species), host many more species than other countries. The same ranking is obtained when the number of alien species per km^2 is considered. Differences in sampling effort may have affected the analyses. However, the number of alien insects is significantly and positively correlated with country surface area (r= 0.3621; P= 0.0384). More westerly countries and islands appear in general relatively more colonized. The number of alien species significantly decreases with the longitude of the countries' centroids (r= -0.6988; P= 0.0038) whereas latitude does not seem to have a significant influence (r=-0.378; P= 0.168). Islands also host proportionally more alien species than continental countries relative to their size (Kruskall-Wallis test on the number of alien species per km^2; $F_{1,53}$ = 6.20; P=0.0160) but this is independent of the coast length (r= 0.174; P= 0.384). In continental countries, bordering the sea does not influence the number of alien insect spe-

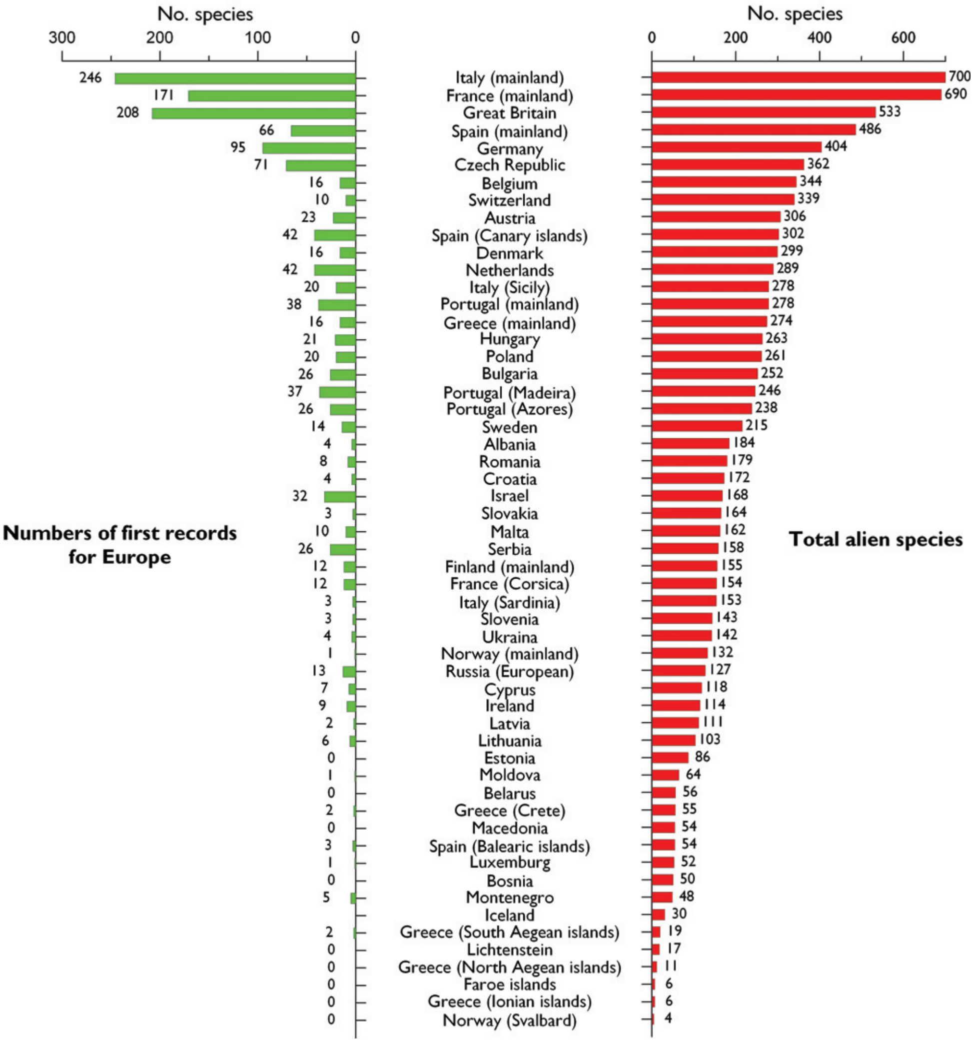

Figure 2.8. Comparison between the number of first records for Europe observed for the alien species in a country (left) and the total number of alien species now present in the country (right).

cies (P=0.6404). In addition, the country or island where a species was first recorded in Europe has been identified for 1399 species out of the 1590 alien arthropods (Figure 2.8). The same country ranking was obtained as for the total number of arthropods present per country. Indeed, there is significant correlation (r= 0.8745; P=0.0000) between the two values.

However, much stronger correlations exist between the number of alien arthropods in a country and the total volume of merchandise imports of the country (r= 0.875; P=0.0000), the density of the road network (r= 7578; P= 0.0001), and the size of the human population (r= 0.5918; P= 0.0047). These results confirm the decisive importance of socioeconomic and demographic drivers in arthropod invasion.

References

Brockerhoff EG, Bain J, Kimberley M, Knížek M (2006) Interception frequency of exotic bark and ambrosia beetles (Coleoptera: Scolytinae) and relationship with establishment in New Zealand and worldwide. *Canadian Journal of Forest Research* 36: 289–298.

DAISIE (Ed) *The Handbook of Alien Species in Europe*. Heidelberg, Germany: Springer. 399 pp.

Eritja R, Escosa R, Lucientes J, Marquès E, Roiz D, Ruiz S (2005) Worldwide invasion of vector mosquitoes: present European distribution and challenges for Spain. *Biological Invasions* 7: 87–97.

Essl F, Rabitsch W (Eds) (2002) Neobiota in Österreich. Umweltbundesamt, Wien. 432 pp.

Geiter O, Homma S, Kinzelbach R (2002) Bestandsaufnahme und Bewertung von Neozoen in Deutschland. Untersuchung der Wirkung von Biologie und Genetik ausgewählter Neozoen auf Ökosysteme und Vergleich mit den potentiellen Effekten gentechnisch veränderter Organismen. Berlin: Umweltbundesamt.

Glavendekić M, Mihajlović L, Petanović R (2005) Introduction and spread of invasive mites and insects in Serbia and Montenegro. In: *Plant protection and plant health in Europe: introduction and spread of invasive species*. BCPC Conference, Humbolt University, Germany, June 2005, 229–230.

Hérard F, Ciampitti M, Maspero M, Krehan H, Benker U, Boegel C, Schrage R, Bouhot-Delduc L, Bialooki P (2006) *Anoplophora* species in Europe: infestations and management processes. *Bulletin OEPP/EPPO Bulletin* 36: 470–474.

Hulme PE (2009) Trade, transport and trouble: managing invasive species pathways in an era of globalization. *Journal of Applied Ecology* 46: 10–18.

Hulme PE, Bacher S, Kenis M, Klotz S, Kühn I, Minchin D, Nentwig W, Olenin S, Panov V, Pergl J, Pyšek P, Roques A, Sol D, Solarz W, Vilà M (2008) Grasping at the routes of biological invasions: a framework for integrating pathways into policy. *Journal of Applied Ecology* 45: 403–414.

Kenis M (2005) Insects-Insecta. In: Wittenberg R (Ed) *An inventory of alien species and their threat to biodiversity and economy in Switzerland*. Délemont: CABI Bioscience Switzerland, 131–212.

Kenis M, Auger-Rozenberg MA, Roques A, Timms L, Péré C, Cock MJW, Settele J, Augustin S, Lopez-Vaamonde C (2009) Ecological effects of invasive alien insects. *Biol Invasions* 11: 21–45.

Kenis M, Rabitsch W, Auger-Rozenberg MA, Roques A (2007) How can alien species inventories and interception data help us prevent insect invasions? *Bulletin of Entomological Research* 97: 489–502.

Langor DW, DeHaas L, Foottit RG (2009) Diversity of non-native terrestrial arthropods on woody plants in Canada. *Biological Invasions* 11: 5–19.

Liebhold AM, Halverson JA, Elmes GA (1992) Gypsy moth invasion in North America: a quantitative analysis. *Journal of Biogeography* 19: 513–520.

Liebhold AM, MacDonald WL, Bergdahl D, Mastro VC (1995) Invasion by exotic forest pests: a threat to forest ecosystems. *Forest Science Monographs* 30: 1–49

Mattson WJ, Niemelä P, Millers I, Inguanzo Y (1994) *Immigrant phytophagous insects on woody plants in the United States and Canada: an annotated list.* General Technical Report NC-169. St. Paul, Minnesota, USA: USDA Forest Service, North Central Forest Experiment Station.

Mattson WJ, Vanhanen H, Veteli T, Sivonen S, Niemelä P (2007) Few immigrant phytophagous insects on woody plants in Europe: legacy of the European crucible? *Biological Invasions* 9: 957–974 .

Mondor EB, Tremblay MN, Messing RH (2007). Morphological and ecological traits promoting aphid colonization of the Hawaiian Islands. *Biological Invasions* 9: 87–100.

Niemelä P, Mattson WJ (1996) Invasion of North American forests by European phytophagous insects: legacy of the European crucible? *BioScience* 46: 741–753.

Nobanis (2005) *The North European and Baltic Network on Invasive Alien Specie*s. www.nobanis.com.

Pelizzari G, Dalla Monta L, Vacante V (2005) List of alien insect and mite pests introduced to Italy in sixty years (1945 – 2004). In: *Plant protection and plant health in Europe: introduction and spread of invasive species*. BCPC Conference, Humbolt University, Germany, June 2005, 275.

Pimentel D, Lach L, Zuniga R, Morrison D (2002) Environmental and economic costs associated with non-indigenous species in the United States. In: Pimentel D (Ed) *Biological Invasions. Economic and Environmental costs of Alien Plants, Animal and Microbe Species*. Boca Raton, USA: CRC Press, 285–306.

Pimentel D, Zuniga R, Morrison D (2005) Update on the environmental and economic costs associated with alien-invasive species in the United States. *Ecological Economics* 52: 273–88.

Pyšek P, Bacher S, Chytry M, Jarošik V, Wild J, Celesti-Grapow L, Gasso N, Kenis M, Lambdon PW, Nentwig W, Pergl J, Roques A, Sol D, Solarz W, Vila M, Hulme PE (2009) Contrasting patterns in the invasions of European terrestrial and freshwater habitats by alien plants, insects and vertebrates. *Global Ecology and Biogeography* 19: 317–331.

Reemer M (2003) Invasieve Arthropoda in Nederland: Een eerste inventarisatie. Leiden: Stichting European Invertebrate Survey. 63 pp.

Ripka G (2010) [An overview of the alien arthropod pest species in Hungary (I.)] (in Hungarian). *Növényvédelem* 2.

Roll E, Dayan T, Simberloff D (2007) Non-indigenous species in Israel and adjacent areas. *Biological Invasions* 9: 629–643.

Roques A (2010) Alien forest insects in a warmer world and a globalized economy: Impacts of changes in trade, tourism and climate on forest biosecurity. *New Zealand Journal of Forestry*, suppl 40: 77–94.

Roques A, Rabitsch W, Rasplus JY, Lopez-Vaamonde C, Nentwig W, Kenis M (2009) Alien terrestrial invertebrates of Europe. In: DAISIE (Ed) *The Handbook of Alien Species in Europe*. Heidelberg, Germany: Springer, 63–79.

Šefrová H, Laštůvka Z (2005) Catalogue of alien animal species in the Czech Republic. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis* 53: 151–170.

Smith RM, Baker RHA, Malumphy CP, Hockland S, Hammon RP, Ostojá-Starzewski JC, Collins DW (2007) Recent non-native invertebrate plant pest establishments in Great Britain: origins, pathways, and trends. *Agricultural and Forest Entomology* 9: 307–326.

Tomov R, Trencheva K, Trenchev G, Cota E, Ramadhi A, Ivanov B, Naceski S, Papazova-Anakieva I, Kenis M (2009) *Non-indigenous insects and their threat to biodiversity and economy in Albania, Bulgaria and Republic of Macedonia*. Sofia-Moscow: Pensoft, publishers, 112 pp.

Valade R, Kenis M, Hernandez A, Augustin S, Mari Mena N, Magnoux E, Rougerie R, Lakatos F, Roques A, Lopez-Vaamonde C (2009) Mitochondrial and microsatellite DNA markers reveal a Balkan origin for the highly invasive Horse-Chestnut leaf miner Cameraria ohridella (Lep. Gracillariidae). *Molecular Ecology* 18 : 3458–3470.

Vilá M, Basnou C, Pyšek P, Josefsson M, Genovesi P, Gollasch S, Nentwig W, Olenin S, Roques A, Roy D, Hulme PE and Daisie Partners (2009) How well do we understand the impacts of alien species on ecosystem services? A pan-European cross-taxa assessment. *Frontiers in Ecology and the Environment* 8: 135–144.

Walther GR, Roques A, Hulme PE, Sykes MT, Pyšek P, Kühn I, Zobel M, and members of the ALARM Climate Change – Biological Invasions Working Group (2009) Alien species in a warmer world: risks and opportunities. *Trends in Ecology and Evolution* 24: 686–692.

Williamson M (1996) Biological Invasions. London: Chapman and Hall. 244 pp.

Wittenberg R, Cock MJW (Eds) (2001) *Invasive alien species: a toolkit of best prevention and management practices.* Wallingford, UK: CABI Publishing. 228 pp.

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RESEARCH ARTICLE

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Pathways and vectors of alien arthropods in Europe
Chapter 3

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Abstract

This chapter reviews the pathways and vectors of the terrestrial alien arthropod species in Europe according to the DAISIE-database. The majority of species (1341 spp., 86%) were introduced unintentionally, whereas 218 species (14%) were introduced intentionally, almost all of these for biological control purposes. The horticultural/ornamental-pathway is by far the most important (468 spp., 29%), followed by unintentional escapees (e.g., from greenhouses, 204 spp., 13%), stored product pests (201 spp., 12%), stowaways (95 spp., 6%), forest and crop pests (90 spp. and 70 spp., 6% and 4%). For 431 species (27%), the pathway is unknown. The unaided pathway, describing leading-edge dispersal of an alien species to a new region from a donor region where it is also alien, is expected to be common for arthropods in continental Europe, although not precisely documented in the data. Selected examples are given for each pathway. The spatiotemporal signal in the relevance of pathways and vectors and implications for alien species management and policy options are also discussed. Identifying and tackling pathways is considered an important component of any strategy to reduce propagule pressure of the often small and unintentionally translocated, mega-diverse arthropods. This requires coordination and clear responsibilities for all sectors involved in policy development and for all associated stake-holders.

Keywords

alien species, non-native species, pathways, vectors, Europe

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3.1 Introduction

To become an alien species, boundaries of natural distribution ranges must be overcome with the help of man-made structures, goods and services. These activities and purposes are the pathways of invasions. A plethora of vectors, which are the agents of these translocations, is available to break new grounds and reach new areas. Interestingly, there is no common understanding in this separation in the biological invasion literature (e.g. Ruiz and Carlton 2003, Carlton and Ruiz 2005, Nentwig 2007, Hulme et al. 2008). In this overview, however, pathways are understood as the routes (including motivations to use them) and vectors as the physical objects (ships, plants etc) that carry species along. Several attempts to further classify pathways and vectors are available (e.g. Carlton and Ruiz 2005), but here I follow Hulme et al. (2008), who identified six principal pathways for biological invasions (Table 3.1). Only one of these is founded by intentional motivations, that is the deliberate release of organisms, with biological control as the most important example. The others are utilised unintentionally, accidentally and may come from any direction. These are escapes from contained environments and captivity; contaminants of commodities; stowaways, transported as hitch-hikers with vehicles and cargo; corridors, where transport infrastructure enables the spread of a species; and the unaided pathway, where an alien species conquers a nearby region under its own dispersal capacity. Evidently, these different pathways have major implications for risk assessment, regulations, management and control (Hulme et al. 2008, Hulme 2009).

Human-mediated translocations differ from natural dispersal by orders of magnitude both quantitatively and qualitatively as can be seen by island colonization rates (e.g. Gillespie and Roderick 2002, Gaston et al. 2003) and genetic consequences (e.g. Wilson et al. 2009). Also, the origin of the source differs as natural colonization usually happens from adjacent populations, whereas translocated individuals may come from all over the world.

In the DAISIE-database, three levels of pathways, are distinguished. At the first level, intentional and unintentional ambitions are classified. At the second level, pathways are identified, except that the contaminant, stowaway and corridor pathways are summarized as “transport”. At the third level, these are further specified into broad categories (e.g. biological control, crops, horticultural/ornamental, forestry, stored products). In addition, at the second and third level, the category “unknown” is also used and assigned to 392 and 431 species, respectively (25–27%). This is a similar contingent as for the exotic insects in Japan (24%, Kiritani and Yamamura 2003). Introductions of species are not necessarily restricted to one pathway; many species can be considered “polyvectic” (Carlton and Ruiz 2005), transported by more than one pathway or multiple vectors. Accordingly, some species in the DAISIE-database were assigned to more than one pathway/vector. Furthermore, it has to be said very clearly that many assignments were only “best guess” or “most likely” assessments, deduced from the preferred habitats, food

Table 3.1. Pathway terminology and examples of vectors of terrestrial alien arthropod species in Europe.

Pathway	Motivation	Vectors	Examples
Release	Intentional	None	Biological control
Escape	Unintentional	None	Greenhouses
Contaminant	Unintentional	Food sources, ornamentals, vegetables, fruits, wood, animals, ...	Stored product pests, Wood-borers, Leaf-miners, Gall-producers, Endoparasites
Stowaway	Unintentional	Any cargo	Ants, Cockroaches
Corridor	Unintentional	Ships, cars	*Cameraria ohridella*
Unaided	Unintentional	None	Secondary spread from point of entry

plants or ecology, because the intimate pathway/vector of many arthropod species often remains ambiguous.

In this chapter, pathways and vectors of the terrestrial alien arthropods in Europe are reviewed, with the few alien aquatic insects included, but excluding other freshwater alien arthropods such as crayfish species. There are a multitude of further pathways relevant for the marine and freshwater environments (e.g. ballast water, hull-fouling) and for other organisms such as vascular plants and vertebrates (e.g. seed contamination, hunting, pets) (e.g. García-Berthou et al. 2005, Galil et al. 2009, Genovesi et al. 2009).

3.2. Intentional release

With few exceptions, terrestrial arthropods are not intentionally imported. Such exceptions are grasshoppers and crickets as pet food and – more significantly – domesticated honeybees (*Apis mellifera*) of different provenances (subspecies), which are used for breeding, with the aim of producing higher honey yields (Jensen et al. 2005, Moritz et al. 2005). The same is true for the bumblebee subspecies used for pollination in greenhouses (e.g., *Bombus terrestris dalmatinus* in the UK, Ings et al. 2006).

At the end of the 19th century, two saturniid moths, *Samia cynthia* and *Antheraea yamamai*, were introduced from Asia for silk production, but yields was not profitable enough for this to be continued. Both species persist locally in the wild in Europe with most populations being initiated by escapes or releases by amateur lepidoptera-breeders.

Intentional releases for human food consumption are more prevalent for organisms such as molluscs, fish and aquatic Crustacea (oysters, snails, crayfish, crabs), which are not included in this book. Also, there are no “game insects”, and only a few pets. Further, there are no introductions of arthropods for aesthetic or conservation purposes (but see further below), a major pathway for other animal groups around the globe (e.g. Nentwig 2007). In the DAISIE-database, 218 species (14%) were introduced intentionally, almost all of these for biological control purposes (Table 3.2).

Table. 3.2. Pathways of the alien arthropod species in Europe, according to the DAISIE-database. Due to double entries the sum differs.

Pathway	Number of species (%)	
Intentional	218 (14%)	
Released		175 (11%)
Unintentional	1341 (86%)	
Animal husbandry		42 (2.6%)
Greenhouse escapees		204 (13%)
Crops		70 (4.3%)
Forestry		90 (5.6%)
Horticultural/Ornamental		468 (29%)
Leisure		13 (0.8%)
Stored products		201 (12%)
Stowaways		95 (5.9%)
Unknown		431 (27%)

3.2.1. Biological control: Ecology vs Economy

The most important pathway for deliberate release of terrestrial alien arthropods is biological control (BC). There has been some controversy about the pros and cons of this technique to control pest organisms (e.g. Howarth 1991, van Lenteren et al. 2006, Babendreier 2007, Murphy and Evans 2009). Whereas non-target effects are considered problematic by conservationists, these are often considered acceptable from an economic point of view. Hence, the underlying basic assumptions and intentions for this controversy are entirely different and comparisons awkward.

BC makes use of the "enemy-release" of introduced organisms, which are disburdened from their natural predators or parasites and boom in the new range. Subsequently, mass-reared releases of those enemies from the original area are conducted, aiming at permanent establishment and control of the pest organisms below damaging thresholds. Not particularly from a "pathway point-of-view", but from a general assessment of non-target effects, it is useful to distinguish between this classical BC and augmentative BC, where control is achieved by periodic releases without permanent establishment intended. Similarly, flightless strains of *H. axyridis* were released in the Czech Republic in 2003 to control for aphids with the goal of no further unaided spread (Brown et al. 2008).

In Europe, there are both success-stories and failures to report from intentional releases, with the former prevailing (e.g. *Encarsia formosa* used against whiteflies in greenhouses; *Trichogramma brassicae*, an "alien in Europe" used against European corn borer *Ostrinia nubilalis*; *Aphelinus mali* from North America used against the Woolly apple aphid *Eriosoma lanigerum*).

Occasionally, released enemies are aliens from other regions than their targets. In Europe, for example, the San Jose scale *Diaspidiotus perniciosus*, described from California, but introduced with infested trees or fruits from Asia, is considered a pest in commercial fruit orchards causing economic losses due to reduced yields. Negative effects are mitigated by application of Neem and other oils, but also by release of the North American parasitoid wasp *Encarsia perniciosi*, which is used for control in North America.

In general, however, the application of BC has been of subordinate relevance in Europe, compared to other regions of the world. The same is true for the application of other technologies where arthropods are released (SIT – Sterile Insect Technique; RIDL – Release of Insects carrying a Dominant Lethal), which may be applied to control alien agricultural pests and mosquitos (Thomas et al. 2000, Alphey et al. 2009).

Ex-situ conservation or reintroduction programmes in insects are still rare, but they do occur for some native species in Europe (butterflies in the UK: Oates and Warren 1990; *Erebia epiphron* in the Czech Republic: Schmitt et al. 2005; *Gryllus campestris* in the UK and Germany: Witzenberger and Hochkirch 2008). Recently, controversial discussions on assisted colonization have emerged in the context of protecting species from climate change by translocating and releasing them beyond their current range limits (e.g. Hoegh-Guldberg et al. 2008, Ricciardi and Simberloff 2009).

3.3. Unintentional release

The unintentional translocation of species is the most common pathway for alien arthropod species invasions into Europe (86% of the species, Table 3.2).

3.3.1. Escapes: Out of the Green

Arthropods are infrequently domesticated, reared and used as pets, although examples of tropical species do exist (e.g. tarantulas, walking sticks and leaves, leaf-cutting ants, millipedes). Establishment in the wild in Europe is highly unlikely for such species, even under severe climate change scenarios. However, escapes from captivity do regularly occur, although they are rarely noticed and published. Insects reared as living food for vertebrate pets (e.g. crickets, grasshoppers, mealworms) seem to be of limited significance, whereas pests and insects used for biological control in semi-contained environments, particularly greenhouses, are of much greater importance. Greenhouses are not escape-proof facilities for insects as confirmed by surveys in the areas surrounding such buildings (e.g. Vierbergen 2001, Aukema and Loomans 2005). Well-known examples include the Western Flower Thrips *Frankliniella occidentalis*, the Cotton Aphid *Aphis gossypii*, and the Cotton Whitefly *Bemisia tabaci*, all of which reproduce in the field in southern Europe but are restricted to greenhouses in western, central, or northern Europe. Serving as stepping stones, it is expected that some future invaders in Europe will be recruited out of this pool of species, particularly if climate warms as predicted. In the DAISIE-database, more than 200 arthropod species are listed as living in greenhouses.

One of the most famous stories of a greenhouse escapee is the Multicoloured Asian lady beetle or Harlequin ladybird *Harmonia axyridis*, termed the "most-invasive ladybird on Earth" (Roy et al. 2006). This large coccinellid beetle, native to East-Asia, was introduced to North America and Europe for aphid control in greenhouses, but escaped into the wild. It is a highly competitive intra-guild predator reducing and displacing native coccinellid species and other members of the aphid-feeding guild (Roy and Wajnberg 2008). Its subsequent unaided spread across much over Europe within just a few years (Brown et al. 2008) highlights the capacity of invasive alien species to successfully conquer naïve environments.

3.3.2. Contaminant: Going for a ride?

The contaminant pathway describes the unintentional transport of species within or on a specific commodity, contrary to stowaways, which are accidentally associated with any commodity. Stored product pests, for example, are translocated with the movements of the products and many species have subsequently achieved a cosmopolitan distribution. In Europe, 201 alien insect species (12%) were introduced as stored product pests, feeding on a variety of food sources (e.g. cereals, rice, seeds, nuts, fruits) with considerable economic damage, including species which are likely to have been introduced by human activities in neolithic or pre-Christian centuries, e.g. *Sitophilus granarius* and *Oryzaephilus surinamensis* (Levinson and Levinson 1994). In Europe and temperate regions in general, care of stored products achieves higher protection levels than in subtropical and tropical areas, where up to 10% of weight loss may occur, representing loss of nutritional quality, with associated impacts on human welfare (Rees 2004).

Other pest species are strictly associated with the exchange or trade of their host plants (e.g. ampelophagous species feeding exclusively on grapevines - *Viteus vitifoliae*, *Scaphoideus titanus*; species feeding exclusively on palms - *Rhynchophorus ferrugineus*, *Diocalandra frumentii*; monophagous leaf-miners and gall-producers - *Parectopa robiniella*, *Phyllonorycter robiniella*, *Dryocosmus kuriphilus*) and therefore directly related to these vectors.

Other examples include phytophagous species translocated with ornamentals or horticultural host plants (e.g. scales and aphids) and xylophagous bark- and wood-infesting insects, above all beetle larvae, feeding in living trees. One of the best known examples is the Citrus longhorned beetle *Anoplophora chinensis*, which has repeatedly been reported infesting Bonsais imported from China. Larvae of *A. chinensis* and more often of the Asian longhorned beetle *Anoplophora glabripennis* were also intercepted with wood packaging material (see Haack et al. 2010 for a review). Recognizing the relevance of this vector enforced adoption of the International Standard for Phytosanitary Measures No. 15, which sets standards for thermal and chemical treatment of wood packaging material used for international trade. Although now found in lower numbers, living beetles are still being intercepted, indicating some gaps in this procedure.

Roques (2010) assembled examples of the possible introduction of alien insects during major international events such as the 2004 Olympic Games in Athens, where imported palm trees were widely planted and coincided with the first arrival of the red palm weevil *Rhynchophorus ferrugineus*.

The most striking example of contamination is associated with the introduction of the Potato (Colorado) beetle, *Leptinotarsa decemlineata*, to Europe. Spanish conquistadors in the 16th century brought the potato plant from South America to Europe, although it was not appraised as a human food source until the mid-17th century. After a severe decline of potato cultivation in Ireland in 1845–1857, caused by the introduced potato blight fungi *Phytophthora infestans*, emigrants brought the plant to North America, where the beetle exploited the new host plant. Between 1876 and 1922, the beetle was subsequently introduced into Europe on several occasions, not being able to establish in European potato fields until 1922, when it succeeded in France. The beetle has since spread east throughout Europe and Asia, reaching China in the 1980s (Alyokhin 2009). It should also be noted that the Colorado beetle was involved in propaganda to defame Great Britain and the United States of America during World War II and the Cold War.

Kenis et al. (2007) found that the majority of alien insects for Austria and Switzerland were contaminants and stowaways, with, in decreasing order, host plants (40% of which on ornamentals and 20% on vegetables and fruits), stored products and wood material as the main sources. Similar results were obtained with interceptions documented by EPPO between 1995 and 2004 (Roques and Auger-Rozenberg 2006). Altogether, introductions of arthropods with ornamental and horticultural plants and plant material, cut flowers, vegetables, and fruits, clearly preponderate in the DAISIE-data (29%, Table 3. 2). It is self-evident that there is a taxonomic bias with the type of commodity. For example, plant-feeding species (e.g. aphids, scales) are closely associated with ornamental plants, whereas wood-boring species (e.g. scolytids, cerambycids) are linked to living and dead wood imports. A rather uncommon invasion history pertains to the inadvertent introduction of the nearctic waterboatman *Trichocorixa verticalis* into Portugal and Spain. It is likely to have happened with the import and release of Eastern Mosquitofish *Gambusia holbrooki* for mosquito control (Sala and Boix 2005).

Living organisms as well as commodities can be contaminated. For example, many haematophagous alien arthropod species (e.g. Culicidae, Siphonaptera, Phthiraptera, Ixodidae) host parasites and pathogens and serve as reservoir, carriers or biovectors of human and animal infectious diseases. Moreover, phytophagous alien arthropod species (e.g. Hemiptera) may transmit plant pathogens (e.g. phytoplasmas, viruses).

Several examples are associated with beekeeping. Both endoparasites (the tracheal mite *Acarapis woodi*) and ectoparasites (the notorious *Varroa*-mite *Varroa destructor*), inquiline scavengers (the Small Hive Beetle *Aethina tumida*, captured only once in Europe and eradicated in quarantine in Portugal), and bacterial and fungal diseases (chalkbrood, foulbrood, nosemosis) are exchanged throughout the globe through honeybee imports (e.g. Sammataro et al. 2000, Coffey 2007).

The ultimate agent of Colony Collapse Disorder (CCD) known from North America, Europe and Asia is still under debate (e.g. Ratnieks and Carreck 2010) and it may well be a multi-triggered phenomenon, which causes the complete disappearance of adult worker bees of a colony. Beside environmental causes (e.g. pesticides), several diseases and pathogens are suspected to contribute or elicit CCD, e.g. *Nosema ceranae*, a microsporidian native to Asia and suspected to have host-switched to the European honeybee (Klee et al. 2007, Higes et al. 2009).

3.3.3. Stowaways: Where do you want to go today?

Stowaways are unintentionally introduced organisms that are related to transport infrastructure and vehicles, but independent of the type of commodity. Translocation with ballast water or soil movement are typical examples. In terrestrial environments, any cargo transported by air, water or land has the potential to move species beyond their natural range and habitat boundaries. Several cockroach species, e.g. *Blatta orientalis* and *Periplaneta americana*, are typical stowaways, having been translocated worldwide. Kiritani and Yamamura (2003) argued that passenger hand luggage arriving in airplanes to Japan may contain one consignment infested by fruit flies each day. Roughly two thirds of the intercepted pest species at US ports of entry between 1984 and 2000 were associated with baggage, and a further 30% with cargo (McCullough et al. 2006). However, to a certain extent, the separation between the contaminant and the stowaway pathway is ambiguous or not mutually exclusive.

Roques et al. (2009) cites the Asian tiger mosquito *Aedes albopictus* as an example of the stowaway pathway, this species being translocated as eggs and larvae within any small amount of standing water. Water within used tyres or ornamental plants (lucky bamboo *Dracaena* spp.) is a cause of the trans-continental introduction of *A. albopictus* to Europe, North America, Africa and Australia (e.g. Reiter 1998). Short-distance dispersal seems to be limited to passive transport by cars and trucks, or movement of infested tyres and plants (Scholte and Schaffner 2007). Establishment in other parts of Europe is very likely within the next decades, supported by climate change (Schaffner et al. 2009). *Aedes albopictus* is a vector of several viruses (e.g. Dengue, Chikungunya, West Nile) and of increasing relevance for Europe (Scholte and Schaffner 2007, van der Weijden et al. 2007). The movement of used tyres is also likely to be responsible for the most recently introduced mosquito species, *Ochlerotatus atropalpus*, native to North America and detected in several European countries (France, Italy, Netherlands), where it was subsequently eradicated (Scholte et al. 2009).

Many insects are attracted to light and most transport hubs (airports, seaports) are illuminated during night-times, increasing the probability of translocation with vehicles after boarding a vector. For example, it is speculated that the attraction to light facilitates the repeated introduction of adult *Diabrotica virgifera* with aircrafts from

North America to Europe, because of regular “first” records of the species in the vicinity of airports. From there the species spreads unaided depending on habitat (maize fields) availability.

Ants (Formicidae) are among the most invasive organisms globally, particularly hazardous on oceanic islands (e.g. Holway et al. 2002, Lach and Hooper-Bùi 2010). Entire colonies with gynes and workers may be translocated as stowaways with soil and litter accompanying ornamental plants, with logs or with other commodities offering shelter. The majority of introduced ants in the USA have been detected on plant material (Suarez et al. 2005). Some of the characteristic traits of tramp ants, e.g. preference for disturbed habitats, polygyny, budding, small body size, support successful translocation and subsequent establishment around the globe (e.g. McGlynn 1999). In Europe, the Argentine ant *Linepithema humile* and the garden ant *Lasius neglectus* are currently considered to be of prime importance (see Kenis and Branco, chapter 5). Whereas the former was introduced as a stowaway with unknown commodities to Europe (Madeira and mainland Portugal) in the 19th century (Wetterer et al. 2009), the origin (likely Asia Minor), pathway and vector (eventually contaminant of garden soil) and successful secondary spread of the latter are still under debate (Ugelvig et al. 2008).

Two more examples of Hymenoptera, initially introduced as stowaways, are the oriental mud dauber *Sceliphron curvatum* and the Asian hornet *Vespa velutina*. The former was introduced in the late 1970s via air cargo from Central Asia to Austria and produces conspicuous mud nests in which paralysed spiders are provisioned as food supply for the developing larvae (Schmid-Egger 2004). The latter was only recently detected in France, probably introduced with pieces of pottery from China (Villemant et al. 2006). These two species have subsequently spread rapidly, unaided, and may be of increasing relevance to native sphecids, hornets and honeybees.

3.3.4. Corridors: Like a rolling stone

The corridor pathway highlights the role transport infrastructures play in the introduction of alien species; shipping canals are the most important example. Gilbert et al. (2004) have shown that the spread of *Cameraria ohridella* in Germany was related to the highway routes, Pekar (2002) argues that the spread of the spider *Zodarion rubidum* was facilitated by the railway system and there is anectodal evidence for repeated northwards transport of the flightless Southern Oak Bush Cricket (*Meconema meridionale*) and the Speckled Bush-Cricket (*Leptophyes punctatissima*) with cars along highways from Southern Europe. Although infrastructure networks undoubtedly contribute to the distribution of alien terrestrial arthropod species in Europe, it seems to be of subordinate relevance and is often intermingled with the contaminant/stowaway pathway.

3.3.5. Unaided: One day I'll fly away

The unaided pathway describes leading-edge dispersal, that means situations where spread results in alien species arriving in a new region from a donor region where it is also alien. This holds true for many alien arthropods occurring in the wild in Europe, being introduced once and spreading after successful establishment. Several examples were mentioned in the chapters above, although this is not reflected in the DAISIE-database (Table 3. 2). Unaided spread often follows initial introduction by one of the other pathways into Europe, although long-distance dispersal events may contribute to the distribution patterns and accelerate rates of spread, as shown for the horse chestnut leafminer *Cameraria ohridella* in Germany and France (Gilbert et al. 2004, 2005). The chestnut gall wasp *Dryocosmus kuriphilus* was introduced with infested plant material from China to Italy and is now spreading unaided to neighbouring countries, but may also bridge larger distances with transport of infested plant material.

Dispersal capacities of arthropods can be impressively high. The conifer seed bug *Leptoglossus occidentalis* and the Harlequin ladybird *Harmonia axyridis* spread over much of Europe within just a decade (e.g. Lis et al. 2008, Rabitsch 2008, Brown et al. 2008) presumably on their own wings. In addition, repeated and independent introductions from the area of origin and/or secondary introductions from the alien range over long distances undoubtedly occur, but such events are difficult to prove and require specific techniques (e.g. molecular biology) (e.g. *Diabrotica virgifera* – Miller et al. 2005, Ciosi et al. 2008).

Controversy surrounds the definition of the alien status of species extending their range due to recent anthropogenic climate change. As long as they utilize the beforementioned pathways, e.g. are translocated with vehicles, but then find suitable climate conditions to establish populations, they should be considered alien. If a species extends its range unaided, but only colonizes disturbed or secondary habitats under strong human influence, such species may be considered as alien. Particularly in arthropods, however, it is sometimes difficult or even impossible, to unambiguously identify the boundaries of the natural range of a species. Historic introductions of today's cosmopolitan species, taxonomic impediment and the lack of recording schemes for most groups cause a high degree of uncertainty in the delimitation of the native range of some species. Host plant distribution, habitats, and molecular techniques may serve as a clue for disentangling factors (e.g. Kavar et al. 2006, Valade et al. 2009).

Unaided dispersal is also often assumed for modelling rates of spread of alien species. Liebhold and Tobin (2008) provided examples for the radial rate of spread in alien insects, which span from 1 to 500 km year^{-1}. In Europe, the western flower thrips *Frankliniella occidentalis* stays ahead with up to 249 km year^{-1} (Kirk and Terry 2003). However, in many if not most cases, additional pathways including long-distance dispersal or at least a combined stratified dispersal need to be taken into account for more realistic scenarios of spread (e.g. Gilbert et al. 2004 for the horse chestnut leafminer *Cameraria ohridella*).

3.4. Future trends and management

There is no reason to assume a decrease in people's movements and restrictions in the transport of goods in the near future. Biological homogenization will tie continents and biodiversity, increasing species richness locally and decreasing it globally; the rate of change will be much more rapid than the hypothesised formation of Neopangaea (Scotese 2001). The ultimate consequences of such a process for the functioning of ecosystems and their services to mankind are far from being well understood.

There is a spatiotemporal signal in the relevance of pathways and vectors. Whereas soil was used as ship ballast in earlier days of European colonization (e.g. Vazquez and Simberloff 2001) this was replaced by ballast water in later years. With the construction of bigger and faster ships, even more organisms were translocated rapidly and with the advent of aircrafts this rate was yet further accelerated. Fast transit enables more species to survive transport and subsequently establish successfully in new regions. In addition, continental, land-locked areas became easily accessible (Mack 2003). Asia has recently gained increasing relevance as a country of export globally (Roques 2010) and as a donor region of alien species, particularly for insects associated with woody plants introduced to Europe (Roques et al. 2009). New trends in the ornamental trade by changed consumer behaviour has created new markets. Only two decades ago, bonsais were rare in European households, but have become a recent fashion; sales are increasing in most areas. Generally, the horticultural/ornamental pathway is of paramount significance for the alien arthropods of Europe (Kenis et al. 2007, Table 3. 2) and there is ample scope for enhancing existing plant protection services (e.g. by increasing personnel at points of entry) and providing best-practice guidance to the ornamental trade industry. It has been shown, however, that interception and establishment data of alien insects for Europe differ significantly (Kenis et al. 2007, Roques 2010). This discrepancy may eventually be explained by the changed relevance of pathways and time-lag phenomena (Crooks 2005). In any case, it demonstrates that additional endeavours are necessary to abate undesirable effects on ecology and economy.

Import and export of goods follows economic rules and global trade mirrors biological invasion patterns (e.g. Levine and D'Antonio 2003, Taylor and Irwin 2004, Kobelt and Nentwig 2008, Westphal et al. 2008, Roques et al. 2009). Chiron et al. (2009) showed such a pattern for bird introductions on both sides of the "iron curtain" in Europe and it is expected that a similar pattern will be found for arthropods. However, information on introduction dates, number of propagules, etc. are usually lacking for arthropod invasions, so that such analyses are difficult to achieve.

Anthropogenic climate change acts upon several levels of biological invasions (e.g. Walther et al. 2009, Thomas and Ohlemüller 2010). It may directly change the realized climatic niche of species, cause habitat shifts (e.g. stepping-stone scenarios) and range shifts in latitude and altitude. Ødegaard and Tømmerås (2000) showed that eight out of 25 alien ground-beetle species used compost heaps as stepping-stones for subsequent establishment in the wild in northern Europe. Global climate change, however, may further act indirectly in changing trade and consumer habits, influencing invasion pathways and vectors by creating new opportunities and depleting traditional routes.

Species-specific eradication plans are a legally binding obligation in the plant health sector and – to some extent – also in the human and veterinary medical sectors. Regulation and harmonization in Europe, however, lags far behind other regions (Hunt et al. 2008) and this is even worse for species of environmental concern. Thinking of arthropods as a mega-diverse group it is highly likely that numbers and impacts of alien species will increase worldwide.

For invasive species management, it is pivotal to tackle pathways, especially in the case of small and unintentionally translocated arthropod species. For example, Skarpass and Økland (2009) proposed measures of how to reduce introduction risk of bark beetles with timber imports. Whereas considerable knowledge has been accumulated for marine pathways, one has to conclude, in agreement with Lockwood et al. (2007), that surprisingly little information is available on the exact magnitude, direction and variation of terrestrial pathways. This is especially true for Europe, where targeted research on invasion pathways should be encouraged. Following identification of the most important pathways, relevant vectors need to be thoroughly tested for their likelihood of interception (e.g. quarantine) or disruption (e.g. import ban or special obligatory and certified treatments) aiming at reducing propagule pressure. There are different options for action to be taken between maximal prevention at border controls and free trade. However, it has to be assumed that "vector management serves as a filter and not as a wall to exotic species" (Carlton and Ruiz 2005: 48).

Anoplophora species provide instructive examples of how obligatory management actions are dealt with in practice in Europe. The reasonable goal of complete eradication is hampered by the implementation of national legislations, by costs borne by individual countries, and repeated introductions as a consequence of the single market policy. A united Europe should opt for better coordination, the polluter-pays-principle, an alien emergency fund, and clear responsibilities. Ultimately, a dedicated independent agency is necessary to deal effectively with biological invasions in Europe (Hulme et al. 2009).

References

Alphey L, Benedict M, Bellini R, Clark GG, Dame DA, Service MW, Dobson SL (2009) Sterile-Insect Methods for Control of Mosquito-Borne Diseases: An Analysis. *Vector-borne and Zoonotic Diseases*, doi:10.1089/vbz.2009.0014

Alyokhin A (2009) Colorado potato beetle management on potatoes: current challenges and future prospects. In: Tennant P, Benkeblia N (Eds) *Potato II.* Fruit, Vegetable and Cereal Science and Biotechnology 3: 10–19.

Aukema B, Loomans A (2005) *Orius laevigatus* in the Netherlands (Heteroptera, Anthocoridae). *Nederlandse Faunistische Mededelingen* 23: 125–127.

Babendreier D (2007) Pros and Cons of Biological Control. In: Nentwig W (Ed) *Biological Invasions*. Ecological Studies 193: 403–418.

Brown PMJ, Adriaens T, Bathon H, Cuppen J, Goldarazena A, et al. (2008) *Harmonia axyridis* in Europe: spread and distribution of a non-native coccinellid. *BioControl* 53: 5–21.

Carlton JT, Ruiz GM (2005) Vector science and integrated vector management in bioinvasions ecology: conceptual frameworks. In: Mooney HA, Mack RN, McNeely JA, Neville LE, Schei PJ, Waage JK (Eds) *Invasive Alien Species. A New Synthesis*. Scope 63, Island Press, Washington, 36–58.

Chiron F, Shirley S, Kark S (2009) Behind the iron curtain: Socio-economic and political factors shapes exotic bird introdurctions into Europe. *Biological Conservation*, doi 10.1016/j.biocon.2009.10.021

Ciosi M, Miller NJ, Kim KS, Giordano R, Estoup A, Guillemaud T (2008) Invasion of Europe by the western corn rootworm, *Diabrotica virgifera virgifera*: multiple transatlantic introductions with various reductions of genetic diversity. *Molecular Ecology* 17: 3614–3627.

Coffey MF (2007) Parasites of the Honeybee. Teagasc, Crops Research Centre, Oak Park, Carlow, 81 pp.

Crooks JA (2005) Lag times and exotic species: the ecology and management of biological invasions in slow-motion. *Ecoscience* 12: 316–329.

Galil B, Gollasch S, Minchin D, Olenin S (2009) Alien marine biota of Europe. In: DAISIE (Eds) *Handbook of Alien Species in Europe*. Springer, Dordrecht, 93–104.

García-Berthou E, Alcaraz C, Pou-Rovira Q, Zamora L, Coenders G, Feo C (2005) Introduction pathways and establishment rates of invasive aquatic species in Europe. *Canadian Journal of Fisheries and Aquatic Sciences* 62: 453–463.

Gaston KJ, Jones AG, Hanel C, Chown SL (2003) Rates of species introductions to a remote oceanic island. *Proceedings of the Royal Society London* 270: 1091–1098.

Genovesi P, Bacher S, Kobelt M, Pascal M, Scalera R (2009) Alien mammals of Europe. In: DAISIE (Eds) *Handbook of Alien Species in Europe*. Springer, Dordrecht, 119–128.

Gilbert M, Gregoire J-C, Freise JF, Heitland W (2004) Long-distance dispersal and human population density allow the prediction of invasive patterns in the horse chestnut leafminer *Cameraria ohridella*. *Journal of Animal Ecology* 73: 459–468.

Gilbert M, Guichard S, Freise J, Grégoire J-C, Heitland W, Straw N, Tilbury C, Augustin S (2005) Forecasting *Cameraria ohridella* invasion dynamics in recently invaded countries: from validation to prediction. *Journal of Applied Ecology* 42: 805–813.

Gillespie RG, Roderick GK (2002) Arthropods on islands: colonization, speciation, and conservation. *Annual Review of Entomology* 47: 595–632.

Haack RA, Hérard F, Sun J, Turgeon JJ (2010) Managing invasive populations of Asian longhorned beetle and Citrus longhorned beetle: a worldwide perspective. *Annual Review of Entomology* 55: 521–546.

Higes M, Martin-Hernández R, Garrido-Bailón E, González-Porto AV, Garía-Palencia P, Meana A, del Nozal MJ, Mayo R, Bernal JL (2009) Honeybee colony collapse due to *Nosema ceranae* in professional apiaries. *Environmental Microbiology Reports* 1(2): 110–113.

Hoegh-Guldberg O, Hughes L, McIntyre S, Lindenmayer DB, Parmesan C, Possingham HP, Thomas CD (2008) Assisted colonization and rapid climate change. *Science* 321: 345–346.

Holway DA, Lach L, Suarez AV, Tsutsui ND, Case TJ (2002) The causes and consequences of ant invasions. *Annual Review of Ecology and Systematics* 33: 181–233.

Howarth FG (1991) Environmental impacts of classical biological control. *Annual Review of Entomology* 36: 485–509.

Hulme PE (2009) Trade, transport and trouble: managing invasive species pathways in an era of globalization. *Journal of Applied Ecology* 46: 10–18.

Hulme PE, Bacher S, Kenis M, Klotz S, Kühn I et al. (2008) Grasping at the routes of biological invasions: a framework for integrating pathways into policy. *Journal of Applied Ecology* 45: 403–414.

Hulme PE, Pyšek P, Nentwig W, Vilá M (2009) Will threat of biological invasions unite the European Union? *Science* 324: 40–41.

Hunt EJ, Kuhlmann U, Sheppard A, Qin T-K, Barratt BIP, et al. (2008) Review of invertebrate biological control agent regulation in Australia, New Zealand, Canada and the USA: recommendations for a harmonized European system. *Journal of Applied Entomology* 132: 89–123.

Ings TC, Ward NL, Chittka L (2006) Can commercially imported bumble bees out-compete their native conspecifics? *Journal of Applied Ecology* 43: 940–948.

Jensen AB, Palmer KA, Boomsma JJ, Pedersen BV (2005) Varying degrees of *Apis mellifera ligustica* introgression in protected populations of the black honeybee, *Apis mellifera mellifera*, in northwest Europe. *Molecular Ecology* 14: 93–106.

Kavar T, Pavlovčič P, Sušnik S, Meglič V, Virant-Doberlet M (2006) Genetic differentiation of geographically separated populations of the southern green stink bug *Nezara viridula* (Hemiptera: Pentatomidae). *Bulletin of Entomological Research* 96: 117–128.

Kenis M, Rabitsch W, Auger-Rozenberg M-A, Roques A (2007) How can alien species inventories and interception data help us prevent insect invasions? *Bulletin of Entomological Research* 97: 489–502.

Kiritani K, Yamamura K (2003) Exotic insects and their pathways for invasion. In: Ruiz GM, Carlton JT (Eds) *Invasive Species. Vectors and Management Strategies.* Island Press, Washington, 44–67.

Kirk WDJ, Terry LI (2003) The spread of the western flower thrips *Frankliniella occidentalis* (Pergrande). *Agricultural and Forest Entomology* 5: 301–310.

Klee J, Besana AM, Genersch E, Gisder S, Nanetti A et al. (2007) Widespread dispersal of the microsporidium *Nosema ceranae*, an emergent pathogen of the western honey bee, *Apis mellifera*. *Journal of Invertebrate Pathology* 96: 1–10.

Kobelt M, Nentwig W (2008) Alien spider introductions to Europe supported by global trade. *Diversity and Distributions* 14: 273–280.

Lach L, Hooper-Bùi M (2010) Consequences of ant invasions. In: Lach L, Parr CL, Abbott KL (Eds) *Ant Ecology*. Oxford Univ. Press, Oxford, 261–286.

Levine JM, D'Antonio CM (2003) Forecasting biological invasions with increasing international trade. *Conservation Biology* 17: 322–326.

Levinson HZ, Levinson, AR (1994) Origin of grain storage and insect species consuming desiccated food. *Anzeiger für Schädlingskunde* 67: 47–60.

Liebhold AM, Tobin PC (2008) Population ecology of insect invasions and their management. *Annual Review of Entomology* 53: 387–408.

Lis JA, Lis B, Gubernator J (2008) Will the invasive western conifer seed bug *Leptoglossus occidentalis* Heidemann (Hemiptera: Heteroptera: Coreidae) seize all of Europe? *Zootaxa* 1740: 66–68.

Lockwood JL, Hoopes MF, Marchetti MP (2007) Invasion Ecology. Blackwell Publ., Oxford, 304 pp.

Mack RN (2003) Global plant dispersal, naturalization, and invasion: pathways, modes, and circumstances. In: Ruiz GM, Carlton JT (Eds) *Invasive Species. Vectors and Management Strategies*. Island Press, Washington, 3–30.

McCullough DG, Work TT, Cavey JF, Liebhold AM, Marshall D (2006) Interceptions of nonindigenous plant pests at US ports of entry and border crossings over a 17-year period. *Biological Invasions* 8: 611–630.

McGlynn TP (1999) The worldwide transfer of ants: geographical distribution and ecological invsions. *Journal of Biogeography* 26: 535–548.

Miller N, Estoup A, Toepfer S, Borguet D, Lapchin L, Deirid S, Kin KS, Reynaud P, Furlan L, Guillemaud T (2005) Multiple Transatlantic introductions of the western corn rootworm. *Science* 310: 992.

Moritz RFA, Härtel S, Neumann P (2005) Global invasions of the western honeybee (*Apis mellifera*) and the consequences for biodiversity. *Ecoscience* 12: 289–301.

Murphy ST, Evans HC (2009) Biological control of invasive species. In: Clout MN, Williams PA (Eds) *Invasive Species Management. A Handbook of Principles and Techniques*. Oxford Univ. Press, Oxford, 77–92.

Nentwig W (2007) Pathways in Animal Invasions. In: Nentwig W (Ed) *Biological Invasions*. Ecological Studies 193: 11–27.

Oates MR, Warren MS (1990) A review of butterfly introductions in Britain and Ireland. Joint Committee for the Conservation of British Insects and WWF, Godalming, 96 pp.

Ødegaard F, Tømmerås BA (2000) Compost heaps – refuges and stepping-stones for alien arthropod species in northern Europe. *Diversity and Distributions* 6: 45–59.

Pekar S (2002) *Zodarion rubidum* Simon 1914: railroad riders? Newsletter of the British Arachnological Society 95: 11–12.

Rabitsch W (2008) Alien True Bugs of Europe (Insecta: Hemiptera: Heteroptera). *Zootaxa* 1827: 1–44.

Ratnieks FLW, Carreck NL (2010) Clarity on Honey Bee Collapse? *Science* 327: 152–153.

Rees D (2004) Insects of Stored Products. CSIRO Publishing, Collingwood, 192 pp.

Reiter P (1998) *Aedes albopictus* and the world trade in used tires, 1988–1995: the shape of things to come? *Journal of the American Mosquito Control Association* 14: 83–94.

Ricciardi A, Simberloff D (2009) Assisted colonization is not a viable conservation strategy. *Trends in Ecology and Evolution* 24: 248–253.

Roques A (2010) Alien forest insects in a warmer world and a globalised economy: impacts of changes in trade, tourism and climate on forest biosecurity. *New Zealand Journal of Forestry Science* 40 suppl: S77–S94.

Roques A, Auger-Rozenberg M-A (2006) Tentative analysis of the interceptions of non-indigenous organisms in Europe during 1995–2004. *EPPO Bulletin* 36: 490–496.

Roques A, Rabitsch W, Rasplus J-Y, Lopez-Vaamonde C, Nentwig W, Kenis M (2009) Alien terrestrial invertebrates of Europe. In: DAISIE (Eds) The Handbook of Alien Species in Europe. Springer, Dordrecht, 63–79.

Roy HE, Wajnberg E (2008) From Biological Control to Invasion: the Ladybird *Harmonia axyridis* as a Model Species. Springer, 287 pp.

Roy HE, Brown P, Majerus MEN (2006) *Harmonia axyridis*: a successful biocontrol agent or an invasive treat? In: Eilenberg J, Hokkanen H (Eds) *An ecological and societal approach to biological control*. Progress in Biological Control 2: 295–309.

Ruiz GM, Carlton JT (2003) Invasive species. Vectors and Management Strategies. Island Press, Washington, 518 pp.

Sala J, Boix D (2005) Presence of the nearctic water boatman (*Trichocorixa verticalis verticalis* (Fieber, 1851) (Heteroptera, Corixidae) in the Algarve region (S Portugal). *Graellsia* 61: 31–36.

Sammataro D, Gerson U, Needham G (2000) Parasitic mites of honey bees: life history, implications, and impact. *Annual Review of Entomology* 45: 519–548.

Schaffner F, Hendrickx G, Scholte EJ, Medlock J, Angelini P, Ducheyne E (2009) Development of *Aedes albopictus* risk maps. TigerMaps project report. European Centre for Disease Prevention and Control, Stockholm, 52 pp.

Schmid-Egger C (2004) *Sceliphron curvatum* (F. Smith 1870) in Europa mit einem Bestimmungsschlüssel für die europäischen und mediterranen *Sceliphron*-Arten (Hymenoptera, Sphecidae). *Bembix* 19: 7–28.

Schmitt T, Cizek O, Konvicka M (2005) Genetics of a butterfly relocation: large, small and introduced populations of the mountain endemic *Erebia epiphron* silesiana. *Biological Conservation* 123: 11–18.

Scholte EJ, Schaffner F (2007) Waiting for the tiger: establishment and spread of the *Aedes albopictus* mosquito in Europe. In: Takken W, Knols BGJ (Eds) *Emerging pests and vector-borne diseases in Europe*. Wageningen Academic Publ., Wageningen, 241–260.

Scholte EJ, Den Hartog W, Braks M, Reusken C, Dik M, Hessels A (2009) First report of a North American invasive mosquito species *Ochlerotatus atropalpus* (Coquillett) in the Netherlands, 2009. *Euro Surveillance* 14(45) 19400.

Scotese R (2001) Atlas of Earth History, The Paleomap Project. Arlington, Texas, 52 pp.

Skarpass O, Økland B (2009) Timber import and the risk of forest pest introductions. Journal of Applied Ecology 46: 55–63.

Suarez AV, Holway DA, Ward PS (2005) The role of opportunity in the unintentional introduction of nonnative ants. *Proceedings of the National Academy of Sciences* 102: 17032–17035.

Taylor BW, Irwin RE (2004) Linking economic activities to the distribution of exotic plants. *Proceedings of the National Academy of Sciences* 101: 17725–17730.

Thomas CD, Ohlemüller R (2010) Climate change and species' distributions: an alien future? In: Perrings C, Mooney H, Williamson M (Eds) *Bioinvasions & Globalization. Ecology, Economics, Management, and Policy*. Oxford University Press, Oxford, 19–29.

Thomas DT, Donnelly CA, Wood RJ, Alphey LS (2000) Insect population control using a dominant, repressible, lethal genetic system. *Science* 287: 2474–2476.

Ugelvig LV, Drijfhout FP, Kronauer DJC, Boomsma JJ, Pedersen JS, Cremer S (2008) The introduction history of invasive garden ants in Europe: Integrating genetic, chemical and behavioural approaches. *BMC Biology* 6(11): 1–14.

Valade R, Kenis M, Hernandez-Lopez A, Augustin S, Mari Mena N, Magnoux E, Rougerie R, Lakatos F, Roques A, Lopez-Vaamonde C (2009) Mitochondrial and microsatellite DNA markers reveal a Balkanic origin for the highly invasive Horse-Chestnut leaf miner *Cameraria ohridella* (Lepidoptera, Gracillariidae). *Molecular Ecology* 18: 3458–3470.

Van der Weijden WJ, Marcelis RAL, Reinhold W (2007) Invasions of vector-borne diseases driven by transportation and climate change. In: Takken W, Knols BGJ (Eds) *Emerging pests and vector-borne diseases in Europe*. Wageningen Academic Publ., Wageningen, 439–463.

Van Lenteren JC, Bale J, Bigler F, Hokkanen HMT, Loomans AJM (2006) Assessing risks of releasing exotic biological control agents of arthropod pests. *Annual Review of Entomology* 51: 609–634.

Vazquez DP, Simberloff D (2001) Taxonomic selectivity in surviving introduced insects in the United States. In: Lockwood JL, McKinney ML (Eds) *Biotic Homogenization*. Kluwer Acad. Pl., New York, 103–124.

Vierbergen G (2001) Occurrence of glasshouse Thysanoptera in the open in the Netherlands. In: Marullo R, Mound L (Eds) *Thrips and Tospoviruses*: Proceedings of the 7th International Symposium on Thysanoptera. CSIRO, Canberra, 390 pp.

Villemant C, Haxaire J, Streito J-C (2006) Premier bilan de l'invasion de *Vespa velutina* Lepeletier en France (Hymenoptera, Vespidae). *Bulletin de la Société entomologique de France* 111: 535–538.

Walther G-R, Roques A, Hulme PE, Sykes MT, et al. (2009) Alien species in a warmer world: risks and opportunities. *Trends in Ecology and Evolution* 24: 686–693.

Westphal MI, Browne M, MacKinnon K, Noble I (2008) The link between international trade and the global distribution of invasive alien species. *Biological Invasions* 10: 391–398.

Wetterer J, Wild AL, Suarez AV, Roura-Pascual N, Espadaler X (2009) Worldwide spread of the Argentine ant, *Linepithema humile* (Hymenoptera: Formicidae). *Myrmecological News* 12: 187–194.

Wilson JRU, Dormontt EE, Prentis PJ, Lowe AJ, Richardson DM (2009) Something in the way you move: dispersal pathways affect invasion success. *Trends in Ecology and Evolution* 24: 136–144.

Witzenberger K, Hochkirch A (2008) Genetic consequences of animal translocations: A case study using the field cricket, *Gryllus campestris* L. Biological Conservation 141: 3059–3068.

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RESEARCH ARTICLE

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Invaded habitats
Chapter 4

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Abstract

More than 65% (1040 species) of arthropod species alien *to* Europe are associated with human-made habitats, especially parks and gardens, human settlements and agricultural lands, whereas woodlands are yet colonized by less than 20% of the alien fauna, which still has a negligible representation in the other natural and semi-natural habitats. Large differences in habitat affinity are observed between alien taxonomic groups. Phytophagous species are predominant among aliens, representing 47.2% of species alien *to* Europe.

Keywords

alien, arthropod, habitat, Europe, level of invasion, urban, semi-urban

4.1 Introduction

The lack of a general assessment on the level of habitat invasion in Europe has up to now limited the possibilities of evaluating the risks arthropod invaders pose to different habitats. Such an assessment is a fundamental component of early detection and identification of those environments that are more prone to invasion, that will provide a baseline for optimizing actions to prevent, monitor and control invasion (Pyšek et

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al. 2010). For that reason, here we present a synthesis of the data on habitat preference of terrestrial arthropods alien *to* Europe compiled from chapters 7-13 of this book, providing an overview of which habitats are most invaded in Europe, and to assess differences among alien taxa in terms of habitat affinity.

We compared the numbers of established alien species occurring in 11 European habitats defined according to the European Nature Information System, level 1 (EUNIS) (Davies et al. 2004). This standard classification of European habitats has been chosen as a platform in several different studies on biological invasions in Europe (Chytrý et al. 2008, Daisie 2009, Pyšek et al. 2010). In this classification, a 'habitat' is defined as '*a place where plants or animals normally live, characterized primarily by its physical features (topography, plant or animal physiognomy, soil characteristics, climate, water quality, etc.) and secondarily by the species of plants and animals that live there*' (Davies *et al.*, 2004). Appendix II presents the different habitat types used throughout the taxa chapters. For more convenience, our analysis grouped them into the following broad categories roughly corresponding to the level I of EUNIS: coastal habitats (EUNIS class B); wetlands and riparian habitats (C); mires (D); grasslands (E); heathlands, hedgerows and shrub plantations (F); woodlands (G); cultivated habitats (I1); parks and gardens (we grouped the classes I2 and X11, X22, X23, X24, X25); and urban settlements (J) to which we added a specific code for greenhouses (J100). These broad categories may not precisely reflect the habitat(s) actually colonized by some species, but their use standardizes comparisons between very different taxa such as arthropods, plants and vertebrates.

The habitats in the system adopted here differ considerably in the number of alien arthropod species they contain. Aliens show a strong affinity for the habitats intensively disturbed by human activities (Figure 4.1.). Considering all established alien terrestrial arthropods, the highest percentage occurs in parks and gardens (500 out of the 1590 alien species found in Europe- 31.4%) and in human settlements (31.0 %), whilst slightly less occur in cultivated habitats, which host 29.7% of these alien species. Altogether, human-made habitats host 65.4% (1040 species) of the fauna of arthropods alien *to* Europe, most of these species being likely to occur in several different habitats. In contrast, less than 10% of the alien species have yet colonized natural and semi-natural habitats such as wetlands, riparian habitats, grasslands and heathlands, and less than 20% occur in woodlands and forests (Figure 4.1). These results confirm the analysis of Roques et al. (2009) which relied on a lower number of alien arthropod species. Pyšek et al. (2010) also stated that alien plants are mostly found in human-made, urban or cultivated habitats, unlike vertebrates, which are more evenly distributed among habitats, the most invaded of which are aquatic and riparian habitats, woodland and cultivated land.

Some habitats are differentially preferred by certain taxonomic groups (Table 4.1). For instance, many alien species are pests of ornamental plants in parks and gardens. In particular, mites are an important group attacking urban trees, shrubs and flowering plants. More than 40% of alien mites are observed in this habitat. Similarly, alien hemipterans, especially aphids, and lepidopterans have colonized parks and gar-

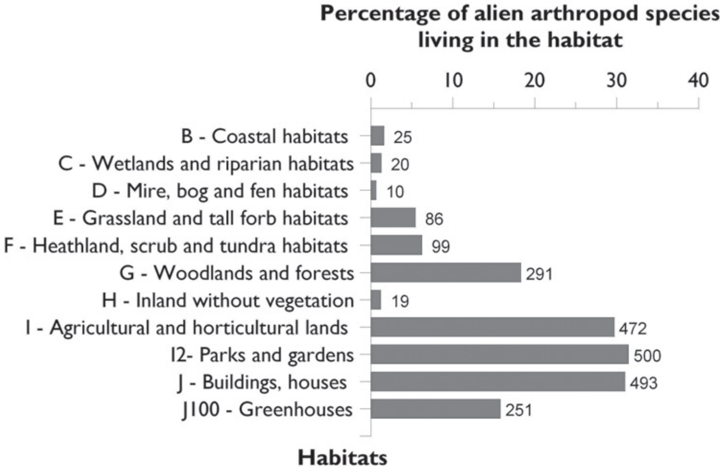

Figure 4.1. Main European habitats colonized by the 1590 species of terrestrial arthropods alien *to* Europe. The number over each bar indicates the absolute number of alien species recorded per habitat. Note that a species may have colonized several habitats.

dens effectively, 78.9% and 56.7% of their species being observed there, respectively (Table 4.1).

Built-up, industrial and other artificial habitats are invaded to a high degree by spiders. Indeed, more than 90% of the alien spiders are found in buildings. Psocoptera is another well-represented group in this habitat with 81.6% of its alien species in Europe occurring there, as is Phthiraptera (67.7%) and Coleoptera (57.3%), a number of species of the latter group being associated with stored products. By contrast, alien Hymenoptera are mostly present in agricultural lands which are colonized by 65.0% of the alien species in this taxon, probably in relation with the multiple parasitoid releases that have occurred for biological control purposes. Greenhouses constitute another important man-made habitat type, which hosts most alien myriapods (64.7%) and thrips (55.8%).

Why do most introduced terrestrial arthropods apparently stay confined to human- modified habitats in their alien range of distribution? Several ecological conditions may be considered: i) disturbed urban and semi-urban areas may have a lower resistance to aliens, especially because of a lower pressure of potential natural enemies and, for phytophagous aliens, less vigorous host plants; ii) some species may prefer human-related habitats in their native range and are thus more likely to be carried into a new area by human transport, than species living in natural environments (Kenis et al. 2007). For instance, exotic ornamental plants are generally used in man-made habitats such as nurseries, parks and gardens and roadside plantings and shelter belts. Most alien phytophagous species introduced alongside these ornamentals remain as yet strictly associated with their original, exotic host (46.4% in Europe; Roques, 2008). They have not so far colonized native trees, and thus they develop only in parks and gardens and in hedgerows where such exotic plants are planted. A striking example is that of the horse-chestnut leaf-mining moth *Cameraria ohridella*, which in its area of origin, the southern Balkans, lives in mountain ravines, whereas in its introduced area of Central and Western Europe, preferentially colonizes urban parks and gardens where its host tree has been extensively planted (Valade et al. 2009).

However, there could be a time-lag between the introduction to human habitats and adaptation and spread to natural habitats. Therefore, many alien species currently confined to human-made habitats should be monitored for their potential spread to natural areas (Roques et al. 2009). For instance, species such as the Asian longhorn beetles, *Anoplophora* spp., (Coleoptera, Cerambycidae) have the potential to live in urban areas, in cultivated lanes (e.g. those planted with poplars) as well as in natural forests where potential host plants occur. However, dispersal from man-made habitats to natural forests appears to be a slow process. For the first twenty-two years since its arrival in North America, *A. glabripennis* was restricted to trees in urban areas, but in 2008, it was found in natural forests dominated by *Acer* trees (Haack et al. 2010).

Finally, phytophagous species are predominant among the alien terrestrial arthropods, representing 47.2% (751 of 1590) of alien species to Europe, Parasitoids and predators only account for 32.6 % (518 spp.) whilst detritivores represent 20.8% (331 spp.). A few species exhibit several phytophagous guilds, whilst the habits of just 19 species are still unknown.

References

Chytrý M, Maskell LC, Pino J, Pyšek P, Vilà M, Font X, Smart SM (2008) Habitat invasions by alien plants: a quantitative comparison among Mediterranean, subcontinental and oceanic regions of Europe. *Journal of Applied Ecology*, 45: 448–458.

DAISIE (2009) *Handbook of alien species in Europe*. Dordrecht: Springer. 399 pp.

Davies CE, Moss D, Hill MO (2004) EUNIS habitat classification, revised 2004. Paris: European Environment Agency, Copenhagen and European Topic Centre on Nature Protection and Biodiversity.

Haack RA, Hérard F, Sun JH, Turgeon JJ (2010) Managing invasive populations of Asian longhorned beetle and Citrus longhorn beetle: A worldwide perspective. *Annual Review of Entomology* 55: 521–546.

Kenis M, Rabitsch W, Auger-Rozenberg M-A, Roques A (2007) How can alien species inventories and interception data help us prevent insect invasions? *Bulletin of Entomological Research* 97: 489–502.

Pyšek P, Bacher S, Chytrý M, Jarošík V, Wild J, Celesti-Grapow L, Gassó N, Kenis M, Lambdon P, Nentwig W, Pergl J Roques A, Sádlo J, Solarz W, Vilà M, Hulme PE (2010) Contrasting patterns in the invasions of European terrestrial and freshwater habitats by alien plants, insects and vertebrates. *Global Ecology and Biogeography* 19: 317–331.

Roques A. (2008). The pan-European inventory of alien species established on trees on shrubs, a tool for predicting taxa and ecosystems at risk -final results of the DAISIE project. In *Alien invasive species and international trade, 2nd meeting of IUFRO Working Unit 7.03.12,* *May 26-30, 2008, National Conservation Training Center, Shepherdstown, WV, USA.* Available at [http://www.forestry.gov.uk/pdf/IUFRO_ Shepherdstown_Roques_Sheperdstown_ end.pdf/FILE/IUFRO_Shepherdstown_ Roques_Sheperdstown_end.pdf]

Roques A, Rabitsch W, Rasplus JY, Lopez-Vaamonde C, Nentwig W, Kenis M (2009) Alien terrestrial invertebrates of Europe. In: Daisie (Ed) *Handbook of Alien Species in Europe*. Dordrecht: Springer, 63–79.

Valade R, Kenis M, Hernandez A, Augustin S, Mari Mena N, Magnoux E, Rougerie R, Lakatos F, Roques A, Lopez-Vaamonde C (2009) Mitochondrial and microsatellite DNA markers reveal a Balkan origin for the highly invasive Horse-Chestnut leaf miner Cameraria ohridella (Lep. Gracillariidae). *Molecular Ecology* 18: 3458–3470.

Table 4.1. Comparative colonization of European habitats by the different taxonomic groups of terrestrial arthropods alien to Europe. The total number of established alien species observed in each habitat is figured. A species may have colonized several habitats. The percentage of species observed in the habitat with regard to the total number of alien species in the taxonomic group in Europe (last line) is given between brackets. 'Polyneoptera' includes Blattodea, Dermaptera, Isoptera, Orthoptera and Phasmatodea (see Chapter 13.3).

EUNIS categories	Crustacea	Myriapods	Aranea	Acari	Coleoptera	Diptera	Hemiptera	Hymenoptera	Lepidoptera	Phthiraptera	Polyneoptera[1]	Psocoptera	Siphonaptera	Thysanoptera	Zygentoma/ Collembolla
A- Marine habitats	-	-	-	-	-	-	-	-		-		-	-	-	-
B- Coastal habitats	-	3 (8.8)	-		12 (3.0)	6 (6.1)	2 (0.6)	-	2 (2.1)	-		-	-	-	-
C- Riparian habitats	-	-	-	6 (5.9)	5(1.3)	4 (4.1)	1 (0.3)	3 (1.0)	-	1 (3.2)		-	-	-	-
D- Mires, bogs, fens	-	1 (2.9)	-	-	3 (0.8)	4 (4.1)	1 (0.3)	1 (0.3)	-	-		-	-	-	-
E- Grasslands	-	2 (5.9)	6 (12.8)	2 (2.0)	24 (6.0)	6 (6.1)	19 (6.0)	8 (2.7)	3 (3.1)	4 (12.9)	7 (18.9)	-	2 (28.6)	3 (5.8)	-
F- Heathlands	-	2 (5.9)	6 (12.8)	9 (8.8)	39 (9.8)	4 (4.1)	16 (5.0)	4 (1.3)	13 (13.4)	1 (3.2)	2 (5.4)	-	1 (14.3)	2 (3.8)	-
G- Woodlands	3 (17.6)	4 (11.8)	6 (12.8)	10 (9.8)	77 (19.3)	12 (12.2)	61 (19.2)	74 (24.9)	19 (19.6)	8 (28.6)	1 (2.7)	12 (19.0)	2 (28.6)	2 (3.8)	-
H- Bare lands	-	2 (5.9)	6 (12.8)	-	2 (0.5)	1 (1.0)	1 (0.3)	2 (0.7)	2 (2.1)	-	1 (2.7)	2 (3.2)	-	-	-
I- Cultivated lands	-	3 (8.8)	6 (12.8)	33 (32.4)	87 (21.9)	18 (18.4)	91 (28.6)	193 (65.0)	25 (25.8)	-	7 (18.9)	1 (1.6)	-	7 (13.5)	1 (16.7)
I2/X- Parks, gardens	-	9 (26.5)	-	42 (41.2)	69 (17.3)	17 (17.3)	251 (78.9)	23 (7.7)	55 (56.7)	7 (14.3)	2 (5.4)	8 (12.7)	1 (14.3)	15 (28.8)	1 (16.7)
J- Urban, semi-urban	17 (100.0)	8 (23.5)	43 (91.5)	11 (10.8)	228 (57.3)	25 (25.5)	7 (2.2)	31(10.4)	33 (34.0)	21 (71.4)	20 (54.1)	40 (63.5)	5 (71.4)	1 (1.9)	3 (50.0)
J100 - Greenhouses	-	22 (64.7)	2 (4.3)	13 (12.7)	12 (3.0)	6 (6.1)	80 (25.2)	63 (21.2)	16 (16.5)	-	5 (13.5)	-	-	29 (55.8)	3 (50.0)
Total species	**17**	**34**	**47**	**102**	**398**	**98**	**318**	**297**	**97**	**31**	**37**	**49**	**7**	**52**	**6**

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Impact of alien terrestrial arthropods in Europe
Chapter 5

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Abstract

This chapter reviews the effects of alien terrestrial arthropods on the economy, society and environment in Europe. Many alien insect and mite species cause serious socio-economic hazards as pests of agriculture, horticulture, stored products and forestry. They may also affect human or animal health. Surprisingly, there is relatively little information available on the exact yield and financial losses due to alien agricultural and forestry pests in Europe, particularly at continental scale. Several alien species may have a positive impact on the economy, for example parasitoids and predators introduced for the biological control of important pests. Invasive alien arthropods can also cause environmental hazards. They may affect native biodiversity through various mechanisms, including herbivory, predation, parasitism, competition for resource and space, or as vectors of diseases. They can also affect ecosystem services and processes through cascading effects. However, these ecological impacts are poorly studied, particularly in Europe, where only a handful cases have been reported.

Keywords

Biological invasions, economic impact, environmental impact, alien arthropods

5.1. Introduction

Alien insects and other terrestrial arthropods are among the most numerous invaders worldwide. In Europe alone, the update of the DAISIE database (Roques et al. 2009) which is presented in this book considers that 1590 terrestrial arthropod species of

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non-European origin are established in Europe, including 1390 insects, 47 spiders,102 mites, 34 myriapods and 17 crustaceans. Many others originate from a restricted region in Europe but have invaded other parts of the continent. The establishment and spread of these alien species may have various effects. The best documented impacts are economic, particularly due to agricultural or forest pests (Pimentel et al. 2002a, 2002b). Alien arthropods also impact the environment by affecting populations or communities of native species and by disturb natural ecosystem processes and services (Kenis et al. 2009). They affect human and animal health. Finally, alien organisms have a social impact when they influence human well-being (Binimelis et al. 2007).

In this chapter, we review the socio-economic and environmental impacts caused by alien terrestrial arthropods in Europe. Human and animal health impacts will be considered with socio-economic impacts since they represent measurable economic and social costs. Although the social costs of invasions are often difficult to measure in monetary terms, we could not find a single example of an alien arthropod in Europe that primarily affects human well-being without an additional economic burden.

The impact of alien species is usually considered to be negative. In some cases, however, the introduction of an alien arthropod may have a positive impact on the economy or the environment, for example when an exotic biological control agent successfully controls a pest, reducing yield losses or preventing the use of pesticides. Positive impacts of alien arthropods will also be considered in this review.

The review is partly based on the DAISIE database, a pan-European inventory of alien species commissioned by the European Union (Hulme et al. 2009). When building the list of alien organisms in Europe, experts were asked whether the organism had an economic or environmental impact in a particular country. Although their judgement provides valuable opinions, these have to be taken with caution because they were largely subjective and often unsupported by published references.

5.2. Socio-economic impact

The economic impact of alien species has been described as the consequence of an interaction between the invader and economically valuable indigenous species (Williamson 1996). Alien arthropods can affect the economy and society in various ways, through their impact on agriculture, horticulture, forestry, stored products, human and animal health, or various services.

Economic impacts can be direct or indirect. Direct economic impacts occur when alien species that affect valuable species or goods cause damage that results in yield losses and increasing production costs. These types of economic impacts are those most often described and can be easily expressed in monetary values (Pimentel et al. 2002a, 2002b). Pest management costs contribute largely to the direct economic impact of alien species. Insect pests imply the yearly application of more than 3000 million kilograms of insecticides globally (Pimentel 2007), a large share of it targeting alien pest species. An alien pest may also cause yield losses in its role as vector of other pests and diseases, through interference with indigenous pollinators or as competitors, parasites or predators of beneficial organisms.

Indirect socio-economic effects associated with the introduction of an alien pest include, among others, restrictions on trade flow, effects on market access, changes in market values, changes to domestic or foreign consumer demand for a product resulting from quality changes, changes in land use and landscape structure, public health concerns, costs associated with research and educational services, societal effects such as unemployment, effects on tourism, etc. Indirect effects are often difficult to evaluate because many of them cannot easily be expressed in monetary terms (Born et al. 2005).

Vilà et al. (2010) estimated from the DAISIE database that 24.2% of the alien invertebrates in Europe have an economic impact. More than a half (51.6%) of the terrestrial arthropods alien to Europe are herbivores and, similarly, about 50% of those with economic impact are phytophagous species. Kenis et al. (2007) found that 40% of the alien insects in Switzerland and Austria had at least one web page describing damage and control methods, suggesting a socio-economic impact. Kenis et al. (2007) also estimated that the rate of native insects reaching pest status in temperate countries is probably much lower than 5%. Alien arthropods are well known for being serious plant pests worldwide. More than half of alien arthropods of economic concern are plant pests, which may directly affect yield losses of a variety of forestry and agricultural crops, such as timber, fruits, vegetables, cereals, ornamentals, etc. Insect pests destroy approximately 14% of all potential food production globally (Pimentel 2007). It is estimated that between 30 and 45% of the insect pests in agriculture and forestry worldwide are of alien origin (Pimentel et al. 2002a, 2002b), despite the fact that they only represent a few percent of the insect fauna.

Economic studies on the impact of alien arthropods worldwide are numerous, but less so in Europe. Born et al. (2005) also stated that most economic analysis on the impacts of alien species has been undertaken outside Europe, particularly in North America, South Africa and Oceania. Below, we discuss the most serious economic alien pests of agriculture, protected horticulture, stored products and infrastructures, forestry and urban trees and human and animal health in Europe. Positive impacts of alien arthropods on the economy are discussed separately.

5.2.1. Outdoor agricultural and horticultural pests

Many alien arthropods affect European agriculture and horticulture, mainly through yield losses and management costs, but also though quarantine measures, market effects and foreign trade impact. Reliable data on average yield and financial losses due to alien agricultural pests are not frequently published, particularly in Europe. This may be partly due to the lack of controlled, replicated experiments in commercial fields required to document such information. Furthermore, crops are often attacked by several pest species and the contribution of yield or monetary loss due to a single species is difficult to assess. Pimentel (2002) has calculated for the British Isles that, since each year arthropods damage or destroy approximately 10% of the crops and 30% of the pests are of exotic origin, alien arthropods cause yield losses of $960 million per year. A similar calculation for the entire European Union would lead to annual economic losses of approximately 10 billion € caused by alien arthropods. This does not include control, eradication or quarantine costs, nor costs linked to foreign trade impact or market effects. The agricultural/horticultural insecticide market represents over one billion € per year in Europe (ECPA 2007), of which probably at least 20 to 30% is to control alien pests.

The first major alien agricultural insect pest that hit the European economy was the American vine phylloxera, *Viteus vitifoliae*, which, in the late 19th century completely destroyed nearly one-third of the French vineyards in the country, i.e. more than 1.000,000 ha, with incalculable economic and social consequences (CABI 2007). The problem was largely solved by replanting European cultivars grafted onto resistant American rootstocks, although some phylloxera biotypes have developed that may overcome the resistance of certain rootstock cultivars.

Another major arthropod that invaded the European fields a while ago is the Colorado potato beetle, *Leptinotarsa decemlineata*. Since its first occurrence in France in 1922, it has spread to most European countries, causing considerable yield losses in potato fields. Nowadays, effective routine control of the beetle has been incorporated into potato cultivation systems and it is difficult to properly assess the economic cost of the beetle alone. In the eastern USA, the cost of controlling infestations averages between US$138 and $368 per hectare but, in this region, infestations are higher than in Europe because of the local development of resistance to the major insecticides (CABI 2007). *Leptinotarsa decemlineata* has not yet invaded the whole of Europe and some countries are still spending significant amounts of money to prevent its entry. For example, in Finland, pre-entry control measures against the beetle cost an average of EUR 171,000 per year in the period from 1999 to 2004 (Heikkilä and Peltola 2006). A cost-benefit analysis showed that the benefit of these protection measures strongly depends on future scenarios, in particular regarding local climatic conditions and agricultural policies.

In the 1990s, the introduction into Europe of the western corn rootworm beetle *Diabrotica virgifera virgifera,* a serious maize pest in North America, generated much attention. A few years after its introduction, mean yield losses in Serbian Maize fields were estimated to be around 30% (Sivcev and Tomasev 2002). Baufelt and Enzian (Baufeld and Enzian 2005) calculated that the potential pecuniary losses in maize due to *D. virgifera virgifera* in a selection of European countries was as high as 147 million €/year, based on a conservative average yield loss of 10%. Consequently, most European countries apply costly regulatory control measures to prevent the pest's establishment in their countries. Nevertheless, in some countries, regulatory control measures may not be economically justified. For example, in UK a cost/benefit analysis showed that, in the absence of a statutory campaign, yield losses of 5% caused by the beetle in maize could have a present value of £0.6 to £2.8 million over 20 years. However, costs of a statutory campaign against the pest over the same period could range from £2.5 to £7.1 million (MacLeod 2006).

Fruit orchards are particularly prone to alien insect invasions. Many of the most serious pests in European orchards are alien, such as the San José scale, *Diaspidiotus perniciosus*, the Mediterranean fruit fly, *Ceratitis capitata*, the oriental fruit moth, *Grapholita molesta*, the citrus leaf miner, *Phyllocnistis citrella*, the woolly whitefly, *Aleurothrixus floccosus*, etc. Some arthropods are harmless by themselves but are vectors of serious diseases, such as the leafhopper *Scaphoideus titanus*, vector of Flavescence dorée in vineyards. These arthropods, and many other alien agricultural and horticultural pests are described in the factsheets (see Chapter 14). Despite their economic importance, there is little information on the exact costs related to orchard pests. However, when data are available, they are impressive. For example, in Israel, Palestine and Jordan, the annual fruit losses due to *C. capitata* were estimated to be about U.S. $365 million, an amount which represents more than half of the total fruit revenue of the area (Enkerlin and Mumford 1997).

5.2.2. Pests of protected horticulture

Most plant pests that occur in greenhouses and other protected environments are of tropical or sub-tropical origin. Some of them also occur on outdoor crops in Southern Europe. Among the most serious alien pests of protected crops in Europe are the leaf miners *Liriomyza huidobrensis* and *L. trifolii*, the whiteflies *Bemisia tabaci* and *Trialeurodes vaporariorum*, the aphids *Aphis gossypii*, *Myzus persicae* and *Macrosiphum euphorbiae,* the western flower thrips *Frankliniella occidentalis* (see factsheets 23, 24, 33, 35, 37 and 78), the citrus mealybug *Planococcus citri* and the moth *Opogona sacchari*. Several of these, particularly aphids, whiteflies and thrips, are vectors of important plant viruses. Mediterranean arthropods such as the lepidopteran defoliator *Cacoecimorpha pronubana*, the leaf mining fly *Liriomyza bryoniae* and the spotted spider mite *Tetranychus urticae* have now invaded protected crops throughout Europe (Brødsgaard and Albajes 1999).

These alien pests cause enormous economic damage to the greenhouse and protected crops industry, through yield losses, control costs, contingency plans, eradication costs or losses in consignments for export. For example, Roosjen et al. (Roosjen et al. 1998) estimated that the annual cost of *F. occidentalis* to the Dutch greenhouse could be US$30 million, plus a further US$19 million from the effects of Tomato spotted wilt tospovirus transmitted by the thrips. An intensive eradication programme carried out to control an outbreak of the melon thrips, *Thrips palmi* in a UK greenhouse in 2000 cost £178,000 (MacLeod et al. 2004). A cost/benefit analysis showed that this eradication programme was four to 19 times cheaper compared with potential losses forecast by modelling the spread and impact of *T. palmi* in glasshouse crops over ten years. In another example, Rautapaa (1984) comparing all the costs caused by exclusion measures (eradication + quarantine) to maintain Finland free from *Liriomyza* *trifolii*, with the costs of living with the pest, obtained ratios 1:3 to 1:13 in favour of eradication/quarantine measures.

5.2.3. Stored product and infrastructure **pests**

In Europe, 113 alien insect species are pests of stored products, feeding on products such as grains, seeds, fruits, fabrics, and wood products. Most are Coleoptera (e.g. Anobiidae, Bostrichidae, Chrysomelidae, Cucujidae, Curculionidae, Dermestidae, Mycetophagidae, Nitidulidae, Ptinidae, Silvanidae and Tenebrionidae), Lepidoptera (mainly Pyralidae; Gelechiidae and Tineidae) and Blattodea (cockroaches). Several alien xylophagous beetles and termites may also seriously damage public infrastructures and domestic impairments, furniture and buildings. Alien stored product and infrastructure pests are usually cosmopolitan insects of tropical or sub-tropical origin, being transported worldwide with their food (Rees 2004).

Both the quantity and quality of the stored products may be affected by pests. An economic evaluation has been carried out for three species in Germany (Reinhardt et al. 2003). The annual costs arising from the two grain beetles *Oryzaephilus surinamensis* and *Rhyzopertha dominica* vary from 11.2 to 35.3 million € and that of the flour moth *Ephestia kuehniella* from 4.6 to 12.3 million €. Considering that these numbers are only for Germany and for three pest species, it is likely that the costs due to the two dozen economically significant alien stored product arthropod pests in Europe exceed 1 billion € per year.

5.2.4. Forestry and urban tree pests

Alien arthropods can have severe economic impacts on forest plantations and urban parks. A total of 438 alien insects are associated with woody plants, representing 28.7% of all European alien species (Roques 2010). So far, European forests have suffered less from invasive arthropods than other continents, and the most important forest pests in Europe are still indigenous species. However, several potentially damaging alien forest pests have recently become established, such as the chestnut gall wasp *Dryocosmus kuriphilus*, the ambrosia beetle, *Megaplatypus mutatus* and the two Asian longhorned beetles *Anoplophora glabripennis* and *A. chinensis* (see factsheets 6, 7, and 17). Exotic trees tend to suffer more from alien pests than native trees (Day and Leather 1997). Forty-seven percent of the alien pest species affecting forest and urban trees are associated mainly or exclusively with exotic tree and shrub species (Roques 2010). For example, eucalyptus trees are particularly prone to damage by invaders from Australia. Nine alien arthropods are presently found in Europe feeding on eucalyptus, including two woodborers, *Phoracantha semipunctata* and *P. recurva,* the eucalyptus snout beetle, *Gonipterus scutellatus*, three psyllids *Ctenarytaina eucaliptii*, *C. spatulata* and *Glycaspis brimblecombi*, two gall wasps *Leptocybe invasa* and *Ophelimus maskelli* and an eriophid mite, *Rhombacus eucaliptii.* In southern Spain, after the first detection of *P. semipunctata* in 1981, the average tree mortality in the subsequent two years was estimated to be about 3%, equivalent to a loss of 6207 ha, despite the costly control measures applied during this period (Gonzalez Tirado 1986). *Gonipterus scutellatus* is considered to cause tree growth losses of up to 30% in Galicia (Mansilla et al. 1996). The arrival of alien forest pests may also have indirect effects on land use and land value. For example, in Portugal, in the years following the arrival of *P. semipunctata*, eucalyptus plantations situated in marginal areas, poorly suitable for the cultivation of this tree species, were abandoned and the land was used for other purposes (M. Branco, unpublished observation).

In contrast to what is observed in forests, a large proportion of the arthropod pests attacking ornamental and urban trees in streets, parks and gardens in Europe are alien, partly because many tree species planted in urban areas are exotic. Common non-European pests of urban trees and shrubs include, among others, the lace bug *Corythucha ciliata*, the scales *Pulvinaria regalis* and *Pseudaulacaspis pentagona,* the American false webworm *Hyphantria cunea* and the arborvitae leaf miner *Argyresthia thuiella* (See factsheets 41, 45, 52, 64 and 77). The citrus longhorned beetle *Anoplophora chinensis* was recently introduced from Asia to Italy, where it is now established and spreading, despite an eradication programme. This polyphagous wood borer has already killed thousands of urban trees and shrubs in an area of nearly 200 km^2 (Tomiczek and Hoyer-Tomiczek 2007). Ornamental palms and their trade in the Mediterranean region are seriously threatened by several alien insects, in particular the Asian weevil *Rhynchophorus ferrugineus* and the South American moth *Paysandisia archon* (EPPO 2008a, 2008b).

Several of the most important tree pests in Europe invaded from other parts of the continent. The maritime pine bast scale, *Matsucoccus feytaudi*, an Iberian species, destroyed thousands of hectares of maritime pine forest in South-eastern France, Corsica and Italy, e.g. (Covassi and Binazzi 1992, Jactel et al. 1998, Riom 1994). Important ornamental tree pests in Central and Western Europe originate from the Balkans, such as the horse-chestnut leaf miner *Cameraria ohridella* (Tremblay 1984) and possibly the plane leaf miner, *Phyllonorycter platani* (Schönrogge and Crawley 2000). Many forest pests from continental Europe have invaded the British Isles, where they may cause severe damage to forest plantations, such as the spruce aphid *Elatobium abietinum* or the larger spruce bark beetle *Dendroctonus micans* (Day and Leather 1997).

Tree pests may have a direct economic effect through decrease of timber value, wood increment loss and tree mortality, treatment costs and costs related to early harvesting and replanting. There are few examples where the costs of alien forest pests have been calculated precisely in Europe. In the British Isles, the estimated cost to losses in forestry products due to alien arthropods is about $2 million per year, that is about 2% of the cost of alien arthropods in the agricultural sector (Pimentel 2002). These numbers may suggest that the direct economic impacts on forest products are much lower than on agricultural crops. The difference might partly be explained by the fact that trees may often sustain pest attacks without substantial growth loss and without tree mortality (Speight and Wainhouse 1989). Furthermore, dead trees may still have economic value as salvage. Still, it should be considered that forests account for only 11% of land cover in the British Isles (Forestry Commission 2006). In other European countries where the percentage of forest land cover is higher (e.g. 72% in Finland), the relative direct economic impact of alien forest pests will be much higher.

Higher impact values are obtained when control costs are included. For example, Reinhardt et al. (Reinhardt et al. 2003) estimated that the control of the horse-chestnut leaf miner, *Cameraria ohridella,* in Germany would cost 10.02 to 33.8 millions € per year and the replacement costs for all horse-chestnut trees would be as high as 10.7 billion €. The eradication and control costs against *A. chinensis* in Northern Italy amounted to 900,000 € in 2005/2006, but are supposed to reach 10 million € in the period 2008–2010 (Ciampitti 2009). Furthermore, forest ecosystems provide a variety of environmental services with high socio-economic value, such as water resources, soil protection, climate amenity, carbon sequestration and leisure. All these may be seriously hampered by tree defoliation and tree mortality caused by alien forest pests.

5.2.5. Arthropods affecting human and animal health

Human and animal health can be affected by various groups of alien arthropods, in particular detritivorous and hematophagous species. These generate economic costs related to control strategies, public health measures, health treatments, sick leave, educational programmes, etc. Some detritivores may affect human health by both food poisoning and disease transmission. For example, cockroaches, four of which are listed as alien in the DAISIE database, can carry microbes on their body surface and infest human and animal food. They can also provoke allergic reactions, including asthma (Brenner et al. 1987, Rivault et al. 1993).

Hematophagous arthropods, besides being a human nuisance through their biting behaviour, are also able to transmit diseases or to cause allergies and dermatitis to human or domestic animals (Lounibos 2002). Seven alien mosquitoes (Diptera: Culicidae) are found in Europe. The Asian tiger mosquito, *Aedes albopictus*, and the Asian rock pool mosquito, *Aedes japonicus*, have already invaded several European countries. They both are natural vector of various viruses and filaria for humans and domestic animals (Mitchell 1995, Schaffner et al. 2009). In summer 2007, in Italy, for the first time in Europe *A. albopictus* was found to be the vector of an infectious disease, the Chikungunya virus (Enserink 2007). Tropical and sub-tropical mosquito species are often accidentally introduced in Europe and, with global warming, there is a risk that more mosquito species and their associated diseases could become established, particularly in southern Europe.

The DAISIE database also mentions six fleas (Syphonaptera), 27 sucking louses (Phthiraptera) and 20 mites that are also able to transmit diseases or to cause allergies and dermatitis to human and animals (Roques et al. 2009). Worth mentioning are the rat flea, *Nosopsyllus fasciatus*, which is the primary vector for bubonic plague and murine typhus (Beaucornu and Launay 1990) and alien ticks of the genus *Hyalomma* that represent emerging risks for humans and animals in Europe by transmitting tick-borne rickettsial diseases (Parola 2004) (see chapter 7.2.). Finally, although the vast majority of the 48 alien Araneae in Europe are of no medical concern, several species of importance to human health are increasingly intercepted at entry ports, and a few are reported as being established, such as two *Loxosceles* spp. from America and a black widow, *Latrodectus hasselti*, from Australia (Kobelt and Nentwig 2008).

5.2.6. Arthropods with a positive economic impact

Although alien arthropods are mostly associated with negative effects, some alien species may generate substantial economic benefits. For example, many predators and parasitoids introduced as biological control agents to control alien pests have a positive economic impact. The update of the DAISIE database presented in this book lists 217 non-European arthropods acting as biocontrol agents of plant pests, or pests of stored products. Parasitoids include mostly chalcidoid wasps, in particular Aphelinidae (63 spp.) and Encyrtidae (55 spp.) whereas the most numerous introduced predators are Coccinellidae (12 spp.). Most of these species were intentionally introduced to control alien plant pests in outdoor crops or used as augmentative biological control agents in greenhouses. In Europe, the majority of the vegetable greenhouse area is under biological control or IPM (van Lenteren 2007), using a large variety of predators and parasitoids (van Lenteren et al. 1997). Various cost-benefit analyses have shown that, in greenhouses, biological control is the most cost-effective method (van Lenteren 2007). Many natural enemies established in the wild in Europe have a substantial impact on plant pests, such as the aphelinid *Aphelinus mali*, parasitoid of the woolly aphid *Eriosoma lanigerum*, and the coccinellid *Rodolia cardinalis*, predator of the cottony cushion scale *Icerya purchasi* (Greathead 1976). Some species released locally have been to spread quickly and rapidly become established in the wild. For example, the Australian parasitoid wasp, *Psyllaephagus pilosus*, which was released locally in southern France in 1997 to control the eucalyptus psyllid *Ctenarytaina eucalypti*, by 1998 had become established and spread westwards by more than 85 km (Malausa 1998). Interestingly, some of the most efficient natural enemies in Europe were introduced unintentionally, such as *Avetianella longoi*, an egg parasitoid of the eucalyptus woodborer *Phoracantha semipunctata* in Italy and Portugal (Farrall et al. 1992, Siscaro 1992), and *Closterocerus chamaeleon*, an Australian parasitoid of the eucalyptus gall wasp *Ophelimus maskelli* found in Portugal in 2007 (Branco et al. 2009).

Pollinators are other insects whose introductions are often considered beneficial. Species and sub-species of honeybee and bumblebee have been introduced into many parts of the world, including Europe, to improve pollination of cultivated plants, either in outdoor crops or in greenhouses (Ings et al. 2005a, 2005b, Moritz et al. 2005). However, the introduction of exotic pollinators and biological control agents may also have negative effects on the environment (see section 5.3 below).

5.3. Environmental impact

Alien arthropods can affect native biodiversity and ecosystem services and processes through various mechanisms (Kenis et al. 2009). Herbivores feeding on native plants can have a direct effect on host plant populations. Similarly, predators, parasites and parasitoids may directly affect their indigenous prey or host. Alien species may hybridize with native species, causing disturbances in native genetic resources. They can also affect the native flora and fauna and ecosystems indirectly, through cascading effects, or by carrying diseases, competing for food or space or sharing natural enemies with native species. However, these ecological impacts, their strength and the mechanisms underlying these impacts are poorly studied. Their interaction with the native fauna and flora has been rarely investigated, particularly if their habitat is of little economic concern. Based on the DAISIE database, Vilà et al. (2010) estimated that the percentage of alien terrestrial invertebrates having an ecological impact in Europe was 13.8%. However, in most cases, the notification of environmental impact was based on the fact that an alien arthropod may feed on a native plant or animal species and not on scientific evidence that populations or communities of native species are affected, or ecosystem processes are disturbed. In their extensive literature survey on the ecological effects of alien insects, Kenis et al. (2009) identified 72 alien insects worldwide for which an ecological impact had been investigated, and evidence for impact in the field was found for 54 of them. Among these, only a handful of cases came from Europe and, until now, none of them has had a tremendous impact on the environment, in contrast to what is observed in other continents. Table 1 shows the species for which an ecological effect on native biodiversity or ecosystems has been observed or investigated in Europe, and a selection of species for which an effect is suspected but for which scientific evidence is still lacking.

5.3.1. Impact by herbivores

In most continents, herbivores account for the largest number of alien insects of ecological concern. For example, several forest pests of Eurasian origin cause dramatic and irreversible effects on various forest ecosystems in North America (Kenis et al. 2009). In Europe, despite the fact that phytophagous insects largely dominate the alien fauna, hardly any are known to have an ecological impact on native biodiversity and ecosystems. A potential exception is the introduction of a butterfly, the small white, *Pieris rapae*, in Madeira, which coincided with the extinction of a congeneric species, the Madeiran large white, *P. brassicae wollastoni* (Wakeham-Dawson et al. 2002). The mechanisms involved in this extinction are unclear. Gardiner (2003) suggests that the introduction of *P. rapae* brought a different strain of the granulosis virus for which the native butterfly had no resistance, although loss of habitat, pollution from agricultural fertilisers and an exotic parasitoid are also blamed. Another study worth mentioning is that of Schönrogge and Crawley (2000), who investigated the impact of the invasion, in UK, of cynipid gall wasps of the genus *Andricus* on native gall wasps through the sharing of parasitoids and inquilines. They did not find evidence that the alien species had a long term effect on populations and communities of native species. Péré et al. (2010) observed that horse-chestnut trees *Aesculus hippocastanum* infested by the invasive leaf miner *Cameraria ohridella* had a negative effect on neighbouring populations and communities of native leaf miners. Although they suspected that the effect is due to shared natural enemies, further studies did not confirm this hypothesis (Péré and Kenis, unpubl. data).

Since recently, however, introductions of phytophagous insects in Europe are causing increasing concern for their current or potential impact on the native fauna or flora. The two most serious alien palm pests in Europe, *Rhynchophorus ferrugineus* and *Paysandisia archon*, are not only a problem for the trade of ornamental plants. They are also able to develop on, and kill three endemic palm species, *Phoenix theophrasti* in Crete and *P. canariensis* in the Canary Islands, in the case of both insects, *and Chamaerops humilis* in the western Mediterranean region in the case of *P. archon* (EPPO 2008a, 2008b). The Geranium bronze, *Cacyreus marshalli* is a South African lycaenid butterfly introduced into southern Europe, where is has developed as a serious pest of cultivated *Pelargonium* spp. Laboratory tests in Italy showed that it can also develop and kill native *Geranium* spp. (Quacchia et al. 2008) but further studies are needed to assess better the risk and impact on the wild flora and on native *Geranium*-consuming lycaenids.

The citrus longhorned beetle *Anoplophora chinensis* is presently still restricted to urban areas in Northern Italy, but it is expected to invade forests, where it could kill a large number of tree and shrub species and modify natural ecosystems. The chestnut gall wasp, *Dryocosmus kuriphilus*, a Chinese species damaging chestnut in Japan and North America has been recently found in Italy and is rapidly spreading to neighbouring countries, representing a serious threat for the European chestnut, a keystone species in some European forest ecosystems (Quacchia et al. 2008). Other alien phytophagous insects for which the ecological impact should be investigated include, among others: the western conifer seed bug, *Leptoglossus occidentalis*, which may affect the natural regeneration of conifers (Rabitsch and Heiss 2005); several seed chalcids of the genus *Megastigmus* that are suspected of displacing native congeneric species (Auger-Rozenberg and Roques 2008, Fabre et al. 2004); and *Metcalfa pruinosa*, a planthopper that massively attacks hundreds of different plant species in Southern Europe (Girolami et al. 1996).

However, the alien insect that represents the most serious threat to European biodiversity and ecosystems may well be the emerald ash borer, *Agrilus planipennis*, an Asian wood borer that was detected in North America in 2002. In a few years, it has already killed over 15 million ash trees, *Fraxinus* spp. (Poland and McCullough 2006). The beetle has recently been detected in the region of Moscow, where it has started to cause similar damage (Baranchikov et al. 2008). Considering its dispersal capacities, there is no doubt that *A. planipennis* will quickly invade the rest of Europe and poses a serious threat to the three European ash species which are valuable components of various European forest ecosystems.

5.3.2. Impact by ants

The alien arthropod which has been most studied for its ecological impact in Europe is undoubtedly the Argentine ant, *Linepithema humile*, a South American ant species that has invaded most continents, becoming one of the most damaging invasive insects on earth (Holway et al. 2002). In Europe, it has been reported in several countries, and has established large wild populations in Spain, Portugal, southern France and Italy. In Spain and Portugal, *L. humilis* was observed to displace the native ants including myrmecochorous ants, which had a negative effect on seed dispersal of native plants (Carpintero et al. 2005, Gómez and Oliveras 2003, Gómez et al. 2003, Way et al. 1997). Blancafort and Gómez (2005) noted that the invasion of *L. humile* reduces fruit-set and seed set of the native plant *Euphorbia characias*. In Madeira, however, it seems that *L. humile* and another invasive ant, *Pheidole megacephala* have little impact, even after 150 or more years of residence, and are dominated by the better adapted native ant, *Lasius grandis* (Wetterer et al. 2006). Way et al. (1997) noted that the displacement of native ants in Portugal was most noticeable on disturbed habitats. Also, *L. humile* preys on and reduces populations of serious tree pests such as the pine processionnary moth, *Thaumetopoea pityocampa,* and the eucalyptus wood borer (Way et al. 1992, 1999).

Lasius neglectus is another invasive ant in Europe, originating from Asia Minor. It is found in several European countries, but mainly in human-modified habitats, from strictly urban sites to gardens and urban woods. Nevertheless, it can be very aggressive against native ants and some populations in Spain have displaced other surface-foraging ants as well as other invertebrates, such as Lepidoptera (Espadaler and Bernal 2008). *Lasius neglectus* also tends arboreal aphids that may have a detrimental impact on trees. In England, Oliver et al. (2008) conducted laboratory studies on competitive interactions between native ants and *Technomyrmex albipes*, another alien ant that is presently restricted to protected habitats but may become invasive outdoors with future climate warming.

5.3.3. Impact by other predators and parasitoids

Biological control agents are usually considered as beneficial because they reduce the impact of pests and the use of pesticides. In some cases, however, they may become pests themselves and threaten non-target species or other beneficial organisms. The best known case in Europe is the harlequin ladybird, *Harmonia axyridis*, an Asian species used in biological control programmes against aphids on greenhouse and field crops since the 1980s. The first feral populations in Europe were found in Germany in 1999 and, since then, it has spread to at least 15 countries (Brown et al. 2008). In North America, where it was released earlier, it is known to displace native ladybirds through intra-guild predation and competition for food (Koch and Galvan 2008), and it is feared that the same effects will be observed on European ladybird species. Laboratory tests have already shown that European species are vulnerable to predation by *H. axyridis* (Burgio et al. 2002, Ware and Majerus 2008, Ware et al. 2008), but evidence for displacement in the field needs to be further studied (Adriaens et al. 2008).

Two parasitoids released to control plant pests in Europe are known to have affected populations of native parasitoids. The North American aphid parasitoid *Lysip-*

hlebus testaceipes, introduced in Mediterranean countries to control *Aphis spiraecola*, may have displaced two congeneric parasitoids, *L. fabarum* and *L. confusus* (Tremblay 1984). Similarly, the introduction of the South American *Cales noacki* in Italy to control the whitefly *Aleurothrixus floccosus*, has resulted in the displacement of the indigenous parasitoid *Encarsia margaritiventris*, parasitoid of the viburnum whitefly *Aleurotuba jelineki* (Viggiani 1994). However, in a recent paper, Viggiani (2008) stated that, in the two cases, the effects on the native parasitoids were largely local, that none of the affected native parasitoids is now endangered and that this displacement had no effect on pest populations.

Alien mosquitoes are not only a threat for human or animal health. They may also affect native mosquito species through competition (Juliano and Lounibos 2005). Following the invasion of the tiger mosquito, *Aedes albopictus* in Italy, Carrieri et al. (2003) carried out laboratory experiments to investigate potential competitive interactions with the native *Culex pipiens*. They found that *A. albopictus* was competitively superior in resource competition but, to date, the displacement of native mosquitoes has not been demonstrated in the field.

5.3.4. Impact by pollinators and impact on pollination

In Europe, as in other continents, insect pollinators, particularly bees, are declining, which may have dramatic consequences for the functioning of natural ecosystems and agriculture (Biesmeijer et al. 2006). Although the exact mechanisms leading to bees' decline is a matter of debate, there is no doubt that the accidental introduction of natural enemies has played a significant role. In particular, the parasitic mite, *Varroa destructor*, which originates from the Far East and was accidentally introduced into most continents since the 1950s, has largely contributed to the decline of cultivated honeybee, partly because of its association with viruses (Sammataro et al. 2000). This has surely had an indirect ecological effect on plant pollination, although this effect is difficult to quantify. In other parts of the world, it has been shown that *V. destructor* also has a serious impact on feral honeybee populations (Kraus and Page 1995), but such studies are still lacking in Europe. Honeybees and wild bees may soon be threatened by a new invader, the Asian hornet, *Vespa velutina* (see factsheet 64). This species was introduced in south-western France some years ago, probably in pieces of pottery imported from China (Villemant et al. 2006). It is known as an important predator of bees in Asia, and it has already been reported preying on domestic honeybees in France. In addition, it may displace the European hornet, *Vespa crabro*. The current and potential impact of this new alien species should be assessed for the whole of Europe and management measures should be developed.

The release in western and Northern Europe of two subspecies of the honeybee *Apis mellifera* originating from southern and eastern Europe, *A. m. ligustica* and *A. m. carnica*, has caused large-scale gene flow and introgression between these sub-species and the native black honeybee, *A. m. mellifera* (De La Rùa et al. 2002, Jensen et al. 2005, Moritz et al. 2005). In the Canary Islands, Dupont et al. (2003) showed that the introduced honeybees depleted nectar of a native plant, which reduced visitation by native pollinators and may have consequences on pollination. The bumblebee, *Bombus terrestris*, another important pollinator in Europe, is threatened by the importation of sub-species from the Middle East (*B. t. dalmatinus*) and Sardinia (*B. t. sassaricus*) introduced in Europe as pollinators of greenhouse crops. Commercial subspecies may hybridize with native ones and even displace them in the wild (Ings et al. 2005a, 2005b, 2006).

5.4. Acknowledgements

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5.5. References

Adriaens T, San Martin y Gomez G, Maes D (2008) Invasion history, habitat preferences and phenology of the invasive ladybird Harmonia axyridis in Belgium. *BioControl* 53: 69–88.

Auger-Rozenberg MA, Roques A (2008) Share the resources or displace the natives: different strategies in invasive *Megastigmus* seed insects. In: Proceedings of the 23rd International Congress of Entomology, Durban (South Africa), July 2008.

Baranchikov Y, Mozolevskaya E, Yurchenko G, Kenis M (2008) Occurrence of the emerald ash borer, *Agrilus planipennis* in Russia and its potential impact on European forestry. *Bulletin OEPP/EPPO Bulletin* 38: 233–238.

Baufeld P, Enzian S (2005) Maize growing, maize high-risk areas and potential yield losses due to Western Corn Rootworm (*Diabrotica virgifera virgifera* LeConte) damage in selected European countries. In: Vidal S, Kuhlmann U, Edwards CR (Eds) *Western Corn Rootworm: Ecology and Management*. Wallingford, UK: CABI Publishing, 285–302.

Beaucornu JC, Launay H (1990) *Les puces de France et du Bassin Méditerranéen Occidental. Faune de France 76*. Paris : Fédération Française des Sociétés de Sciences Naturelles. 548 pp.

Biesmeijer JC, Roberts SPM, Reemer M, Ohlemuller R, Edwards M, Peeters T, Schaffers AP, Potts SG, Kleukers R, Thomas CD, Settele J, Kunin WE (2006) Parallel declines in pollinators and insect-pollinated plants in Britain and the Netherlands. *Science* 313: 351–354.

Binimelis R, Born W, Monterroso I, Rodrígez-Labajos B (2007) Socio-economic impact and assessment of biological invasions. In: Nentwig W (Ed) *Biological Invasions*. Berlin: Spinger-Verlag.

Blancafort X, Gómez C (2005) Consequences of the Argentine ant, *Linepithema humile* (Mayr), invasion on pollination of *Euphorbia characias* (L.) (Euphorbiaceae). *Acta Oecologica* 28: 49–55.

Born W, Rauschmayer F, Bräuer I (2005) Economic evaluation of biological invasions -a survey. *Ecological Economics* 55: 321– 336.

Branco M, Boavida C, Durand N, Franco JC, Mendel Z (2009) Presence of the Eucalyptus gall wasp, *Ophelimus maskelli* (Ashmead) and its parasitoid *Closterocerus chamaeleon* Girault, in Portugal: first record, geographic distribution and host preference. *Phytoparasitica* 37: 51–54.

Brenner RJ, Koehler P, Patterson RS (1987) Health Implications of Cockroach Infestations. *Infections in Medicine* 4: 349–355.

Brødsgaard HF, Albajes R (1999) Insect and mite pests. In: Albajes R, Lodovica Gullino M, van Lenteren JC, Elad Y (Eds) Integrated Pest and Disease Management in Greenhouse Crops. Amsterdam: Kluwer Academic Publishers, 48–60.

Brown PMJ, Adriaens T, Bathon H, Cuppen J, Goldarazena A, Hägg T, Kenis M, Klausnitzer BEM, Kovar I, Loomans A, Majerus MEN, Nedved O, Pedersen J, Rabitsch W, Roy HE, Ternois V, Zakharov I, Roy DB (2008) *Harmonia axyridis* in Europe: spread and distribution of a non-native coccinellid. *BioControl* 53: 5–21.

Burgio G, Santi F, Maini S (2002) On intra-guild predation and cannibalism in *Harmonia axyridis* (Pallas) and *Adalia bipunctata* L. (Coleoptera: Coccinellidae). *Biological Control* 24: 110–116.

CABI (2007) *Crop Protection Compendium*. Wallingford, UK: CAB International. CD-ROM.

Carpintero S, Reyes-López J, Arias de Reyna L (2005) Impact of Argentine ants (*Linepithema humile*) on an arboreal ant community in Doñana National Park, Spain. *Biological Conservation* 14: 151–163.

Carrieri M, Bacchi M, Bellini R, Maini S (2003) On the competition occurring between *Aedes albopictus* and *Culex pipiens* (Diptera: Culicidae) in Italy. *Environmental Entomology* 32: 1313–1321.

Ciampitti M (2009) Case study: *Anoplophora chinensis* and *A. glabripennis*. Oral presentation at the EPPO Workshop on eradication, containment and contingency planning. Nova Gorica, Slovenia, 10–12.02.2009.

Covassi M, Binazzi A (1992) Primi focolai di *Matsucoccus feytaudi* Duc. nella Liguria orientale (Homoptera: Margarodidae). *Redia* 75: 453–466.

Day KR, Leather SR (1997) Threats to forestry by insect pests in Europe. In: Watt, AD, Stork NE, Hunter MD (Eds) *Forests and Insects.* London: Chapman & Hall, 177–205.

De La Rùa P, Serrano J, Galian J (2002) Biodiversity of Apis mellifera populations from Tenerife (Canary Islands) and hybridisation with East European races. *Biological Conservation* 11: 59–67.

Dupont YL, Hanse DM, Valido A, Olesen JM (2003) Impact of introduced honeybees on native pollination interactions of the endemic *Echium wildpretii* (Boraginaceae) on Tenerife, Canary Islands. *Biological Conservation* 118: 301–311.

ECPA (2007) European Crop Protection Association. http://www.ecpa.be [accessed 28.05.2009].

Enkerlin W, Mumford J (1997) Economic evaluation of three alternative methods for control of the Mediterranean fruit fly (Diptera: Tephritidae) in Israel, Palestinian Territories, and Jordan. *Journal of Economic Entomology* 90: 1066–1072.

Enserink M (2007) Tropical disease follows mosquitoes to Europe. *Science* 317: 1485.

EPPO (2008a) Datasheets on quarantine pests. *Rhynchophorus ferrugineus*. *Bulletin OEPP/EPPO* 38, 55–59.

EPPO (2008b) Datasheets on quarantine pests. *Paysandisia archon*. *Bulletin OEPP/EPPO* 38, 163–166.

Espadaler X, Bernal V (2008) *Lasius neglectus*. http://www.creaf.uab.es/xeg/lasius/index.htm

Fabre JP, Auger-Rozenberg MA, Chalon A, Boivin S, Roques A (2004) Competition between exotic and native insects for seed resources in trees of a Mediterranean forest ecosystem. *Biological Invasions* 6: 11–22.

Farrall MH, Paiva MR, Albino P (1992) Registo de uma nova espécie do género *Avetianella* (Hymenoptera, Encyrtidae) parasitóide oófago da broca do eucalipto *Phoracantha semipunctata* (Fab.). *Actas do Congresso Iberica de Entomologia* 5: 475–480.

Forestry Commission (2006) Forestry Statistics 2005. Available at [http://www.forestry.gov.uk/website/foreststats.nsf/byunique/woodland.html#one]

Gardiner BOC (2003) The possible cause of extinction of *Pieris brassicae wollastoni* Butler (Lepidoptera: Pieridae). *Entomologist's Gazette* 54: 267–268

Girolami V, Conte L, Camporese P, Benuzzi M, Martir GR, Dradi D (1996) Possibilita di controllo biologico della *Metcalfa pruinosa*. *Informatore Agrario*, 52: 25.

Gómez C, Oliveras J (2003) Can the Argentine ant (*Linepithema humile* Mayr) replace native ants in myrmecochory? *Acta Oecologica* 24: 47–53.

Gómez C, Pons P, Bas JM (2003) Effects of the Argentine ant *Linepithema humile* on seed dispersal and seedling emergence of *Rhamnus alaternus*. *Ecography* 26: 532–538.

Gonzalez Tirado L (1986) *Phoracantha semipunctata* dans le Sud-Ouest espagnol: lutte et dégâts. *Bulletin OEPP/EPPO* 16: 289–292.

Greathead DJ (Ed) (1976) *A review of biological control in western and southern Europe* . Technical Communication No. 7. Farnham Royal, UK: Commonwealth Institute of Biological Control CAB. 182 pp.

Heikkilä J, Peltola J (2006) Phytosanitary measures under uncertainty: a cost benefit analysis of the Colorado potato beetle in Finland. In: AGJM Oude Lansink (Ed) New *Approaches to the Economics of Plant Health*. Heidelberg, Germany: Springer-Verlag, 147–161.

Holway DA, Lach L, Suarez A, Tsutsui N, Case TJ (2002) The causes and consequences of ant invasions. *Annual Review of Ecology and Systematics* 33: 181–233.

Hulme PE, Nentwig W, Pyšek P, Vilà M (Eds) (2009) DAISIE, *The Handbook of Alien Species in Europe*. Dordrecht: Springer. 399 pp.

Ings TC, Raine NE, Chittka L (2005a) Mating preference of commercially imported bumblebees (Bombus terrestris) in Britain (Hymenoptera: Apidae). *Entomologia Generalis* 28: 233–238.

Ings TC, Schikora J, Chittka L (2005b) Bumblebees, humble pollinators or assiduous invaders? A population comparison of foraging performance in Bombus terrestris. *Oecologia*, 144: 508–516.

Ings TC, Ward NL, Chittka L (2006) Can commercially imported bumble bees out-compete their native conspecifics? *Journal of Applied Ecology* 43: 940–948.

Jactel H, Menassieu P, Ceria A, Burban C, Regad J, Normand S, Carcreff E (1998) Une pullulation de la cochenille *Matsucoccus feytaudi* provoque un début de dépérissement du pin maritime en Corse. *Revue Forestière Française* 50: 33–45.

Jensen AB, Palmer KA, Boomsma JJ, Pedersen BV (2005) Varying degrees of *Apis mellifera ligustica* introgression in protected populations of the black honeybee, *Apis mellifera mellifera*, in northwest Europe. *Molecular Ecology* 14: 93–106.

Juliano SA, Lounibos LP (2005) Ecology of invasive mosquitoes: Effects on resident species and on human health. *Ecology Letters* 8: 558–574.

Kenis M, Rabitsch W, Auger-Rozenberg M-A, Roques A (2007) How can alien species inventories and interception data help us prevent insect invasions? *Bulletin of Entomological Research* 97: 489–502.

Kenis M, Auger-Rozenberg M-A, Roques A, Timms L, Péré C, Cock MJW, Settele J, Augustin S, Lopez-Vaamonde C (2009) Ecological effects of invasive alien insects. *Biological Invasions* 11: 21–45.

Kobelt M, Nentwig W (2008) Alien spider introductions to Europe supported by global trade. *Diversity and Distributions* 14: 273–280.

Koch RL, Galvan TL (2008) Bad side of a good beetle: the North American experience with *Harmonia axyridis*. *BioControl* 53: 23–35.

Kraus B, Page RE Jr. (1995) Effect of *Varroa jacobsonia* (Mesostigmata: Varroidae) on feral *Apis mellifera* (Hymenoptera: Apidae) in California. *Environmental Entomology* 24: 1473–1480.

Lounibos LP (2002) Invasions by insect vectors of human disease. *Annual Review of Entomology* 47: 233–66.

MacLeod A (2006) The benefits and costs of specific phytosanitary campaigns in the UK. Examples that illustrate how science and economics support policy decision making. In: AGJM Oude Lansink (Ed) New *Approaches to the Economics of Plant Health*. Heidelberg, Germany: Springer-Verlag, 163–177.

MacLeod A, Head J, Gaunt A (2004). An assessment of the potential economic impact of *Thrips palmi* on horticulture in England and the significance of a successful eradication campaign. *Crop Protection*b23: 601–610.

Malausa JC (1998) Des insectes au secours des eucalyptus. *Biofutur* 176: 34–37.

Mansilla P, Pérez R (1996) El defoliador del eucalipto *Gonipterus scutellatus*. *Phytoma España* 81: 36–42.

Mitchell CJ (1995) Geographic spread of *Aedes albopictus* and potential for involvement in arbovirus cycles in the Mediterranean basin. *Journal of Vector Ecology* 20: 44–58.

Moritz RFA, Härtel S, Neumann P (2005) Global invasions of the western honeybee (*Apis mellifera*) and the consequences for biodiversity. *Ecoscience* 12: 289–301.

Oliveira MRV, Henneberry TJ, Anderson P (2001) History, current status, and collaborative research projects for *Bemisia tabaci*. *Crop Protection*. 20: 709–723.

Oliver TH, Pittitt T, Leather SR, Cook JM (2008) Numerical abundance of invasive ants and monopolisation of exudate-producing resources – a chicken and egg situation. *Insect Conservation and Diversity* 1: 208–214.

Parola P (2004) Tick-borne rickettsial diseases: emerging risks in Europe. *Comparative Immunology, Microbiology and Infectious Diseases*. 27: 297–304

Péré C, Augustin S, Tomov R, Peng L-H, Turlings TCJ, Kenis M (2009a) Species richness and abundance of native leaf miners are affected by the presence of the invasive horse-chestnut leaf miner. *Biological Invasions*. Online first. Doi: 10.1007/s10530–009–9518–0.

Péré C, Augustin S, Turlings TCJ, Kenis M (2009b) The invasive alien leaf miner, *Cameraria ohridella* and the native maple, Acer pseudoplatanus: a fatal attraction? *Agricultural and Forest Entomology*. In press.

Pimentel D (2002) Non-native invasive species of arthropods and plant pathogens in the British Isles. In: Pimentel D (Ed) *Biological Invasions. Economic and Environmental costs of Alien Plants, Animal and Microbe Species*. Boca Raton, USA: CRC Press, 151–155.

Pimentel D (2007) Area-Wide Pest Management: Environmental, Economic, and Food Issues. In: Vreysen MJB, Robinson AS, Hendrichs J (Eds) *Area-Wide Control of Insect Pests:* from research to field implementation. Dordrecht, The Netherlands: Springer, 35–47.

Pimentel D, Lach L, Zuniga R, Morrison D (2002a) Environmental and economic costs associated with non-indigenous species in the United States. In: Pimentel D (Ed) *Biological Invasions. Economic and Environmental costs of Alien Plants, Animal and Microbe Species*. Boca Raton, USA: CRC Press, 285–306.

Pimentel D, McNair S, Janecka J, Wightman J, Simmonds C, O'Connell C, Wong E, Russel L, Zern J, Aquino T, Tsomondo T (2002b) Economic and environmental threats of alien plant, animal and microbe invasions. In: Pimentel D (Ed) *Biological Invasions. Economic and Environmental costs of Alien Plants, Animal and Microbe Species*. Boca Raton, USA: CRC Press, 307–330.

Poland TM, McCullough DG (2006) Emerald ash borer: invasion of the urban forest and the threat to North America's ash resource. *Journal of Forestry* 104: 118–124.

Quacchia A, Ferracini C, Bonelli S, Balletto E, Alma A (2008a) Can the Geranium Bronze, *Cacyreus marshalli*, become a threat for European biodiversity? *Biodiversity and Conservation* 17: 1429–1437.

Quacchia A, Moriya S, Bosio G, Scapio I, Alma A (2008b) Rearing, release and settlement prospect in Italy of Torymus sinensis, the biological control agent of the chestnut gall wasp. *BioControl* 53: 829–839.

Rabitsch W, Heiss E (2005) *Leptoglossus occidentalis* Heidemann, 1910, eine amerikanische Adventivart auch in Österreich aufgefunden (Heteroptera, Coreidae). *Berichte des naturwissenschaftlichmedizinischen Verein Innsbruck* 92: 131–135.

Rautapaa J (1984) Costs and benefits of quarantine measures against *Liriomyza trifolii* in Finland. *EPPO Bulletin*: 14: 343–347.

Rees D (2004) *Insects of Stored Products*. Collingwood, VIC, Australia: CSIRO Publishing, Australia.

Reinhardt F, Herle M, Bastiansen F, Streit B (2003) Economic impact of the spread of alien species in Germany. Berlin, Germany: Federal Environmental Agency (Umweltbundesamt). 229 pp.

Rivault C, Cloarec A, Le Guyader A (1993) Bacterial load of cockroaches in relation to urban environment. *Epidemiology and Infection* 110: 317–325.

Riom J (1994) Le dépérissement du pin maritime dans le Sud-Est de la France au cours des années 1960–1970: Le rôle de la cochenille *Matsucoccus feytaudi* Duc. (Coccoidea, Margarodidae). *Revue Forestière Française* 66, 437–445.

Roosjen M, Buurma J, Barwegen J (1998) Verbetering schade-inschattingsmodel quarantaine-organismen glastuinbouw. *Verslagen en Mededelingen, Plantenziektenkundige Dienst, Wageningen* 197: 1–24.

Roques A (2010) Alien forest insects in a globalized, warmer world: Impacts of global change (trade, tourism, climate) on forest biosecurity. *New Zealand Journal of Forestry Science* (in press).

Roques A, Rabitsch W, Rasplus JY, Lopez-Vaamonde C, Nentwig W, Kenis M (2009) Alien terrestrial invertebrates of Europe. In: Hulme PE, Nentwig W, Pyšek P, Vilà M (Eds) *DAISIE, The Handbook of Alien Species in Europe*. Heidelberg, Germany: Springer, 63–79.

Sammataro D, Gerson U, Needham G (2000) Parasitic mites of honey bees: life history, implications, and impact. *Annual Review of Entomology* 45: 519–548.

Schaffner F, Kaufmann C, Hegglin D, Mathis A (2009) The invasive mosquito *Aedes japonicus* in Central Europe. *Medical and Veterinary Entomology* 23: 448–451.

Schönrogge K, Crawley MJ (2000) Quantitative webs as a means of assessing the impact of alien insects. *Journal of Animal Ecology* 69: 841–868.

Šefrová, H (2001) *Phyllonorycter platani* (Staudinger) a review of its dispersal history in Europe (Lepidoptera, Gracillariidae). *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis* 49: 71–75.

Siscaro G (1992) *Avetianella longoi* sp. n. (Hymenoptera, Encyrtidae) egg parasitoid of *Phoracantha semipunctata* F. (Coleoptera, Cerambycidae). Bollettino di Zoologia agraria e di Bachicoltura 24: 208–211.

Sivcev I, Tomasev I (2002). Distribution of *Diabrotica virgifera virgifera* LeConte in Serbia in 1998. *Acta* Phytopathologica et Entomologica Hungarica 37: 145–153.

Speight MR, Wainhouse D (1989) *Ecology and Management of forest insects*. New York: Oxford University Press.

Tomiczek C, Hoyer-Tomiczek U (2007) Asian longhorned beetle (*Anoplophora glabripennis*) and citrus longhorned beetle (Anoplophora chinensis) in Europe - actual situation. *Forstschutz Aktuell* 38: 2–5.

Tremblay E (1984) The parasitoid complex (Hym.: Ichneumonoidea) of *Toxoptera aurantii* (Hom.: Aphidoidea) in the Mediterranean area. *Entomophaga* 29: 2003–2010.

Valade R, Kenis M, Hernandez-Lopez A, Augustin S, Mari Mena N, Magnoux E, Rougerie R, Lakatos F, Roques A, Lopez-Vaamonde C (2009) Mitochondrial and microsatellite DNA markers reveal a Balkanic origin for the highly invasive Horse-Chestnut leaf miner *Cameraria ohridella* (Lepidoptera, Gracillariidae). *Molecular Ecology* 18: 3458–3470.

van Lenteren JC (2007) Biological control for insect pests in greenhouses: an unexpected success. In: Vincent C, Goettel MS, Lazarovits G (Eds) *Biological Control. A Global Perspective*. Wallingford, UK: CAB International, 105–117.

van Lenteren JC, Roskam MM, Timmer R (1997) Commercial mass production and pricing of organisms for biological control of pests in Europe. *Biological Control* 10: 143–149.

Viggiani G (1994) Recent cases of interspecific competition between parasitoids of the family Aphelinidae (Hymenoptera: Chalcidoidea). *Norwegian Journal of Agricultural Sciences Supplement* 16: 353–359.

Viggiani G (2008) Reflections and evidences on the present status of biological control of arthropod pests. Presentation at the International Congress of Entomology, 6–12 July 2008, Durban South Africa.

Vilà M, Basnou C, Pysek P, Josefsson M, Genovesi P, Gollasch S, Nentwig W, Olenin S, Roques A, Roy D, Hulme PE, DAISIE partners (2009) How well do we understand the impacts of alien species on ecosystem services? A pan-European, cross-taxa assessment. *Frontiers in the Ecology and the Environment.* Online first. doi:10.1890/080083.

Villemant C, Haxaire J, Streito JC (2006) Premier bilan de l'invasion de *Vespa velutina* Lepeletier en France (Hymenoptera, Vespidae). *Bulletin de la Société entomologique de France* 111: 535–538.

Wakeham-Dawson A, Franquinho Aguiar AM, Martin G (2002) The distribution of endemic butterflies (Lepidoptera) on the island of Madeira, Portugal since 1850, with comments on their current conservation status. *Entomologist's Gazette* 53: 153–180.

Ware RL, Majerus MEN (2008) Intraguild predation of immature stages of British and Japanese coccinellids by the invasive ladybird *Harmonia axyridis*. *BioControl* 53: 169–188.

Ware RL, Evans N, Malpas L, Michie LJ, O'Farrell K, Majerus MEN (2008) Intraguild predation by the invasive ladybird *Harmonia axyridis*. British and Japanese coccinellid eggs. *Neobiota* 7: 263–275.

Way MJ, Cammell ME, Paiva MR (1992) Studies on egg predation by ants (Hymenoptera: Formicidade) especially on the eucalyptus borer *Phoracantha semipunctata* (Coleoptera: Cerambycidae) in Portugal. *Bulletin of Entomological Research* 82: 425–432.

Way MJ, Cammell ME, Paiva MR, Collingwood C (1997) Distribution and dynamics of the Argentine ant Linepithema (Iridomyrmex) humile (Mayr) in relation to vegetation, soil conditions, topography and native competitor ants in Portugal. *Insectes Sociaux* 44: 415–433.

Way MJ, Paiva MR, Cammell ME (1999) Natural biological control of the pine processionary moth Thaumetopoea pityocampa (Den. & Schiff.) by the Argentine ant Linepithema humile (Mayr) in Portugal. Agr Forest Entomol 1: 27–31.

Wetterer JK, Espadaler X, Wetterer AL, Aquin-Pombo D, Franquinho-Aguilar AM (2006) Long-term impact of exotic ants on the native ants of Madeira. Ecol Entomol 31: 358–368.

Williamson M (1996) Biological Invasions. Chapman and Hall, London, p. 244.

Table 5.1. Examples of alien species with current or potential environmental impact in Europe. **A** Species for which field studies have been published **B** Species for which only laboratory studies have been published **C** Species that may have an environmental impact now or in the near future and for which studies are needed. Details and references are found in the text.

	Impact observed	
A	In the field	In the lab
Andricus spp. (Hym.: Cynipidae)	No	
Apis mellifera L. subspecies *carnica*, *caucasica* and *ligustica* (Hym.: Apidae)	Yes	
Bombus terrestris (L.) subspecies *dalmatinus* and *sassaricus* (Hym.: Apidae)	Yes	
Cales noacki Howard (Hym.: Aphelinidae)	Yes	
Cameraria ohridella Deschka & Dimic (Lep.: Gracillariidae)	Yes	
Lasius neglectus Van Loon, Boomsma & Andrásfalvy (Hym.: Formicidae)	Yes	
Linepithema humile (Mayr) (Hym.: Formicidae)	Yes	
Lysephlebus testaceipes (Cresson) (Hym.: Braconidae)	Yes	
Megastigmus rafni Hoffmeyer (Hym. : Torymidae)	Yes	
Megastigmus schimitscheki Novitzky (Hym.: Torymidae)	Yes	
Pieris rapae (L.) (Lep.: Pieridae)	Unclear	
Pheidole megacephala (F.) Hym.: Formicidae)	No	
B		
Aedes albopictus (Skuse) (Dipt.: Culicidae)		Yes
Cacyreus marshalli Butler (Lep.: Lycaenidae)		Yes
Harmonia axyridis (Pallas) (Hym.: Coccinellidae)		Yes
Technomyrmex albipes Smith (Hym.: Formicidae)		Yes
C		
Agrilus planipennis Fairmaire (Col.: Buprestidae)		
Anoplophora chinensis (Forster) (Col. : Cerambycidae)		
Dryocosmus kuryphilus Yasumatsu (Hym.: Cynipidae)		
Leptoglossus occidentalis Heidemann (Hem.: Coreidae)		
Metcalfa pruinosa Say (Hem. : Flatidae)		
Paysandisia archon (Burmeister) (Lep.: Castniidae)		
Rhynchophorus ferrugineus (Olivier) (Col.: Curculionidae)		
Varroa destructor Anderson & Trueman (Acari: Parasitidae)		
Vespa velutina nigrothorax Lepeletier (Hym.: Vespidae)		

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RESEARCH ARTICLE

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Future trends
Chapter 6

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Introduction

The data supplied in the preceding chapters clearly confirm that the ever-increasing rate of arthropod invasions can be attributed to the upward trend in international freight transport, to passenger travel and, more generally, to globalization. The role that humans play in pest introductions as well as their likely dispersion is obvious and consequently there are strong geographic associations between higher numbers of alien pest occurrences and urban areas as already been noted by Colunga- Garcia et al. (2010) and Pyšek et al. (2010). Another important source of introduced arthropods comes from intentional releases, especially of alien hymenopterans, for the purpose of biological control programs. Invasive alien species threaten forests, agriculture, human and animal health. While economic losses attributed to exotic plant pests are poorly estimated in Europe (but see Vilá et al. 2009), they have been estimated at US $37.1 billion per year in U.S. agricultural and forest ecosystems (Pimentel et al. 2005). Invasive species can also cause irreversible changes to ecosystems, but there is no estimate of the full economic costs of their effects on ecosystems and on the human population that is dependent on them.

There is little chance that biological exchanges over borders may decrease in the next decades. Rather, the number of arthropod invasions will continue to grow, threatening economy and ecosystems globally. More and more people or agricultural commodities will cross borders, increasing the likelihood that arthropods will be translocated from

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one area of the world to another (Liebhold et al. 2006). In Europe, monitoring, detection of arthropod invasion mostly relies on poorly connected structures hosted by different countries, using non-interoperable tools that imply months if not years to detect the data for characterizing and managing new aliens. Such delays are unacceptable in cases where immediate action has to be taken. Globalization of biological exchanges should be met by globalization of the tools used to predict, detect and manage future bio-invasions.

Until now, no integrated biosecurity tool has been developed for arthropods (this is also true for all other bioinvaders). An ideal web-based integrated tool would encompass different interlinked modules to:

1. Identify the most likely future arthropod invaders
2. Provide generic and accurate identification tools
3. Compile biological information on these species
4. Predict where such aliens might potentially thrive, and their future distributions in a warmer climate or under
5. Estimate the full costs of the most likely alien arthropods
6. Finally, quantify and map risks associated with these non-indigenous species and prioritize them

Identify the most likely future arthropod invaders

Determining which species to target for development of detection tools, distributional area and risk estimation is not an easy task. However, it is increasingly important to identify potential invasive species prior to their introduction and establishment. This may help to reduce the likelihood of alien invasions and better define management scenarios. Only few studies have been published that help to select the most likely future arthropod invaders to Europe within the many thousands of potential bioinvader arthropods.

Worner and Gevrey (2006) recently developed an original and efficient method to identify potential invasive insects that should be subject to more detailed risk assessments. They based their study on 1) the assumptions that geographical areas with similar pest assemblages share similar biotic and abiotic conditions, 2) a comprehensive database of the global presence or absence of pests. They used artificial neural network analysis to propose a list of species that are ranked according to the risks they pose. It is important to develop further methods of this kind, to implement databases and make them easily accessible through web interfaces. The development of integrated European projects such as PRATIQUE (Enhancements of Pest Risk Analysis Techniques) is a step towards this goal (Baker et al. 2009).

The search for taxa that are particularly invasive worldwide may also benefit from phylogenetic or hierarchical clustering studies. Recent work on the hierarchical patterns in biological invasions has produced results that show both clustering as well as overdispersion of certain life-history traits that are associated with invasion success (e.g. reproductive traits) (Lambdon 2008, Procheş et al. 2008). In some cases, traits associated with invasiveness observed in a set of taxa tend to be more similar in closely related taxa, a phenomenon supposed to be linked to the conservation of ecological niches in closely related species. This observation provides promise that analysing these traits in a strict phylogenetic framework may help to predict better the most likely potential invasive species. However, few phylogenetic analyses of invasiveness have been proposed for arthropods. Such analyses may benefit from the development of DNA barcoding applied to multiple genes (see below) that could help in particular to reconstruct phylogenies within species complexes.

Another approach, for phytophagous invaders at least, could be to identify and establish 'sentinel' host plants in not yet invaded regions, to evaluate the impact of indigenous potential invaders in source regions should they become introduced as exotics at a later date (Britton et al. 2009). This is currently carried out in China for potential pests of European tree species (Roques et al. 2009; Roques 2010).

Provide generic and accurate identification tools

In the last few years, the application of molecular diagnostic methods have greatly accelerated. At the same time, DNA barcoding based on the mtDNA COI gene as well as nuclear markers, have shown great potential to improve the detection of invasive species. DNA barcoding has been used to detect pests efficiently (Armstrong 2010) and may also enable the flagging of invasive species trapped during biodiversity surveys (deWaard et al. 2009). Consequently, DNA barcoding many provide an efficient new tool in the biosurveillance armoury for detection of alien species. Next generation sequencing technologies (e.g. pyro and single-molecule sequencing) may further help to reduce costs and to increase both speed and quantity of molecular detection of arthropod species. In the near future, it is likely that most identifications of arthropods will proceed through comparison of multiple gene sequences to an online global library whose quality is vastly enhanced by taxonomic knowledge. Consequently, developing a worldwide DNA library of barcodes of the most likely invasive species, including all pests and their natural enemies that could be used in biological control project, is of strategic importance to enhance our ability to detect and manage invasive populations. Such a comprehensive database coupled to real time analysis of trapping may help to detect species even at low densities, long before they become established. Developing such an integrated detection toolkit may clearly improve both biosurveillance and biosecurity in the future.

Compile biological information on these species

Any introduced arthropod has an area of origin where it could already be a pest and where it may already have been studied and its biology described. Available lists of invasive species (NISIC, DAISIE, NOBANIS, etc) do not always provide an up-to-date compilation of all available biological information and so may be of limited use for improving future management or predicting spread. To infer better the potential distribution, costs and risks associated with the most likely arthropod invaders, we need to compile all available information on their biology and life-history traits, both in their native and, when possible, in their invaded ranges (Broennimann and Guisan 2008).

Predict where such aliens might potentially thrive

Predicting which arthropods can invade where is critical for their management, and ultimately in limiting the negative impacts of bioinvaders. Niche-based models are widely used to predict potential distributions of invasive insects, mites or other arthropods. These methods use observations either from the invaded or the native range of an invasive species to predict the potential range in the area of introduction. However, despite its increasing use, environmental niche modelling is based on fundamental assumptions that are easily violated and lead to incorrect prediction of the full extent of biological invasions. For example, the alien species may not occupy all suitable habitats when its ecological requirements have changed during the invasion process. Furthermore, predictions are sensitive not only to occurrence and environmental data, but also to the methods used to calibrate the models. These approaches have also been criticised for their lack of consideration of species interactions (natural enemies), dispersal, availability and synchrony with the host plant or host. However, unless we can accurately parameterize the relationship between a species and its environment, no single model predicting the invasive range is likely to represent reality. This task may prove to be not feasible for most arthropods, for which knowledge of their distribution and interactions is as yet fragmentary if not rudimentary. Consequently, multiple modelling methods are required to provide better prediction and error estimates for arthropod distributional areas, especially when based on poor observation datasets.

Moreover, identification of consensus areas of distributional estimate consistency using these different methods may help to produce more reliable estimates of species' potential distributions (Roura-Pascual et al. 2009). A recent study also showed that using predictions based on both abiotic variables (usually climate) and biotic ones (for insect or host assemblage) may be more accurate than predictions based on climatic factors alone (Watts and Worner 2008). Consequently, in an effort to improve the management of invasive arthropods to Europe, we need to 1) develop a comprehenive database of life-history traits and worldwide occurrences of invasive arthropods; 2) build or implement a system providing the most accurate projections based on this database; 3) develop free access tools that implement all these methods; 4) allocate research investment to such a task that will strongly improve both predictive methodology and knowledge of the most likely invasive arthropods and their natural enemies.

Estimate the full costs of the most likely alien arthropods

Until now few general models of the economic costs of biological invasion have been developed. The goal of such models is to develop effective management programs, that seek both to estimate current or future impacts of alien invasive species, and to prevent, control, or mitigate their biological invasion. Estimates of the full costs of biological invasions (i.e., beyond direct damages or control costs) are still rare, since the costs of such complex problems are hard to calculate. Vilá et al. (2009) provided a first continent-wide assessment of impacts on ecosystem services by all major alien taxa, including invertebrates, in terrestrial, freshwater, and marine environments. They tried to compare how alien species from the different taxonomic groups affect "supporting", "provisioning", "regulating", and "cultural" services and interfere with human well-being. However, many of these components are difficult if not impossible to quantify, such as the impacts of alien invasive species on biodiversity, ecosystem functions, human health and other indirect costs, for instance the impacts themselves of control measures. Furthermore, estimating the costs of an invasive arthropod that threatens biodiversity rather than agricultural production is particularly challenging. Precise economic costs associated with the most ecologically damaging alien species are simply not available. Consequently, we need to develop analysis of the ecological impact of introduced arthropods, especially those that are intentionally introduced for biological control purposes (Kenis et al. 2009). This is particularly important if we want in the near future to decrease our intake of pesticides and promote biological control.

Economic applications are also essential to provide more accurate and comprehensive assessments of the benefits and costs of control alternatives that can increase the effectiveness and efficiency of publicly funded programs. There is also a need for the development of better databases and modelling approaches to estimate better damages from invasive species and their control costs. Further research should also be conducted to narrow the uncertainty of the estimates. Work in these areas should help improve invasive species policy and achieve a more effective use of resources. Future cost estimates should be computed, within a real-time estimation procedure, using updated infestation measuresand regional input-output economic data.

Quantify and map risks associated with these non-indigenous species

In the case of invasive species, risk can be defined as the probability that an invader will become established in an area along with some evaluation of the economic consequences of this event. Traditionally, quantifying risks associated with arthropod invasive species require studies on 1) the process of introduction, dispersion and the pathways used; and 2) the economic consequences of spread in recently contaminated areas (Yemshanov et al. 2009). However - as emphasized above - biology, life history and full costs of most potential invasive arthropods are still poorly known and most risk assessment studies rely on expert judgment or rudimentary analytical approaches.

Here again the need of integrated tools is overwhelming to produce efficient risk assessment for policy-makers.

Toward a global european tool

Already 1590 alien arthropod species have been introduced and established in Europe and increased efforts are needed to minimize the risk of introductions and spread of additional species in the future.

Europe is poorly structured to detect rapidly, efficiently manage and control invasive arthropod species. In face of this global problem, European countries mostly have responded through nation-specific strategies and disconnected or weakly integrated projects. This disappointing situation must be changed. Faced with increasing economic pressure and despite already large grants in the past, the European Community has to invest more on invasive species prevention, detection and management.

One of the key elements is the need to establish a European early warning system and rapid response framework (Genovesi 2009). In the present situation where ornamental trade is a dominant pathway for invasion by phytophagous arthropods, a more thorough survey of parks, gardens and nurseries may function as such an early warning system. This could also be accompanied by the installation of more sophisticated quarantine and control measures at invasion 'hubs' for the ornamental plant trade (e.g. in the Netherlands) (Roques 2010).

While there is also a clear need for further research to understand better the ecological and genetic processes that facilitate the introduction and subsequent dispersion of exotic arthropods in agricultural and forest ecosystems (Facon et al. 2006), additional challenges include the improvement of Europe-wide biosurveillance and prediction tools. Clearly, the management of arthropod invasions will be enhanced by the integration and future improvement of already existing but widely dispersed tools. Researchers have to develop prototype Internet based systems to detect and manage better new arthropod invasions, and these tools should be reinforced through international collaborations. We are dealing with an outstanding global problem.

References

Armstrong K (2010) DNA barcoding: a new module in New Zealand's plant biosecurity diagnostic toolbox. *EPPO Bulletin* 40: 91–100.

Baker RHA, Battisti A, Bremmer J, Kenis M, Mumford J, Petter F, Schrader G, Bacher S, De Barro P, Hulme PE, Karadjova O, Lansink AO, Pruvost O, Pyšek P, Roques A, Baranchikov Y, Sun JH (2009) PRATIQUE: a research project to enhance pest risk analysis techniques in the European Union. *EPPO Bulletin* 39: 87–93.

Britton KO, White P, Kramer A, Hudler G (2009) Global Network of Sentinel Plantings: Recruiting Botanic Gardens and Arboreta to Stop the Spread of Invasive Species. In: *Abstracts* *of the IUFRO International Forest Biosecurity Conference*, Roturoa, New Zealand, 16–20 March 2009. *New Zealand Forest Research Institute Bulletin* 233: 104.

Broennimann O, Guisan A (2008) Predicting current and future biological invasions: both native and invaded ranges matter. *Biology Letters* 4: 585–589.

Colunga-Garcia M, Haack RA, Magarey RA, Margosian ML (2010) Modeling spatial establishment patterns of exotic forest insects in urban areas in relation to tree cover and propagule pressure. *Journal of Economic Entomology* 103: 108–118.

deWaard JR, Landry JF, Schmidt C, Derhousoff J, McLean JA et al. (2009) In the dark in a large urban park: DNA barcodes illuminate cryptic and introduced moth species. *Biodiversity and Conservation* 18: 3825–3839.

Facon B, Genton BJ, Shykoff J, Jarne P, Estoup A et al. (2006) A general eco-evolutionary framework for understanding bioinvasions. *Trends in Ecology and Evolution* 21: 130–135.

Genovesi P (2009) Toward a global biosecurity policy. In: *Abstracts of the International Conference of Biological Invasions* (*ICBI*), Fuzhou (Fujian), China, 2–6 November 2009: 9. http://invasivespecies.org.cn/uploadfile/20091207/20091207105632670.pdf.

Kenis M, Auger-Rozenberg MA, Roques A, Timms L, Pere C et al. (2009) Ecological effects of invasive alien insects. *Biological Invasions* 11: 21–45.

Lambdon PW (2008) Is invasiveness a legacy of evolution? Phylogenetic patterns in the alien flora of Mediterranean islands. *Journal of Ecology* 96: 46–57.

Liebhold AM, Work TT, McCullough DG, Cavey JF (2006) Airline baggage as a pathway for alien insect species invading the United States. *American Entomologist* 52: 48–54.

Pimentel D, Zuniga R, Morrison D (2005) Update on the environmental and economic costs associated with alien-invasive species in the United States. *Ecological Economics* 52: 273–288.

Procheş S, Wilson JRU, Richardson DM, Rejmánek M (2008) Searching for phylogenetic pattern in biological invasions. *Global Ecology and Biogeography* 17: 5–10.

Roques A, Fan JT, Yart A, Sun JH (2009) Planting sentinel European trees in China, a tool for identifying potential insect and pathogen invaders. In: *Abstracts of the International Conference of Biological Invasions* (*ICBI*), Fuzhou (Fujian), China, 2–6 November 2009: 85. http://invasivespecies.org.cn/uploadfile/20091207/20091207105632670.pdf.

Roques A (2010) Alien forest insects in a warmer world and a globalized economy: Impacts of changes in trade, tourism and climate on forest biosecurity. *New Zealand Journal of Forestry*, suppl 40: 77–94.

Roura-Pascual N, Brotons L, Peterson AT, Thuiller W (2009) Consensual predictions of potential distributional areas for invasive species: a case study of Argentine ants in the Iberian Peninsula. *Biological Invasions* 11: 1017–1031.

Vilá M, Basnou C, Pyšek P, Josefsson M, Genovesi P, Gollasch S, Nentwig W, Olenin S, Roques A, Roy D, Hulme PE and Daisie Partners (2009) How well do we understand the impacts of alien species on ecosystem services? A pan-European cross-taxa assessment. *Frontiers in Ecology and the Environment* 8: 135–144.

Watts MJ, Worner SP (2008) Comparing ensemble and cascaded neural networks that combine biotic and abiotic variables to predict insect species distribution. *Ecological Informatics* 3: 354–366.

Worner SP, Gevrey M (2006) Modelling global insect pest species assemblages to determine risk of invasion. *Journal of Applied Ecology* 43: 858–867.

Yemshanov D, McKenney DW, de Groot P, Haugen D, Sidders D et al. (2009) A bioeconomic approach to assess the impact of an alien invasive insect on timber supply and harvesting: a case study with *Sirex noctilio* in eastern Canada. *Canadian Journal of Forest Research* 39: 154–168.

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Alien terrestrial crustaceans (Isopods and Amphipods)
Chapter 7.1

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Abstract

A total of 17 terrestrial crustacean species aliens *to* Europe of which 13 isopods (woodlice) and 4 amphipods (lawn shrimps) have established on the continent. In addition, 21 species native to Europe were introduced in a European region to which they are not native. The establishment of alien crustacean species in Europe slowly increased during the 20th century without any marked changes during the recent decades. Almost all species alien *to* Europe originate from sub-tropical or tropical areas. Most of the initial introductions were recorded in greenhouses, botanical gardens and urban parks, probably associated with passive transport of soil, plants or compost. Alien woodlice are still confined to urban habitats. Natural habitats have only been colonized by three amphipod species in the family Talitridae.

Keywords

Woodlice, lawnshrimps, Europe, alien

7.1.1. Introduction

The orders in the arthropod subphylum Crustacea are mainly composed of aquatic-living species, at least during part of their life-cycle. Most alien terrestrial crustaceans belong to the order Isopoda, suborder Oniscidea, commonly named woodlice. But

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several species recorded in Europe belong to the order Amphipoda, and are commonly known as "lawn shrimps" or "landhoppers".

In 2004, the total number of valid Isopod species worldwide was 3637 (Schmalfuss 2003). Woodlice are adapted to various terrestrial environments from sea shores to deserts and have established on all continents. As decomposers of organic plant material, isopods play an important role in ecosystems (Holthuis et al. 1987, Zimmer 2002). Most European species prefer humid and moist micro-habitats (Vandel 1960) like soil, leaf litter, mosses and decaying wood. Several species are known for their myrmecophylic nature.

Amphipods are generally marine or limnicolous, and only a few species can live permanently on land (mainly in the family Talitridae). Some live near the sea, on beaches where they hide under logs and dead algae and vegetation. The true terrestrial amphipods live on the surface of mulch and moist ground (Fasulo 2008). Many of the habitat features of terrestrial amphipods are similar to those of isopods. These little animals are most commonly noticed by their strong, rapid jumps upon being disturbed.

7.1.2. Taxonomy of alien terrestrial crustaceans

Thirty-eight species belonging to ten different families were recorded during this study. The four most commonly represented families (all belonging to Isopoda) are Trichoniscidae (seven species), Porcellionidae (five species), Philosciidae and Armadillidiidae, both with five species (Figure 7.1.1.). Two main categories were considered:

- Aliens *to* Europe, including 17 crustacean species originating from other continents (Table 7.1.1).
- Aliens *in* Europe, represented by 21 crustacean species native to a region of Europe but introduced in another European region to which they are not native. Several other species considered as cryptogenic or cosmopolitan are probably also aliens in some parts of Europe. However, in most cases it was not possible to distinguish their alien range from the native one. Below only those species we classify as aliens *in* Europe:

Armadillidiidae: *Armadillidium assimile* Budde-Lund, 1879, *Armadillidium kossuthi* Arcangeli, 1929, *Armadillidium nasatum* Budde-Lund, 1885, *Armadillidium vulgare* (Latreille, 1804);

- Oniscidae: *Oniscus asellus* Linnaeus, 1758;
- Philosciidae: *Chaetophiloscia cellaria* (Dollfus, 1884);
- Platyarthridae: *Platyarthrus schoblii* Budde-Lund, 1885;
- Porcellionidae: *Porcellio dilatatus* Brandt, 1833, *Porcellio laevis* Latreille, 1804, *Porcellio scaber* Latreille, 1804, *Porcellionides pruinosus* (Brandt, 1833), *Proporcellio vulcanius* Verhoeff, 1908;
- Schiziidae: *Paraschizidium coeculum* (Silvestri, 1897);

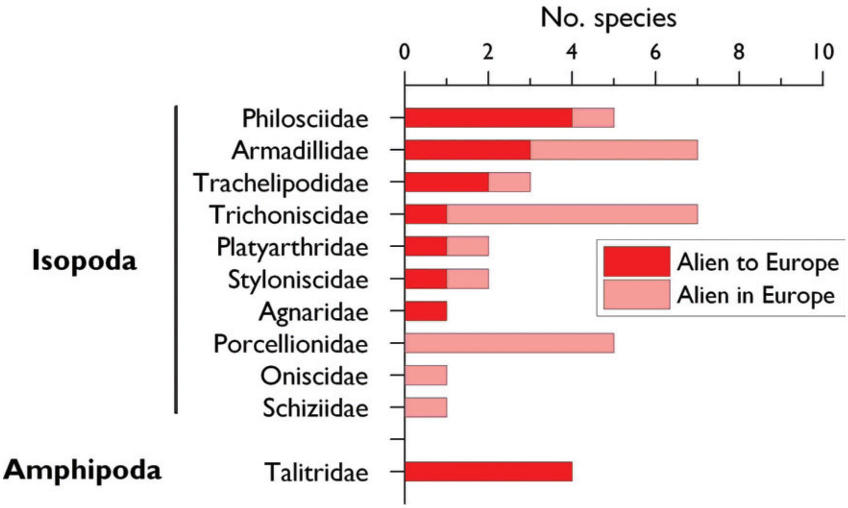

Figure 7.1.1. Taxonomic overview of the Isopoda and Amphipoda species alien *to* and Alien *in* Europe.

- Styloniscidae: *Cordioniscus stebbingi* (Patience, 1907);
- Trachelipidae: *Agabiformius lentus* (Budde-Lund, 1885);
- Trichoniscidae: *Androniscus dentiger* Verhoeff, 1908, *Buddelundiella cataractae* Verhoeff, 1930, *Haplophthalmus danicus* Budde-Lund, 1880, *Metatrichoniscoides leydigi* (Weber, 1880), *Trichoniscus provisorius* Racovitza, 1908, *Trichoniscus pusillus* Brandt, 1833.

Some of the species above have proved to be very successful colonizers and are currently considered as part of the native fauna in parts of Europe, e.g. in Hungary. However, their synanthropic nature and their extremely wide distribution range suggest a long colonisation history as it is the case for *Armadillidium vulgare*.

In the remainder of this chapter, we will focus mainly on the species alien *to* Europe.

7.1.3. Temporal trends of introduction in Europe of alien terrestrial crustaceans

The total number of crustaceans alien *to* Europe has slowly increased during the 20th and the early 21st centuries, but without any acceleration in the rate of arrival. Two alien species were first discovered in Europe in the 19th century, about nine species in the first half of the 20th century and only five species since then. The majority of these alien species have been found in several other countries after their discovery in Europe. However, the number of occupied countries over time has grown steadily rather than exhibiting exponential growth.

A similar pattern is apparent for woodlice species alien *to* Europe. However, because of sparcer information on this group, the date for the first introduction is roughly known for only approximately 50% of species. To our knowledge, at least six species of woodlice classified as aliens of Europe were noticed in the first half of the 20th century and only five more species since then.

Thus, unlike many other invertebrate phyla, the temporal trend in alien crustaceans (both intra-European and alien) has shown no marked changes during recent decades. As "silent invaders" (Hornung et al. 2007) no terrestrial crustaceans are classified as pests in Europe; they are elusive animals. We suspect frequently a large gap between the date of introduction and "discovery" of alien woodlice species. For example, during an intense eight year survey of the isopod fauna in a large region representing 15% of Hungary, three new alien species for this country were found (Farkas 2007).

To conclude, the atypically gradual trend in the number of alien terrestrial Crustacea in Europe could be an artefact of incomplete knowledge. Because of both the increasing worldwide trade in ornamental plants and the general ecology of terrestrial crustaceans (i.e. often hidden in soils), it is more realistic to expect a future exponential increase in the number of alien species (especially intra-European aliens).

7.1.4. Biogeographic patterns of the alien Crustaceans

7.1.4.1. Origin of the alien species

Species alien *to* Europe almost all originate from sub-tropical or tropical areas (Table 7.1.1.). Only one species – *Protracheoniscus major* (Dollfus, 1903)- is likely to be native from Central Asia. For several species, their ranges are poorly known (they are also often introduced in other tropical areas). However, several species do have a precise origin. The most widely distributed alien woodlouse in Europe is the tropical American *Trichorhina tomentosa* (Budde-Lund, 1893), while the most widely distributed amphipod is *Talitroides alluaudi* Chrevreux, 1901. It should be noted that a least six of the seventeen alien species were originally described from Europe (Great Britain, France and Germany) after their introduction.

The crustaceans alien *in* Europe generally originate from the Mediterranean basin (seven species), from western and south-western Europe (five species).

7.1.4.2 Distribution of the alien species in Europe

Within Europe, Crustaceans of alien origin have mainly been recorded in western countries, where they appeared first. The four countries with most species are Great Britain (11 species), the Netherlands (10 species) and Germany (nine species) (Figure 7.1.2). Comparatively few alien species have been recorded in central and eastern Europe to date (e.g. only four species in Hungary). In this part of Europe, the Central-Asian *P. major* is one of the most widespread alien crustaceans. The high number of aliens in western European countries may be linked to the high number of scientists and the intensity of soil research (Hornung 2009).

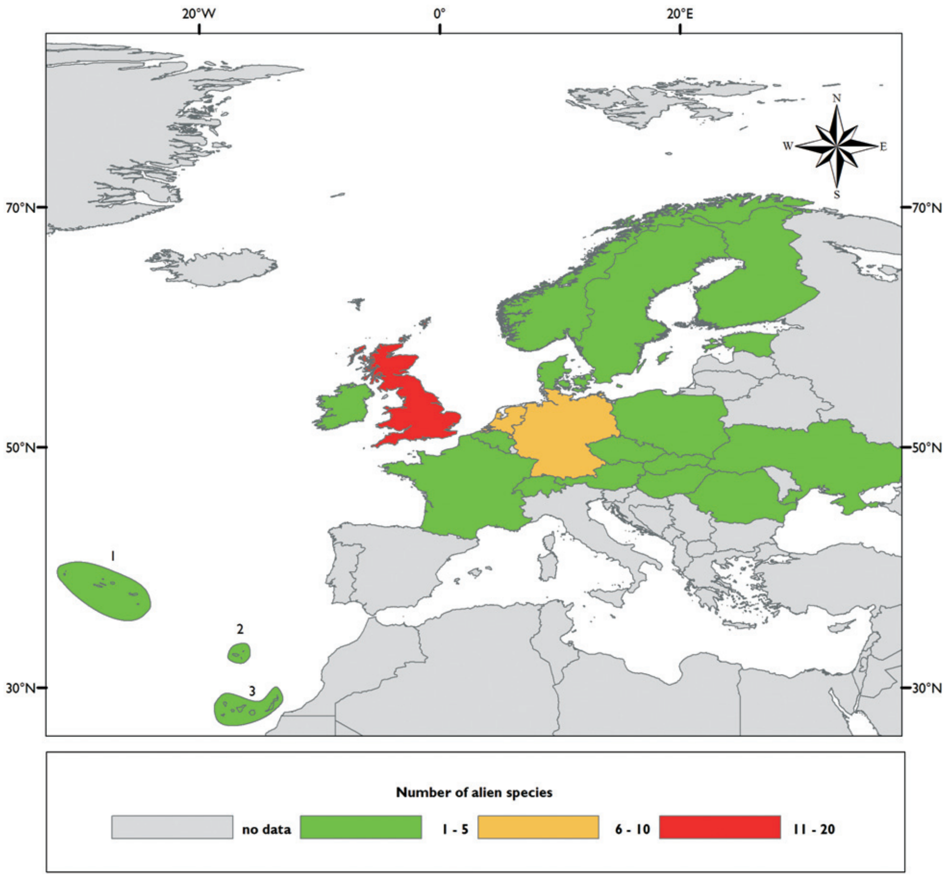

Figure 7.1.2. Colonization of continental European countries and main European islands by myriapod species alien to Europe. Archipelago: **1** Azores **2** Madeira **3** Canary islands.

There are only very few records of alien crustaceans on European islands. *Trichoniscus pusillus* has been reported from the Azores and Madeira, *T. provisorius* and *A. assimile* from the Azores but these species are native of Continental Europe. To our knowledge, the only alien aliens recorded on islands are talitrids, *Arcitalitrus dorrieni* (Hunt, 1925) in Scilly and Guernsey, *Talitroides topitotum* (Burt, 1934) in the Azores and Madeira, and *T. alluaudi* in the Azores and the Canaries. All these species occur outdoors and are therefore considered as naturalised. The rarity of alien terrestrial crustaceans on European islands is likely to be due to the primarily introduction route being major greenhouses in large metropolitan cities (see below).

Crustaceans classified as aliens of Europe are typically species which have expanded their range approximately northwards and eastwards. The eastern and central countries have a higher number of these species than more westerly countries of Europe. For example, Germany and the Czech Republic, taken together, have nine species of alien woodlice of European origin, about 45% of the total in this category.

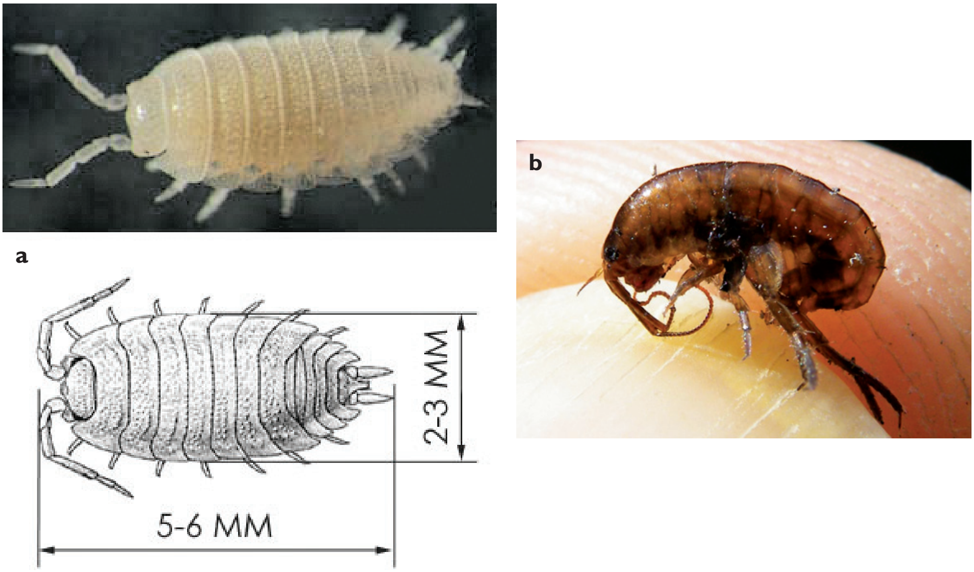

Figure 7.1.3. Alien terrestrial crustaceans. **a** *Trichorhina tomentosa* (Isopoda, woodlice) (credit: Vassily Zakhartchenko) **b** *Arcitalitrus dorrieni* (Amphipoda, lawn shrimp) (Credit: John I. Spicer).

A striking example of successful colonization and establishment of such species is given by *A. nasatum*. This woodlouse is believed to be native to Italy, southern France and Spain (Vandel 1962). Since the start of the 20th century, it has been introduced into greenhouses in a number of additional countries of Northern and Central Europe (e.g. Denmark, Finland, Germany, Hungary, Poland, Slovakia, Sweden), making this species one of the most widely distributed alien woodlice of Europe. Moreover, numerous reports highlight the successful establishment of outdoor populations in several western and central European countries (e.g. the Netherlands, Czech Republic, Romania, Slovenia) (Berg et al. 2008, Giurginca 2006, Navrátil 2007, Vilisics and Lapanje 2005).

Some of the aliens of Europe have also invaded other continents and can be considered as very successful invaders. The most notable ones are *A. vulgare*, *P. scaber* and *P. pruinosus*. *Armadillidium vulgare* and *P. pruinosus* are probably native from Mediterranean regions. In northern temperate parts of Europe, these species are restricted to synanthropic habitats (e.g. gardens, cellars, compost heaps). *P. pruinosus* is one of the woodlice that has been spread most by man across the world (Vandel 1962) and can now be considered as "synanthropically cosmopolitan" (Schmalfuss 2003).

A consequence of the dominance of Mediterranean origin for species classified as aliens of Europe is their decreasing number towards the north of the continent (Vilisics et al. 2007). In the northernmost countries of Europe (e.g. Finland (Vilisics and Terhivuo 2009)) only the most tolerant habitat-generalists, as well as intra-European aliens, are able to become successfully established.

7.1.5. Pathways of introduction of alien terrestrial Crustaceans

Because a great majority of the first isopod introductions were recorded in greenhouses, botanical gardens or urban parks, it is clear that many were associated with passive transport of soil, plants or compost. With few visible effects in such biotopes, terrestrial crustaceans colonize and spread as undetected "silent invaders" (Hornung et al. 2007). Thus, most introductions were unintentional. The one known exception is the spreading of *T. tomentosa*, commonly sold as pet food, triggered by trading activity in Europe. This probably explains why, among all the alien crustaceans, *T. tomentosa* is the most widespread species in Europe.

Another interesting case is the Mediterranean species *P. schoblii*. This myrmecophylous woodlouse is a commensal of the ant *Lasius neglectus* Van Loon, Boomsma & Andrásfalvy, 1990 and was first recorded in Hungary in 2001, a few years after the introduction of the ant. *P. schoblii* was probably introduced at the same time as its ant host (Tartally et al. 2004). It has since been found regularly (Hornung et al. 2005, Tartally et al. 2004, Vilisics 2007, Vilisics et al. 2007) and is now considered established, as is *L. neglectus*.

7.1.6 Ecosystems and habitats invaded in Europe by alien terrestrial Crustaceans

To our knowledge, the only alien crustaceans invading natural habitats are three talitrid species. *Arcitalitrus dorrieni* has invaded leaf litter understoreys of deciduous woodlands in Great Britain and Ireland (Cowling et al. 2003, Vader 1972). *Talitroides alluaudi* is known outdoors in the Canary Islands, and *T. topitotum* in the Madeira Islands, both species in the Azores (Vader 1972). All other species are generally limited to highly artificial habitats and artificial ecosystems: mostly greenhouses, urban parks and houses (especially cellars). The proportion of introduced isopods can be very high in urban areas. A study in Budapest revealed that 35% of the total species (n = 28) were introduced (Vilisics and Hornung 2009). The major settlements of Hungary were characterised as "hotspot for non-native species" (Hornung et al. 2008). This could certainly be applied to many major cities in other European countries.

For the tropical species, especially those recorded only once or twice in Europe, they may not be considered as established (Table 7.1.1.) since their survival is completely dependent on warm greenhouses.

Among all alien woodlice, none have spread to more natural habitats. However, the situation is different for intra-European woodlice native to southern or Mediterranean Europe. These established aliens can successfully expand by dispersal from very disturbed areas (where they were originally introduced) to more semi-natural habitats in rural-suburban zones (Vilisics and Hornung 2009). With global warming and the large-scale disturbance of biomes in Europe, that trend could increase, especially for the species with large ecological spectra.

7.1.7. Ecological and economic impact of alien terrestrial Crustaceans

Alien crustaceans in Europe are not known to carry diseases or to have an impact on native species and natural habitats. Further, they have no economical impact. Based on existing literature, the occurrence of alien woodlice is strictly bound to the urban environment (e.g. greenhouses, botanical and private gardens); alien terrestrial isopods do not yet seem able to survive or to expand to more natural ecosystems.

The case of the alien amphipod *A. dorrieni* is quite different. Terrestrial amphipods are known to have many effects on the soil and leaf litter (Friend and Richardson 1986). *Arcitalitrus dorrieni* has invaded deciduous and coniferous woodlands in western parts of Great Britain. In Ireland, a study showed that 24.7% of annual litter fall in a coniferous woodland was ingested by this species. It is suggested that "this introduced species plays a more important role than native macrofaunal species in nutrient turnover in this particular woodland habitat" (O'Hanlon and Bolger 1999). It is possible that other, as yet undetected, ecological impacts are likely.

Terrestrial crustaceans can represent a large percentage of biomass and abundance in the soil macrofauna (Gongalsky et al. 2005). Thus any successful invasion by a terrestrial alien crustacean could induce some disturbance if it established in relatively natural habitats. For example, in a forested area of Florida, a study on the introduced European woodlouse *A. vulgare* showed that this species' activity "had a strong effect on the chemistry of the mineral layer" (Frouz et al. 2008) and concluded that in some cases it may significantly alter soil conditions".

Woodlice classified as aliens *of* Europe are usually associated with synanthropic habitats and often gain dominance in urban environments (e.g. urban parks, villages, private gardens). The successful colonisation of human- influenced biotopes may lead to the uniformity of local Isopod assemblages. With the decrease of native species in the urban isopod fauna, an ongoing process of biotic homogenisation is prevalent in cities across Europe (Szlávecz et al. 2008, Vilisics and Hornung 2009).

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References

Allspach A (1992) Die Landasseln (Crustacea: Isopoda: Oniscidea) Hessens. *Naturschutz heute* 12: 1–146.

Berg MP, Soesbergen M, Tempelman D, Wijnhoven H (2008) *Verspreidingsatlas Nederlandse landpissebedden, duizendpoten en miljoenpoten (Isopoda, Chilopoda, Diplopoda). European Invertebrate Survey*. Amsterdam: Nederland Vrije Universiteit, Afdeling Dierecologie.

Calman WT (1912) On a terrestrial amphipod from Kew Gardens. *Annals and Magazine of Natural History* 8: 132–137.

Chevreux E (1896) Recherches zoologiques dans les serres du Museum de Paris. sur un amphipode terrestre exotique, *Talitrus alluaudi* nov. sp., acclimate dans les serres du Jardin des Plantes de Paris. *Feuille des jeunes naturalistes* 3: 112–113.

Cowling JE, Spicer JI, Weeks JM, Gaston KJ (2003) Environmental tolerances of an invasive terrestrial amphipod, *Arcitalitrus dorrieni* (Hunt) in Britain. *Comparative Biochemistry and Physiology Part A* 136: 735–747.

Cowling JE, Spicer JI, Gaston KJ, Weeks JM (2004) Current status of an amphipod invader, *Arcitalitrus dorrieni* (Hunt, 1925), in Britain. *Journal of natural history* 38: 1665–1675.

Cowling JE, Weeks, Spicer JI, Gaston KJ (2004) Physiological tolerances of the euterrestrial amphipod Arcitalitrus dorrieni (Hunt) as a key to its geographical distribution? A test using mesocosms. *Comparative Biochemistry and Physiology, Part A* 139: 251–259.

Dollfus A (1896a) Recherches zoologiques dans les serres du Muséum de Paris. *Feuille des jeunes naturalistes* 30: 90–94.

Dollfus A (1896b) On West-Indian terrestrial Isopod Crustaceans. *Proceedings of the General Meetings for Scientific Business of the Zoological Society of London for the year 1896*: 388–400.

Dudich E (1926) Trópusi rák Budapesten. *Természettudományi Közlöny*, 58: 293–295.

Dudich E (1933) Faunisztikai jegyzetek (Faunistiche Notizen) IV. *Állattani Közlemények* 30: 120–129.

Dyduch T (1903) Materialien zu einer Isopodenfauna Galiziens. *Bulletin international de l'Académie des Sciences et des Lettres de Cracovie*: 61–64.

Dominiak B (1970) Badania nad równonogami Polski. *Fragmenta faunistica (Warsaw)* 15: 401–472.

Edney E (1953) The woodlice of Great Britain and Ireland. A concise systematic monograph. *Proceedings of the Linnean Society London* 164: 49–98.

Farkas S (2007) The terrestrial isopod fauna of South Transdanubia (Hungary). *Somogyi Múzeumok Közleményei. B - Természettudomány* 17: 159–168.

Fasulo TR (2008) Terrestrial Amphipods or "Lawn Shrimp" (Crustacea: Amphipoda). University of Florida, Featured Creatures Website. http://creatures.ifas.ufl.edu [accessed July 2001, revised 2008].

Ferrara F, Taiti S (1982) A new Philosciid from eastern Africa (Crustacea, Oniscoidea). *Revue Suisse de zoologie* 89: 439–442.

Flasarová M (1986) Isopoda (Asellota, Oniscoidea) of the Little Carpathians. In: Nosek J (Ed) *The Soil Fauna of the Little Carpathians*, Bratislava, 183–216.

Flasarová M (1988) Zur Kenntnis der Isopoden Mittelböhmens (Crustacea, Isopoda, Asellota et Oniscidea). *Faunistische Abhandlungen (Dresden)* 15: 119–130.

Flasarová M (1995) Die isopoden Nordwestböhmens (crustacea: Isopoda: Asellota et oniscidea). *Acta Scientarum naturalium (Brno)* 29: 1–156.

Forró L, Farkas S (1998) Checklist, preliminary distribution maps, and bibliography of woodlice in Hungary (Isopoda: Oniscidea). *Miscellanea Zoologica Hungarica* 12: 21–44.

Foster NH (1911) On two alien species of woodlice found in Ireland. *The Irish Naturalist* 20: 154–156.

Foster NH, Pack-Beresford DR (1913) Additions to the distributional records of woodlice in Ireland. *The Irish Naturalist* 22: 45–48.

Frankenberger Z (1959) *Fauna ČSR, Svazek 14. Stejnonožci suchozemští - Oniscoidea.* Praha: NČSAV.

Friend JA, Richardson AMM (1986) Biology of terrestrial Amphipods. *Annual Review of Entomology*, 31: 25–48.

Frouz J, Lobinske R, Kalčík J, Arshad A (2008) Effect of the alien crustacean, *Armadillidium vulgare* (Isopoda), and other macrofauna on organic matter dynamics in soil microcosms in a hardwood forest in central Florida. *Florida entomologist* 91: 328–331.

Giurginca A (2006) On some Oniscidea and Diplopoda from Bucharest, Romania. *Archives of Biological Sciences, Belgrade* 58: 31–35.

Gongalsky KB, Savin FA, Pokarzhevskii AD, Filimonova ZV (2005) Spatial distribution of isopods in an oak-beech forest. *European Journal of Soil Biology* 41: 117–122.

Grüner H (1966) Über *Protracheoniscus asiaticus* (Uljanin, 1875) und die verwandten Arten (Isopoda, Oniscoidea). *Mitteilungen des zoologischen Museums Berlin* 42: 307–319.

Gregory S (2009) *Woodlice and Waterlice (Isopoda: Oniscidea & Asellota) in Britain and Ireland*. Centre for Ecology & Hydrology. 175 pp.

Harding PT, Sutton SL (1985) *Woodlice in Britain and Ireland: distribution and habitat*. Huntingdon, UK: Institute of terrestrial ecology, Natural environment research Council. 151 pp.

Hassall M, Turner J, Rands M (1987) Effects of terrestrial isopods on the decomposition of woodland leaf litter. *Oecologia (*Berlin) 72: 597–604.

Holthuis LB (1945) Notes on terrestrial isopoda collected in Dutch greenhouses. *Zoologische Mededeelingen* 25: 43–54.

Holthuis LB (1947) On a small collection of isopod Crustacea from the greenhouses of the Royal Botanic Gardens, *Kew. Annals and Magazine of natural History*, Series 11, 13: 122–137.

Holthuis LB (1956) *Fauna van Nederland* 16. *Isopoda en Tanaidacea*. 16. Leiden, The Netherlands: AW Sijthoff's Uitgeversmaatschappij N.V. 280 pp.

Hornung E, Vilisics F, Sólymos P (2008) Low alpha and high beta diversity in terrestrial isopod assemblages in the Transdanubian region of Hungary. In: Zimmer M, Cheikrouha C, Taiti S (Eds) *Proceedings of the International Symposium of Terrestrial Isopod Biology*, 1–11.

Hornung E, Vilisics F, Tartally A (2005) Occurrence of *Platyarthrus schoblii* (Isopoda, Oniscidea) and its ant hosts in Hungary. *European Journal of Soil Biology* 41: 129–133.

Hornung E, Vilisics F, Szlávecz K (2007) Hazai szárazföldi ászkarákfajok (Isopoda, Oniscidea) tipizálása két nagyváros, Budapest és Baltimore (ÉK Amerika) összehasonlításának példájával. *Termeszetvedelmi Közlem enyek,* 13: 47–58.

Hornung E (2009) personal communication.

Hunt OD (1925) On the amphipod genus *Talitrus*, with a description of a new species from the Scilly Isles, *T. dorrieni* n. sp. *Journal of the Marine Biological Association of the United Kingdom* 13: 854–869.

Ilosvay G (1985) On the isopod, diplopod and chilopod fauna of the Zirc arboretum. *A Bakony természettudomanyi kutatásának eredményei* 16: 43–50.

Jędryczkowski W (1979) Synanthrope landisopoden (isopoda, oniscoidea) polens. *Fragmenta faunistica (Warsaw)* 25: 95–106.

Kesselyák A (1930a) Über isopoden. *Zoologischer Anzeiger* 91: 50–66.

Kesselyák A (1930b) Faunistisches uber Isopoden. *Zoologische Jahrbucher, Abteilung fur Systematik, Okologie und Geographie der Tiere* 60: 239–256.

Kontschán K (2004) Magyarország faunájára új ászkarák (*Reductoniscus constulatus* Kesselyák, 1930- Crustacea: Isopoda: Oniscidea) előkerülése az ELTE füvészkertjeből (Budapest). *Folia Historico Naturalia Musei Matraensis* 28: 89–90.

Korsós Z, Hornung E, Szlávecz K, Kontschán J (2002) Isopoda and Diplopoda of urban habitats: new data to the fauna of Budapest. *Annales Historico-Naturales Musei Nationalis Hungarici* 94: 193–208.

Meinertz T (1934) Die Landisopoden Danemarks. II. Die Onisciden. *Zoologische Jahrbucher, Abteilung fur Systematik, Okologie und Geographie der Tiere* 66: 211–284.

Moore PG, Spicer JI (1986) On the status of *Arcitalitrus dorrieni* (Crustacea: Amphipoda) on the island of Colonsay, Inner Hebrides. *Journal of Natural History* 20: 667–680.

Navrátil M (2007) Stonožky, mnohonožky a suchozemští stejnonožci ve městě (Olomouc, Hodonín). Master's thesis, Univerzita Palackého v Olomouci.

Oliver PG, Meechan C (1993) *Woodlice*. Number 49 in Synopses of the British Fauna (N. S.). London: The Linnean Society of London.

Olsen KM (1995) *Cordioniscus stebbingi* (Patience, 1907) and *Trichorhina tomentosa* (Budde-Lund, 1893), two greenhouse woodlice (Isopoda, Oniscidea) new to Norway. *Fauna Norvegica Ser B* 42: 67.

O'Hanlon RP, Bolger T (1999) The importance of *Arcitalitrus dorrieni* (Hunt) (Crustacea: Amphipoda: Talitridae) in coniferous litter breakdown. *Applied soil ecology* 11: 29–33.

Pack-Beresford D, Foster N (1911) The woodlice of Ireland. Their distribution and classication. *Proceedings of the Royal Irish Academy* 29: 165–189.

Patience A (1907) On a new British terrestrial isopod. *Annals of Scottish natural History* 62: 85–88.

Patience A (1908) On a new British terrestrial isopod (*Trichoniscus linearis* sp. n.). *Annals and Magazine of Natural History* 8: 280–282.

Peart R, Lowry JK (2006) The amphipod genus *Arcitalitrus* (Crustacea: Amphipoda: Talitridae) of New South Wales forests, with descriptions of six new species. *Records of the Australian Museum* 58: 97–118.

Polk P (1959) Notes sur la distribution et la bibliographie des Oniscoidea de la Belgique. *Biologisch Jaarboek (Antwerpen)* 27: 452–460.

Radu VG (1960) Specii de losciide (izopode terestre) in fauna Republicii Populare Romine. *Studii şi Cercetări de Biologie. Academia Republicii Populare Romine, Filiala Cluj* 11: 269–275.

Schmalfuss H (2003) World catalog of terrestrial isopods (Isopoda: Oniscidea). *Stuttgarter Beiträge zur Naturkunde serie A* 654: 341. Revised and updated version. http://www.oniscidea-catalog.naturkundemuseum-bw.de/Cat_terr_isop.pdf.

Schmölzer K (1974) *Catalogus Faunae Austriae, Teil 8e, Isopoda*. Vienna, pp. 1–16.

Semenkevitsh J (1931) Isopoda terrestria der Umgegend von Kiew. *Mémoires de la Classe des Sciences naturelles et techniques de l'Academie des Sciences d'Ukraine* 5: 3–16.

Spicer JI, Tabel H (1996) Notes on the occurrence of the introduced landhopper *Arcitalitrus dorrieni* (Hunt, 1925) on Guernsey, Channel Islands. *Journal of natural history* 30: 1625–1632.

Soesbergen S (2003) *Venezillo parvus* en *Synarmadillo* spec., twee nieuwe landpissebedden in Nederland (Crustacea: Isopoda: Armadillidae). *Nederlandse faunistische Mededelingen* 18: 97–101.

Soesbergen M (2005) En de naam is... *Synarmadillo pallidus* (Crustacea: Isopoda: Armadillidae). *Nederlandse faunistische Mededelingen* 22: 123–126.

Stock JH, Biernbaum CK (1994) Terrestrial Amphipoda (Talitridae) from Ascension and Saint Helena (South Central Atlantic). *Journal of natural history* 28: 795–811.

Strouhal H (1929) Ûber einige Arten der Gattung *Protracheoniscus* Verh. (Isop. terr.). *Annalen des naturhistorischen Museums in Wien* 43: 1–12.

Strouhal H (1951) Die österreichischen Landisopoden, ihre Herkunft und ihre Beziehungen zu den Nachbarländern. *Verhandlungen der zoologisch-botanischen Gesellschaft Wien* 92: 116–142

Sutton SL (1980) *Woodlice*. New York: Pergamon Press.144 pp.

Szlávecz K, Csuzdi C, Korsós Z, Hornung E, Vilisics F (2008) *Earthworms, Isopods and Millipedes on the urban landscape: Patterns in European and American cities*. In: Book of Abstracts of the 3rd Conference of the Competence Network Urban Ecology 'Urban Biodiversity and Design', Erfurt, Germany. May 2008, 234.

Tartally A, Hornung E, Espadaler X (2004) The joint introduction of *Platyarthrus schoblii* (Isopoda: Oniscidea) and *Lasius neglectus* (Hymenoptera: Formicidae) into Hungary. *Myrmecologische Nachrichten* 6: 61–66.

Uteseny K (Taiti S. det.) (2009) Unpublished record.

Vader W (1972) Terrestrial Amphipoda collected in greenhouses in the Netherlands. *Zoologische Bijdragen* 13: 32–36.

Vandel A (1960) *Faune de France 64. Isopodes terrestres (première partie).* Paris : Fédération Française des Sociétés de Sciences Naturelles.

Vandel A (1962) *Faune de France66. Isopodes terrestres (deuxième partie).* Paris : Fédération Française des Sociétés de Sciences Naturelles.

Verhoeff K (1928) Über stenonisciden. *Zoologischer Anzeige* 79: 58–64.

Verhoeff K (1930) Zur Kenntnis osteuropaischer Isopoden. Zoologische Jahrbucher. *Abteilung fur Systematik, Okologie und Geographie der Tiere* 59: 1–64.

Verhoeff K (1937) Über einige neue und bekannte isopoda terrestria. *Sitzungsberichte der Gesellschaft Naturforschender Freunde zu Berlin 1937*: 411–430.

Vilisics F (2007) New and rare species in the isopod fauna of Hungary (Crustacea, Isopoda, Oniscidea): results of field surveys and revisions. *Folia Historico-naturalia Musei Matraensis* 31: 115–123.

Vilisics F, Elek Z, Lövei GL, Hornung E (2007) Composition of terrestrial isopod assemblages along an urbanisation gradient in Denmark. *Pedobiologia* 51: 45–53.

Vilisics F, Hornung E (2009) Urban areas as hot-spots for introduced and shelters for native isopod species. *Urban ecosystems* 12: 333–345.

Vilisics F, Lapanje A (2005) Terrestrial isopods (Isopoda: Oniscidea) from the Slovenian karst. *Natura Sloveniae*, 71: 13–21.

Vilisics F, Sólymos P, Hornung E (2007) A preliminary study on habitat features and associated terrestrial isopod species. In: Tajovský K, Schlaghamerský J, Pižl V (Eds) *Contributions to Soil Zoology in Central Europe II*. České Budějovice: Institute of Soil Biology, Biology Centre, Academy of Sciences of the Czech Republic, 195–199.

Vilisics F, Terhivuo J (2009) Inspection on materials contributing to the knowledge of terrestrial Isopoda (Crustacea, Oniscidea) in Finland. *Memoranda Societatis pro Fauna et Flora Fennica* 85: 9–15.

Wouters K, Tavernier JM, Meurisse L (2000) Distribution and bibliography of the terrestrial Isopoda (Crustacea) of Belgium. *Bulletin de l'Institut Royal des Sciences Naturelles de Belgique* 70: 195–205.

Zimmer M (2002) Nutrition in terrestrial isopods (Crustacea: Isopoda): an evolutionary-ecological approach. *Biological Reviews* 77: 455–493.

Table 7.1.1. List and main characteristics of the Crustacean species alien *to* Europe. Country codes abbreviations refer to ISO 3166 (see appendix I). Habitat abbreviations refer to EUNIS (see appendix II). Only selected references are given. Last update 16/10/2009.

Order *Family*	***Species***	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**References**
Isopoda							
Agnaridae							
	Protracheoniscus major (Dollfus, 1903)	Detritivorous	Central Asia?	1903, PL/UA	AT, CZ, DE, EE, HU, PL, RO, SK, UA	J	Dudich (1926),Dudich (1933), Dyduch (1903), Dominiak (1970), Flasarová (1986), Flasarová (1988), Flasarová (1995), Forró and Farkas (1998), Frankenberger (1959), Ilosvay (1985), Schmölzer (1974), Semenkevitsh (1931), Strouhal (1929), Strouhal (1951), Verhoeff (1930)
Isopoda							
Armadillidae							
	Reductoniscus costulatus Kesselyák, 1930	Detritivorous	Pacific islands	1930, DE	DE, FR, GB, HU, NL	J	Berg et al. (2008), Grüner (1966), Holthuis (1947), Holthuis (1956), Kesselyák (1930a), Kesselyák (1930b), Kontschán (2004), Schmalfuss (2003), Soesbergen (2003), Vandel (1962), Verhoeff (1937)
	Synarmadillo pallidus Arcangeli, 1950	Detritivorous	Congo	2003, NL	NL	J	Berg et al. (2008), Schmalfuss (2003), Soesbergen (2003), Soesbergen (2005)
	Venezillo parvus (Budde-Lund, 1885)	Detritivorous	Tropical regions	2003, NL	GB, NL	J	Berg et al. (2008), Gregory (2009), Schmalfuss (2003), Soesbergen (2003)
Isopoda							
Philosciidae							
	Anchiphiloscia balssi (Verhoeffff, 28)	Detritivorous	East Africa	1928, DE	DE, NL	J	Berg et al. (2008), Ferrara and Taiti (1982), Holthuis (1945), Schmalfuss (2003), Verhoeff (1928)
	Benthana olfersii (Brandt, 1833)	Detritivorous	Brazil (Southeast)	?, DE	DE	J	Schmalfuss (2003)
	Burmoniscus meeusei (Holthuis, 1947)	Detritivorous	Asia	1947, GB	GB	J	Harding and Sutton (1985), Holthuis (1947)

Order *Family*	*Species*	Regime	Native range	1st record in Europe	Invaded countries	Habitat	References
	Burmoniscus orientalis Green, Ferrara & Taiti, 1990	Detritivorous	Asia	2005, AT	AT	J	Uteseny (2009)
Isopoda ***Platyarthridae***							
	Trichorhina tomentosa (Budde-Lund, 1893)	Detritivorous	America (Tropical)	1896, FR	AT, CH, BE, CH, CZ, DE, FR, GB, HU, IE, NL, NO, PL[1]	J	Berg et al. (2008), Dollfus (1896a), Foster (1911), Foster and Pack-Beresford (1913), Harding and Sutton (1985), Holthuis (1945), Jedryckowsky (1979), Korsós et al. (2002), Meinertz (1934), Olsen (1995), Pack-Beresford and Foster (1911), Polk (1959), Schmalfuss (2003), Verhoeff (1937), Wouters et al. (2000)
Isopoda ***Styloniscidae***							
	Styloniscus spinosus (Patience, 1907)	Detritivorous	Madagascar, Mauritius	1907, GB	GB	J	Edney (1953), Harding and Sutton (1985), Patience (1907), Schmalfuss (2003)
Isopoda ***Trachelipodidae***							
	Nagurus cristatus (Dollfus, 1889)	Detritivorous	Pantropical	1956, NL	DE, GB, NL, RO	J	Allspach (1992), Berg et al. (2008), Harding and Sutton (1985), Holthuis (1956), Oliver and Meechan (1993), Radu (1960), Schmalfuss (2003)
	Nagurus nanus Budde-Lund, 1908	Detritivorous	Tropical regions	1985 GB	GB, IE	J	Foster (1911), Foster and Pack-Beresford (1913), Harding and Sutton (1985), Schmalfuss (2003), Sutton (1980)
Isopoda ***Trichoniscidae***							
	Miktoniscus linearis (Patience, 1908)	Detritivorous	USA (East) ?	1908,GB	DE, GB	J	Kesselyák (1930a), Patience (1908), Schmalfuss (2003), Vandel (1962)

Order *Family*	*Species*	Regime	Native range	1st record in Europe	Invaded countries	Habitat	References
Amphipoda							
Talitridae							
	Arcitalitrus dorrieni (Hunt, 1925)	Detritivorous	Australia (East)	1925, GB	GB, IE, NL	G1, J	Cowling et al. (2003), Cowling et al. (2004a), Cowling et al. (2004b), Hunt (1925), Moore and Spicer (1986), Peart and Lowry (2006), Spicer and Tabel (1996)
	Brevitalitrus hortulanus Calman, 1912	Detritivorous	Tropical regions?	1912, GB	GB, NL	J	Calman (1912), Friend and Richardson 1986, Vader (1972)
	Talitroides alluaudi (Chevreux, 1896)	Detritivorous	Tropical regions, Seychelles Isl.?	1896, FR	BE, CH, CZ, DE, DK, ES-CAN, FI, FR, GB, HU, NL, PL, PT-AZO, SE	G1, J	Chevreux (1896), Dudich (1926), Friend and Richardson (1986), Hunt (1925), Vader (1972)
	Talitroides topitotum (Burt, 1934)	Detritivorous	Indo-Pacific	1942, DE	DE, GB, NL, PT-AZO, PT-MAD	G,J	Friend and Richardson (1986), Stock and Biernbaum (1994), Vader (1972)

1 *Trichorhina tomentosa* is on sale as reptile food in many European pet shops.

After this table was established, Gregory (2009) mentioned the presence of two more alien species in Great Britain, *Styloniscus mauritiensis* (Barnard, 1936) (Styloniscidae) from Hawaii and Mauritius and *Setaphora patiencei* (Bagnall, 1908) (Philosciidae) from The Réunion and Mauritius islands.

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Myriapods (Myriapoda)
Chapter 7.2

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Abstract

Alien myriapods in Europe have never been subject to a comprehensive review. Currently, 40 species belonging to 23 families and 11 orders can be regarded as alien to Europe, which accounts approximately for about 1.8% of all species known on the continent. Millipedes (Class Diplopoda) are represented by 20 alien species, followed by centipedes (Class Chilopoda) with 16, symphylans with 3 and pauropods with only 1. In addition there are numerous cases of continental species introduced to the Atlantic and Mediterranean islands or others of southern origin transported and established in North European cities. The earliest record of an alien myriapod dates back to 1836, although the introduction of some species into Europe could have begun already in historical times with an increase in trade between ancient Greeks and Romans with cities in the Near East and North Africa. In post-medieval times this process should have intensified with the trade between Europe and some tropical countries, especially after the discoveries of the Americas and Australia. The largest number of alien myriapods (25, excl. intercepted) has been recorded from Great Britain, followed by Germany with 12, France with 11 and Denmark with 10 species. In general, northern and economically more developed countries with high levels of imports and numerous busy sea ports are richer in alien species. The various alien myriapods have different origins, but most of them show tropical or subtropical links (28 species, 70%). Eight of them (20%) are widespread in the Tropical and Subtropical belts, eleven (circa 28%) are of Asian origin, seven show links with South and Central America, and one each originates from North America, North Africa, Australasia, and islands in

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the Indian Ocean. Ten myriapods are of unknown origin (cryptogenic). Only 12 species (*ca.* 30%) of all have established in the wild in Europe. At the present time alien myriapods do not cause serious threats to the European economy and there is insufficient data on their impact on native fauna and flora.

Keywords
Diplopoda, Chilopoda, Symphyla, Pauropoda, Europe, alien, invasions, intercepted species, biogeographical patterns

7.2.1. Introduction

Myriapods are terrestrial wingless arthropods with elongated bodies composed of more or less similar segments, most of which bear one or two pairs of legs. Four classes are recognised: Pauropoda, Symphyla, Chilopoda and Diplopoda. Approximately 15 000 species from nearly 160 families are currently known in the world. The Diplopoda is by far the most diverse group, comprising roughly 11 000 species (Adis and Harvey 2000). A total of 2,245 myriapod species or subspecies from 15 orders and 70 families are currently known in Europe (http://www.faunaeur.org/statistics.php), of which 1,529 are Diplopoda, 481 Chilopoda, 41 Symphyla and 125 Pauropoda. All members of the class Diplopoda (millipedes) have two pairs of legs per diplosegment for most segments. Several morphotypes have been recognised, i.e. juloid, polydesmoid, polyxenoid, platydesmoid and glomeroid (Kime and Golovatch 2000), of which the former two are especially rich in species both in Europe and worldwide. Most of the species are cylindrical or flattened dorsally, often with prominent lateral projections, generally medium- to large-sized (up to 8–9 cm in the genera *Pachyiulus* and *Eurygyrus*). Some species of the order Glomerida, or pill millipedes, are oniscomorph, capable of rolling up into a tight ball. Members of the order Polyxenida, or “dwarf millipedes”, are minute in size and with peculiar hairs along the body arranged in groups and tufts like small pin-cushions or brushes. The number of legs varies between species, often (especially in juloids) even individually, the record being 375 pairs in the North American siphonophoridan species *Illacme plenipes* Cook & Loomis, 1928 (Marek and Bond 2006).

Species of the class Chilopoda (centipedes) have an elongated flattened trunk and bear one pair of legs per segment, with a total number ranging between 15 and 191 pairs. Centipede body length varies from a few millimeters in some species of genus *Lithobius* (*Monotarsobius*) to approximately 30 cm in the Neotropical species *Scolopendra gigantea* (Minelli and Golovatch 2001). All centipedes have a pair of poison claws, or forcipules, which represent modified first body appendages. About 3,500 valid species and subspecies from 5 orders and 22 families are known in the world (Minelli 2006, Edgecombe and Giribet 2007). The other two myriapod classes – Symphyla and Pauropoda – consist of very small species, with body length of 2–8 and 0.5–1.9 mm respectively, both still remaining very poorly studied. The number of described symphylans and pauropods in the world is roughly estimated to about 200 and 700, respectively (Adis and Harvey 2000).

Most millipedes, as well as all pauropods and symphylans, are phytophages, detritivores or saphrophages. A few millipedes can be regarded as omnivores, e.g. *Blaniulus guttulatus* (Fabricius, 1798), *Uroblaniulus canadensis* (Newport, 1844), or even predators, like *Apfelbeckia insculpta* (L. Koch, 1867), *Callipus foetidissimus* (Savi, 1819), and *Abacion magnum* (Loomis, 1843), which have been observed feeding on earthworms, flies and spiders (Hoffman and Payne 1969, Golovatch 2009). Other species feed on their own exuvia or fecal pellets (Minelli and Golovatch 2001).

Centipedes are mostly predatory, feeding on different available prey items in the soil (earthworms, enchytraeids, snails, slugs, small insects – both larvae and adults – and other arthropods). More details on the biology and ecology of millipedes, centipedes and the two other, smaller myriapod classes can be found in Hopkin and Read (1992), Lewis (1981), and Verhoeff (1933, 1934).

Little information is as yet available on the non-indigenous myriapods in Europe (DAISIE 2009, Roques et al. 2009). The most recent overview of alien organisms in Europe (see DAISIE 2009, p. 225) lists two centipedes (*Lamyctes emarginatus*, *Lamyctes caeculus*) and three millipedes (*Oxidus gracilis*, *Eurygyrus ochraceus*, *Sechellobolus dictyonotus* = *Paraspirobolus lucifugus*) as alien to Europe. Some papers have been, however, published on the ecology, morphology and post-embryonic development of several alien centipedes (Andersson 1984, 2006, Bocher and Enghoff 1984, 1975a, Negrea 1989) and millipedes (Enghoff 1975b, 1978, 1987, Golovatch et al. 2000, et al. 2002). Lists of alien species have been published for a few countries only, such as Germany (Kinzelbach et al. 2001), Austria (Gruber 2002, Gruber and Christian 2002), the Czech Republic (Šefrová and Laštůvka 2005), Switzerland (Wittenberg 2005), Italy (Zapparoli and Minelli 2005) and Great Britain (Barber 2009a, b). Increasing attention has been paid in the last decades to species which have accidentally arrived in Europe (see Barber 2009a, BBC News 2005, Christian and Szeptycki 2004, Gregory and Jones 1999, Lewis 1988, Lewis and Rundle 1988 for centipedes and Andersson and Enghoff 2007, Enghoff 2008a and Read 2008 for millipedes).

7.2.2. Taxonomy of the myriapod species alien to Europe

Altogether, 40 species belonging to 23 families and 11 orders can be regarded as alien to Europe (Table 7.2.1). This accounts approximately for about 1.8% of all myriapods known on the continent. Millipedes are represented by 20 alien species, followed by centipedes with 16, symphylans with 3 and pauropods with only 1. The relative proportion of alien species is highest in Symphyla (7.3%) and Chilopoda (3.3%), and the lowest in Pauropoda (0.8%) and Diplopoda (1.3%). The centipede family Henicopidae is the richest in alien species (5 species), followed by Scutigerellidae, Mecistocephalidae, Scolopendridae, Paradoxosomatidae and Pyrgodesmidae, each with three species. The remaining 17 families are represented by only one or two species each (Figure 7.2.1).

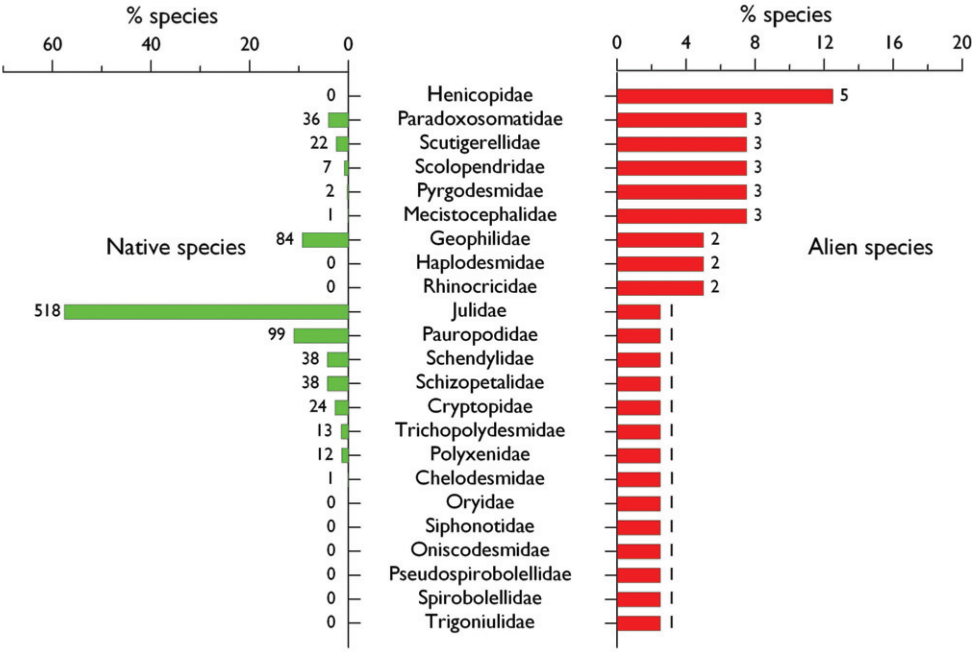

Figure 7.2.1. Relative importance of each family in the alien (right side) and native (left side) myriapod fauna in Europe. Number near the bar indicates the number of species. Families are listed in a decreasing order based on the number of alien or, in alternative, native species.

Striking is the absence of alien species in Europe of the species-rich order Spirostreptida since spirostreptidans, for instance *Hypocambala anguina* (Attems, 1900) and *Glyphiulus granulatus* Gervais, 1847, are quite widespread in the tropical countries and show a clear tendency to anthropochorism (Jeekel 1963, Shelley 1998).

Several myriapods have been intercepted at their arrival in Europe from consignments from other countries but have never managed to establish themselves. Barber (2009a) provided a list of centipede species captured and registered by the Central Science Laboratory (now FERA) in the UK when imported with exotic plants, fruits and luggage (Table 7.2.2). Two of them, *Lithobius forficatus* and *L. peregrinus*, are European natives which have long been introduced to Australia and New Zealand, so their interception in Great Britain is a clear case of re-introduction.

A similar list for intercepted millipedes examined by the Central Science Laboratories between 1975 and 2006 (S. Reid *pers. comm.*) is more substantial with some 85 entries over this period of time (Table 7.2.2). Of these 36 were records of *Oxidus gracilis* from a wide range of different parts of the world (W & S. Europe, Canary Islands, Israel, N., C. and S. America, Australia, China, Japan, Malaysia, Singapore, India, Nepal, N., W. and S. Africa and Madagascar). Other types found included members of the Polydesmida (dalodesmids, parodoxomatids, polydesmids), Spirosteptida (from Australia, New Zealand and Africa), Julidae and Blaniulidae. Amongst species from the latter two families were the NW European *Blaniulus guttulatus* and *Cylindroiulus* *londinensis* (both from Australia) and *Ommatoiulus moreletii* (originating in the Iberian Peninsula, introduced to Australia in 1953 and now a pest species there; in this list reported from both that country (tree fern) and South Africa (melon fruit)).

Man-aided introductions of species from one part of Europe to another have played a prominent role. One of the most common synanthropic centipedes in North Europe is the Mediterranean "house centipede" *Scutigera coleoptrata* (Linnaeus, 1758). It has been introduced to a number of North European cities, e.g., Copenhagen, Edinburgh, Aberdeen, Leiden, etc., where it survives only in buildings. The earliest record in the British Isles of this species is perhaps that by Gibson-Carmichael (1883) who recorded it from a paperworks near Aberdeen. It could have been established there already for 25 years and arrived in bundles of rags from South Europe (Barber 2009a); at the present time it is sporadically reported from inside buildings in various parts of Britain and seems to be common in houses in St. Peter Port (Guernsey) and St. Helier (Jersey) in the Channel Islands from where it has also been reported from outdoor sites. Other cases of south or central European species being introduced to northern countries that perhaps still survive only in buildings, hothouses, gardens or similar man-made habitats are: *Tuoba poseidonis* (Verhoeff, 1901) in Finland, *Dicellophilus carniolensis* (C.L. Koch, 1847), *Lithobius lucifugus* L. Koch, 1862, *Lithobius peregrinus* Latzel, 1880, *Haplopodoiulus spathifer* (Brölemann, 1897) and *Cylindroiulus salicivorus* Verhoeff, 1908 in Great Britain, *Cylindroiulus vulnerarius* (Berlese, 1888) in Sweden, *Pachyiulus varius* (Fabricius, 1781) in Norway, etc. (Barber 1995, Barber and Eason 1986, Barber and Keay 1988, Bergersen et al. 2006, Lee 2006, Read 2008).

Even within the same geographic area some indigenous species occur at localities that are not part of their primary distribution area, most probably as a consequence of accidental anthropogenic introductions. Examples are the records from Italy of *Lithobius infossus* Silvestri, 1894 near Padua (Minelli 1991), of *L. peregrinus* Latzel, 1880 in northeastern and central Italy (Minelli 1991, Zapparoli 1989, Zapparoli 2006), of *Pleurolithobius patriarchalis* (Berlese, 1894) in the Egadi, Pontine and Campania islands (Zapparoli and Minelli 1993), and of *Scolopendra cingulata* near Milan (Manfredi 1930).

Island invasions by continental species is another phenomenon worth mentioning. Eason in a study on the Icelandic fauna, concluded that most centipede and millipede species probably arrived by human transport (Eason 1970). Examples of recent introductions to Iceland are *Geophilus truncorum* Bergsøe & Meinert, 1866, *Polydesmus inconstans* Latzel, 1884, and *Brachydesmus superus* Latzel, 1884, which "… have only been found on Heimaey, one of the Vestman Islands, which supports a town and where casual introduction by human transport is likely: they have probably been introduced quite recently and the two millipedes seem still to be confined to the outskirts of the town". Regarding the other two possibly allochthonous species, *Lithobius forficatus* (Linnaeus, 1758), and *Lithobius erythrocephalus* C.L. Koch, 1847, Eason wrote, "these two species may be confined to the south owing to the relatively warm and humid southern climate, but their restricted distribution might also be explained by their having been introduced by Norse settlers ....". The first Norse settlements on Iceland were established in the ninth century A.D., so this must have happened after that time.

According to Enghoff (2008b), of the 21 species of centipedes recorded in Madeira 17 are introduced and 2 are probably introduced. High rates of introduction are also known for the Azores and Canary Islands (Borges and Enghoff 2005, Zapparoli and Oromi 2004) (Table 7.2.3). All symphylans on the Canary Islands have been considered as possibly introduced. Likewise, only two of 21 millipede species are considered native on the Azores (Enghoff and Borges 2005).

The geophilomorph centipede *Nyctunguis persimilis* Attems, 1932 was originally described from Turkey and has not been found there since in spite of the active work of the second author who has published several papers on the Turkish centipede fauna during the last 20 years. Taking into account that the species was recently found in synanthropic habitats in the outskirts of Vienna (Christian 1996) and that all other congeners occur in the Nearctic region, it is very likely that the type locality (the surroundings of Ankara, Turkey) is erroneous and the material was actually mislabeled (Zapparoli 1999).

Mecistocephalus maxillaris (Gervais, 1837), one of the first alien centipedes to be recorded in Europe, is another poorly known species. It was described from the gardens of the Muséum National d'Histoire Naturelle, Paris, and subsequently recorded from numerous places around the world. However, most of the records were certainly based on misidentifications with the morphologically similar *M. guildingii* or *M. punctifrons* actually being involved (Bonato et al. 2009). According to Bonato et al. (2009), most of the records in Europe e.g., those from Germany, Great Britain, France (not the type specimen but material taken subsequently from a greenhouse in the Paris Museum, cf. Brolemann 1930) and Portugal (Madeira), are referable to *M. guildingii*, while those from the Netherlands and Denmark require further clarification.

The actual taxonomic status and native range of *Ghilaroviella* cf. *valiachmedovi* remains uncertain. The same applies to the millipede *Chondrodesmus* cf. *riparius* which shows some differences from the original description by Carl (1914) and its identity cannot be clarified without a comprehensive review of the entire genus (Enghoff 2008a).

7.2.3. Temporal trends in the introduction of alien myriapod species to Europe

Introductions of alien myriapods into Europe probably began several centuries ago, even though a precise arrival date is hard to determine. Only 10 out of 40 species were recorded for the first time in Europe in the 19th century while most of the records date from the 20th (26 species) and 21st centuries (4 records).

Gervais was virtually the first person to record alien myriapods in Europe (Gervais 1836, 1837). He described the tropical millipede *Iulus lucifugus* (now *Paraspirobolus lucifugus*) and the geophilomorph centipede *Mecistocephalus maxillaris* from greenhouses of the Paris Museum. The means of arrival of both species remains obscure but must be linked to the establishment of the greenhouses and the planting of tropical flowers, perhaps already by the end of the 18th century. *P. lucifugus* has been subsequently recorded in intervals of around 60–70 years from greenhouses near Hamburg (Latzel 1895), Hortus Botanicus Amsterdam (Jeekel 1977), a greenhouse in Copenhagen (Enghoff 1975b), and more recently from the Tropical Biome at the Eden project (Lee 2006). This can hardly be regarded as reflecting the actual course of colonization but rather the date of investigation and the level of effort involved in each case.

The only alien millipede that has invaded some natural ecosystems in Europe and acclimatized is the East Asian species *Oxidus gracilis*. Perhaps the earliest records of this species in Europe are those of Tömösváry (1879) from the Margaret Island in Danube, Hungary, and of Latzel (1884) from greenhouses in Zeist, Utrecht, and Amsterdam in the Netherlands. Subsequently it was also found in Edinburgh in 1898 and in Kew Gardens in Great Britain (Evans 1900, Pocock 1902). In Finland the species was first recorded in 1900, but since the sample already contained several specimens the species must have arrived there at least two years earlier (Palmén 1949). The mechanism of dispersal of the species within Europe is certainly related to the trading and growing of tropical plants in the greenhouses as in some places this process must have happened more than once. According to Palmén (1949), the population of *O. gracilis* in the greenhouses of Hanko, South Finland went extinct during the period 1939–1943 when they were not kept warm. In 1946 a single female was found in a greenhouse with plants imported from Belgium, in 1947 its numbers increased considerably and the next year it was already very abundant in the whole greenhouse complex.

Golovatch (2008) suggested that the intense trade ties between the ancient town of Khersonesos in the Crimea and the town of Pergam (= Bergama), a major centre of red ceramics production of the time in present-day Turkey, as possible pathways for the introduction of *Eurygyrus ochraceus* in the Ukraine. He also pointed out that the Bulgarian population near Varna may owe its origin to the very active commerce in Roman times between Bergama and the colonies in Moesia (= currently northern Bulgaria and southern Romania), including Odessos (= Varna). The area and trade connections were already quite developed by the mid-4th century B.C. or even earlier, under ancient Greeks, so this introduction must have happened around that time.

Members of the genus *Lamyctes* are represented in Europe only by parthenogenetic populations. Males of *L. emarginatus* are known only from Macaronesia, New Zealand, Tasmania and Hawaii (see also Attems (1935) and Zapparoli (2002) for the record of a single male from Greece), while males of *L. coeculus* are only known from a greenhouse in Italy and from Cuba (Enghoff 1975a). Taking into account that the entire family Henicopidae is predominantly distributed in the Southern Hemisphere, and presuming that the regions where males are being found are the native areas of the species, *L. emarginatus* could have been introduced to Europe from one of the above regions, most likely from Australia or New Zealand. The earliest confirmed record is from Denmark in 1868 (see Meinert 1868). *Lamyctes coeculus* was first found in a greenhouse in Italy at the end of 19th century (Brölemann 1889), but its presence in the area would have been older. It has been recently found in Great Britain (Barber 2009b).

The earliest records of *Cylindroiulus truncorum* in Europe date from the 1920's and, according to Schubart (1925), the Central European populations are probably of relatively recent origin. In Finland it was first reported in 1945 and in the following three years its numbers increased considerably. It is completely lacking in older collections (Palmén 1949).

One of the recent introductions is the large Neotropical millipede *Chondrodesmus* cf. *riparius* which was first recorded in 2000 in a flowerpot in the telephone office of Umeå University, northern Sweden. It was found again elsewhere in Sweden in 2006 and, later, in January 2007, it was also recorded in a flowerpot with a palm (*Phoenix robbelini*) in an office in Copenhagen and in a flowerpot in Bonn (Enghoff 2008a). There are further records of the species from flowerpots in Germany and also a recent one in Norway (Göran Andersson in litt.), so it seems that the species is dispersing well with palm pots.

The study of the invertebrate fauna of Kew Gardens, Great Britain began already at the beginning of 20th century with papers by Pocock (1902, 1906) and continues today (Blower and Rundle 1980, 1986, Read 2008). Some of the species recorded by Pocock such as *Scolopendra morsitans*, *Trigoniulus corallinus* and *Asiomorpha coarctata* have not been re-found since then and most likely could not become established in Kew Gardens. At the same time *Paraspirobolus lucifugus*, *Amphitomeus attemsi*, *Cylindrodesmus hirsutus*, *Rhinotus purpureus* and *Pseudospirobolellus avernus*, species not previously known from Britain have been recorded recently in the Tropical Biome at the Eden project in Cornwall (Read 2008, Barber 2009b, Barber et al. 2010).

7.2.4. Biogeographic patterns of the myriapod species alien to Europe

Records of exotic species are not evenly distributed in Europe but this is mainly due to the different levels of investigation of this area. The highest number of species (25) has been recorded from Great Britain, followed by Germany with 12, France with 11 and Denmark with 10 alien myriapods (Figure 7.2.2). In general, northern and economically more developed countries with high levels of imports and numerous busy sea ports are richer in alien species. These countries also, in general, have poorer native faunas meaning that a small number of aliens can constitute a large percentage of the fauna. Several species are hitherto known in Europe from a single country only, e.g. *Prosopodesmus panporus*, *Pseudospirobolellus avernus*, *Tygarrup javanicus* and *Cryptops doriae*, which implies recent introductions or poor dispersal abilities. Others, such as *Eurygyrus ochraceus*, *Paraspirobolus lucifugus* and *Lamyctes coeculus*, have a larger but yet fairly restricted distribution limited to two or more countries. The most widespread species are the parthenogenetic centipede *Lamyctes emarginatus*, whose range in Europe spreads from the Urals to Iceland [outdoor species], and the bisexual millipede *Oxidus gracilis*, reported from 33 countries, including several Mediterranean islands.

The various alien myriapods have different origins, but most of them show tropical or subtropical links (28 species, 70%). Eight of them (20%) are widespread in the Tropical and Subtropical belts, very often introduced by human agency to islands and synanthropic areas on continents. Their native range cannot so far be determined with certainty (Figure 7.2.3). Eleven (circa 28%) alien myriapods are of Asian origin, the majority (10 species) having their native range in East or Southeast Asia, and only one from West Asia, namely Anatolia. *Cylindroiulus truncorum* is perhaps the only North African myriapod introduced to Europe just as *Brachyiulus pusillus* (Leach, 1814) so far is the only European julid introduced to North Africa (Akkari et al. 2009). The only species that seems to be an Australasian native (Australia and New Zealand) is *Lamyctes emarginatus*. Among henicopids, *Rhodobius lagoi* and *Ghilaroviella* cf. *valiachmedovi* are of particular interest being members of monotypic genera and the only representatives in Europe of the subfamily Anopsobiidae which comprises chiefly species with Gondwanan distribution patterns. Besides *Rhodobius*, four other monotypic genera represent the subfamily in the Northern Hemisphere, occurring in Vietnam, Japan, Kazakhstan, and Tajikistan (Edgecombe 2003, Farzalieva et al. 2004). Of Central or South American origin are seven species (circa 18%), and one each from North America and islands in Indian Ocean. The sole record of the pantropical geophilomorph centipede *Orphnaeus brevilabiatus* in Europe comes from Bohuslän, a Swedish province in the northern part of the W coast, where the animal was collected in the 19th century (Andersson et al. 2005).

Ten centipedes and millipedes have been considered as cryptogenic (= species of unknown origin which cannot be ascribed as being native or alien). Some of them such as the geophilid *Arenophilus peregrinus* and the schendylid *Nyctunguis persimilis*, which have only been reported from the Isles of Scilly, Great Britain and Austria respectively (Barber 2008, Christian 1996) whereas all the other species of these genera live in North America, are of likely Nearctic origins. Another suspected introduction of uncertain origin is *Nothogeophilus turki* which has hitherto been known only from Scilly and the Isle of Wight, Great Britain (Lewis et al. 1988) and represents a monotypic genus. However, we cannot completely exclude the possibility that some cryptogenic species suspected to be alien are actually native to Europe. Support for this notion we find in the scolopendromorph centipede *Theatops erythrocephalus* C.L. Koch, 1847, which occurs in various natural habitats (including caves) in the Pyrenees and the western part of the Balkans (with a gap between these geographic areas), while all its other four congeners occur in North America (Minelli 2006).

Unknown also is the origin of the symphylid *Hanseniella oligomacrochaeta* described from a hothouse in the Botanical Garden in Berlin; according to Scheller (2002), all species in the genus *Hanseniella* have tropical-subtropical distributions. The haplodesmid *Prosopodesmus panporus* is only known from the Royal Botanic Gardens in Kew, England, while its other described congener, *P. jacobsoni* Silvestri, 1910, is pantropical (Golovatch et al. 2009). Likewise, it is uncertain whether *Napocodesmus endogeus*, a millipede described solely from females collected in the garden of Cluj University, is a European native or not. According to Tabacaru et al. (2003), the generic allocation

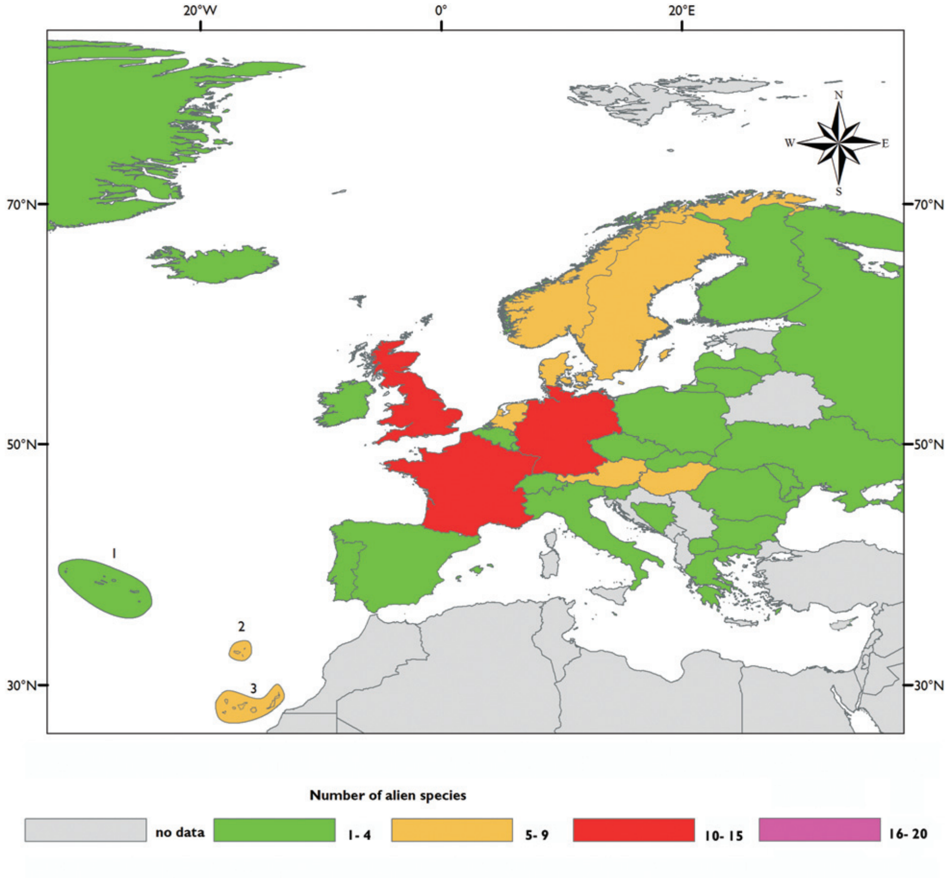

Figure 7.2.2. Colonization of continental European countries and main European islands by myriapod species alien to Europe. Archipelago: **1** Azores **2** Madeira **3** Canary islands.

of the second species described in the genus, *N. florentzae* Tabacaru, 1975, hitherto known from Romania and Moldova, is not certain and since there are no other records of *N. endogeus* in nature it might be an introduced species.

7.2.5. Pathways for the introduction of alien myriapod species in Europe

All of the alien myriapods have most probably been accidentally introduced to Europe with plant material in relation to human activities and trade between Europe and other continents such as Asia, Australasia and the Americas. This process must have begun with an increase in trade between ancient Greek and Romans with cities in Asia Minor and North Africa and should have intensified in post-medieval times with the trade between Europe and some East Asiatic countries (e.g. Japan, China) and the geographic discoveries of the Americas and, later, of Australia. This process is still going on with

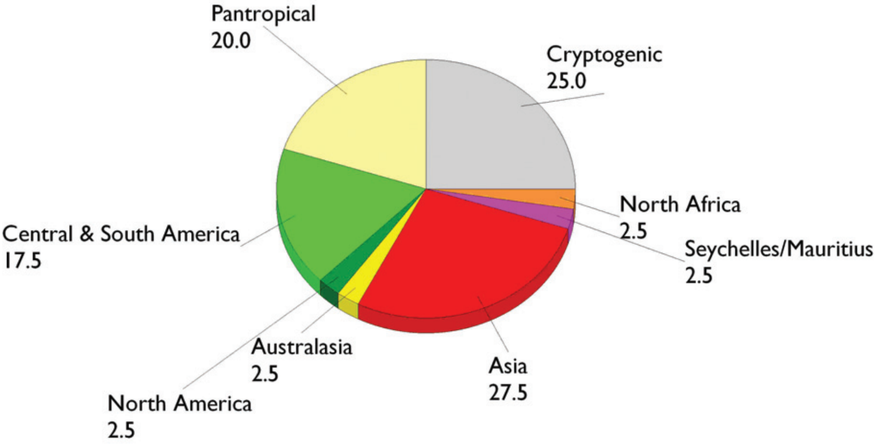

Figure 7.2.3. Geographic origin of the myriapod species alien to Europe (in percent).

the trade of tropical flowers and other plants and their cultivation in houses and greenhouses or with the importing of goods from tropical countries. Even large species could be transported this way, as is the recent case of the discovery of the largest centipede *Scolopendra gigantea*, found in 2005 in a house in London, which is thought to have arrived with a cargo of electrical goods or fruit (BBC News 2005). Pocock (1906) suggested the possible countries whence a variety of alien species found in Kew Gardens were introduced with their host plants: India (*Scolopendra morsitans*, *Mecistocephalus guildingii*), Sri Lanka (*Chondromorpha kelaarti*), Barbados (*Anadenobolus monilicornis*), Saint Vincent Island (*A. vincenti*).

The distribution of the alien diplopods in Europe shows that all the species living here in greenhouses are much more widespread compared to e.g. the restricted outdoor species *Eurygyrus ochraceus*. It is also likely that the obligate thelytokous parthenogenesis (= sexual reproduction giving rise to females only) shown in continental Europe by several of the exotic millipedes and at least one of the centipedes has facilitated their survival during transport and their establishment on the continent. However, bisexual populations are known from the Azores and the Canary Islands for *Lamyctes emarginatus* (Enghoff 1975a). Species from other centipede orders, such as the mecistocephalid *Tygarrup javanicus* also presumably reproduce by parthenogenesis since so far only females have been found in the hothouse at the Eden project, in Great Britain (Barber 2009b).

The number of exotic diplopods in Europe is far smaller (3–4 times) than that of European species introduced to other continents. Apparently, this could mean that the arrival and, especially, becoming resident in Europe is much more difficult than the converse process. The asymmetry has probably nothing to do with quarantine controls at European borders. Instead, it may be due to specific ecological and biological patterns exhibited by the successful invaders. Many of the alien millipedes and centipedes which have successfully invaded Europe be-

Figure 7.2.4. *Scolopendra gigantea* Linnaeus, 1758 [Chilopoda: Scolopendromorpha: Scolopendridae] caught in 2005 in apartment in London, perhaps arrived with a cargo of electric goods or fruit. Source: BBC News: http://news.bbc.co.uk/go/em/fr/-/1/hi/england/london/4201634.stm

Figure 7.2.5. *Tygarrup javanicus* Attems, 1929 [Chilopoda: Geophilomorpha: Mecistocephalidae]. United Kingdom: Eden Project, Cornwall. Credit: Anthony Barber.

long to genera moderately rich to rich in species, such as *Poratia, Chondrodesmus, Lamyctes, Cryptops*, etc. A pertinent question arises as to why often only one species succeeds in establishing populations on foreign continents, sometimes becoming quite widespread to even cosmopolitan, whereas its rather numerous congeners fail to do so. Specific adaptive ecological patterns may be an issue, but, as noticed

Figure 7.2.6. *Rhinotus purpureus* (Pocock, 1894) [Diplopoda: Polyzoniida: Siphonotidae]. Japan: Minami-Daito. Credit: Zoltán Korsós.

Figure 7.2.7. *Eurygyrus ochraceus* C.L. Koch, 1847 [Diplopoda: Callipodida: Schizopetalidae]. Ukraine: Crimea. Credit: Kiril Makarov.

above, obligate or opportunist parthenogenesis is probably a major trait favoring dispersal at least because a single founder juvenile or female is sufficient to arrive at destination and found a population. It has to be noted that the successful myriapod invaders tend to be among the smallest species, thus being more easily transported, better fitted to find a suitable microhabitat, and sometimes requiring a shorter time and even a smaller number of developmental stages to reach maturity (Golovatch 2009).

Figure 7.2.8. *Chondrodesmus* cf. *riparius* Carl, 1914 [Diplopoda: Polydesmida: Chelodesmidae]. Denmark: Copenhagen. Credit: Gert Brovad.

Figure 7.2.9. *Oxidus gracilis* (C.L. Koch, 1847) [Diplopoda: Polydesmida: Paradoxosomatidae]. Italy: Porto Badino (Borgo Hermada – Terracina). Credit: Massimiliano Di Giovanni.

Figure 7.2.10. *Paraspirobolus lucifugus* (Gervais, 1836) [Diplopoda: Spirobolida: Spirobolellidae]. Japan: Okinawa. Credit: Zoltán Korsós.

Another possible pathway of the introduction of exotic myriapods to Europe is their intentional import as 'pets', and their further escape from pet keepers. Large *Scolopendra* spp., as well as some large and colorful millipedes of the orders Spirobolida, Spirostreptida and Sphaerotheriida are quite popular pet animals subjected to trade in pet shops. Although there are many guides and internet resources available for keeping and caring for exotic species, there is no reliable information about the importance of the 'pet' trade for the introduction of alien myriapods to Europe. However, the establishment of pet myriapods in the wild is in most cases very unlikely.

7.2.6. The most invaded ecosystems and habitats

Man-made artificial environments (pastures and cultivated lands, greenhouses, urban and suburban areas) constitute the main habitat types hosting alien myriapods (Table 7.2.1). Species of tropical and subtropical origin are likely to be restricted to greenhouses or equivalent artificially warmed habitats. Some of them, in the summer season in the southern countries perhaps could survive also outdoors in close proximity to the hothouses. However, 11 species have been reported from natural habitats in Europe, where they most likely were able to establish viable populations. So far the alien species of symphylans and pauropods are unknown in natural areas, which is not the case with several species of the other two myriapod classes. The millipede *Oxidus gracilis*, which is bisexual everywhere and is naturalized in several areas in Europe and in the Caucasus, has been found in forests close to suburban and urban areas (Tömösváry 1879), in woodlands of *Robinia pseudoacacia* in the Kanev Nature Reserve, Ukraine

Figure 7.2.11. *Trigoniulus corallinus* (Gervais, 1847) [Diplopoda: Spirobolida: Trigoniulidae]. Taiwan. Credit: Zoltán Korsós.

(Chornyi and Golovatch 1993) and records from caves also exist (Strasser 1974, Vicente and Enghoff 1999). On the Canary Islands the species is quite widespread invading various, mostly dry and warm, habitats (Arndt et al. 2008). According to Palmén (1949), *O. gracilis* dies when subjected for 2 hours to a temperature of minus 4°C. This means that in North Europe the species can survive only in hothouse conditions. *Cylindroiulus truncorum* mainly inhabits synanthropic habitats: greenhouses, gardens, parks, woodpiles, school grounds, cemeteries, spoil heaps, horticultural nurseries (Kime 2004, Korsós and Enghoff 1990).

Eurygyrus ochraceus occurs in the Crimea only in a patch of semi-natural xerophytic vegetation ca. 1 km long and 100–300 m wide along a watershed. It was reported to be rather common, although not too abundant on the site and is definitely an anthropochore (Golovatch 2008).

Lamyctes emarginatus shows remarkable plasticity regarding the surrounding environment, although in the British Isles there is preponderance of rural records in comparison with (sub)urban ones. In artificial habitats it has been reported from gardens, roads, roadside verges, hedges, embankments, crops of *Zea mays* and *Medicago sativa*, even in human rubbish (Eason 1964, Minelli and Iovane 1987, Barber and Keay 1988). In natural habitats it lives in various woods (deciduous or mixed coniferous/deciduous) and has also been recorded from open and coastal areas (Barber and Keay 1988, Zerm 1997, Zapparoli 2006). According to Andersson (2006), it predominates in open and disturbed areas with sparse vegetation. A great many of these localities are associated with lake shores, river gravels or river banks. *L. emarginatus* shows clear preferences for temporarily flooded sites, no matter for how long the inundation lasts. Its appearance as a pioneer species on mine sites may indicate that the species shows preference to disturbed habitats (Zerm 1997). In close proximity to water pools the species abundance can reach 95% of all centipedes (Minoranskii 1977).

Two of the (presumed) alien geophilomorphs, *Arenophilus peregrinus* and *Nothogeophilus turki,* have been recorded in coastal areas, where they occur under stones and in soil close to rocky sea cliffs with sparse vegetation although *A. peregrinus* has been found inland in Cornwall in woodland and one of the Isle of Wight records for *Nothogeophilus turki* was from an area of demolished buildings with copious rubbish on the ground although no more than 5 m from the tidal river (A.N. Keay *pers. comm.).*

Considerable fluctuation in the abundance of some alien species have been observed by Barber (2009b) in the tropical hothouse of the Eden Project. *P. lucifugus* which was not found in 2003/4, was rather restricted in its occurrence in 2005, had become abundant throughout by 2009. Likewise, *C. doriae* which has been relatively uncommon and limited in occurrence in 2005 was the dominant species there in 2009. Conversely, *T. javanicus*, which had been abundant in 2005, was difficult to find in 2009 (Barber 2009b).

7.2.7. Ecological and economic impact

Alien myriapods are unlikely to pose major threats to native biodiversity and ecosystems. The number of species established in the wild being very limited (12 species, *ca* 30%) for the moment (Table 7.2.1). Diplopods are detrivorous animals, consuming 10–15% of the leaf litter in temperate forest and as thus contribute significantly to soil formation processes through the fragmentation of leaves which stimulates microbial activity. They may thus indirectly influence the fluxes of nutrients (Hopkin and Read 1992). Nevertheless, some alien diplopods could be harmful to cultivated plants, especially in the artificial habitats where temperature and humidity conditions allow species establishment and expansion. Invasive soil invertebrates may also have an impact on the structure and function of natural ecosystems. They can change soil carbon, nitrogen and phosphorus pools and can considerably affect the distribution and function of roots and micro-organisms (Arndt and Perner 2008). In addition, mass occurrences and swarming, which have been observed in several countries in Europe, may have negative ecological and economic impact although the causes still remain obscure (Sahli 1996, Voigtländer 2005). An example of a plant-damaging alien myriapod is *Oxidus gracilis*, which is regarded as a pest in several European countries. This species is very common in greenhouses where its density may exceed 2500 ind./m^2. It is known for attacking vegetable and fruit crops such as sugar beet, potatoes, strawberries, cucumbers, orchard fruits, roots of wheat, and flowers in outdoor cultivated areas. Furthermore, several thousand *O. gracilis* were once found after rain in a house in Lenoir City, Tennessee, USA, with most of the city infested during the same outbreak (Hopkin and Read 1992). As a curiosity, one might also mention the report by the classical writer Theophrastus, according to whom an army of millipedes once overran Rhoeteum in the present province of Çanakkale (northwestern Turkey) and drove its human inhabitants into the sea (Sharples 1994, Enghoff and Kebapći 2008).

Several plants can withstand the attacks of symphylans but they may cause severe damage to growing crops both in fields and greenhouses (Scheller 2002). Arndt and Perner (2008) recently carried out a study on the impact of invasive ground-dwelling predatory species, including alien centipedes, in the native laurel forest habitat in the Canary Islands. They found that centipedes in laurel forests seem to be much more variable than carnivorous ground beetles since the 14 recorded species include representatives of three orders with very different characters. They tentatively recognised four functional groups of centipedes: a micro-cephalic schendylid type, (ii) a geophilid type with medium head size and extreme body length, (iii) a scolopendromorph type, and (iv) a macro-cephalic lithobiomorph type. These groups suggest patterns of invasion similar to the coleopteran predators: autochthonous and introduced species of the same size class and group are mutually exclusive (Arndt 2006).

The potential role of tropical giant millipedes and centipedes (*Scolopendra* spp.) kept as pets has been little analyzed as a source of health problems in relation to their defensive fluids or their bites which can cause pathological reactions if exposed to skin, mouth/throat or eyes (Rein 2002).

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References

Adis J, Harvey M (2000) How many Arachnida and Myriapoda are there world-wide and in Amazonia? *Studies on Neotropical Fauna and Environment* 35 (2): 139–141.

Adis J, Golovatch S, Wilck L, Hansen B (2000) On the identities of *Muyudesmus obliteratus* Kraus, 1960 versus *Poratia digitata* (Porat, 1889) with first biological obstervations on parthenogenetic and bisexual populations (Diplopoda: Polydesmida: Pyrgodesmidae). In: Wytwer J, Golovatch SI (Eds) *Progress in Studies on Myriapoda and Onychophora. Fragmenta Faunistica* Warszawa 43 (Supplement): 149–170 (for 1999).

Akkari N, Stoev P, Lewis JGE (2008) The scolopendromorph centipedes (Chilopoda, Scolopendromorpha) of Tunisia: taxonomy, distribution and habitats. *ZooKeys* 3: doi: 10.3897/zookeys.3.51

Akkari N, Stoev P, Enghoff H, Nouira S (2009) The millipede order Julida (Myriapoda: Diplopoda) in Tunisia, with an overview of the North African species. *Soil Organisms* 81 (3): 453–488.

Andersson G (1984) Post-embryonic development of *Lamyctes fulvicornis* Meinert. *Entomologica Scandinavica* 15: 9–14.

Andersson G (2006) Habitat preferences and seasonal distribution of developmental stadia in *Lamyctes emarginatus* (Newport, 1844) (*L. fulvicornis* Meinert, 1868) and comparison with some *Lithobius* species (Chilopoda, Lithobiomorpha). *Norwegian Journal of Entomology* 53 (2): 311–320.

Andersson G, Enghoff H (2007) Nyinförd mångfoting – palmbladfoting *Chondrodesmus* cf. *riparius*. *Fauna och Flora* 102 (4): 2–5.

Andersson G, Meidell B, Scheller U, Winqvist J-Å, Osterkamp-Madsen M, Djursvoll P, Budd G, Gårdenfors U (2005) Nationalnyckeln till Sveriges flora och fauna. Månfotingar. Myriapoda. Uppsala: Art Databanken, SLU. 351 pp.

Arndt E (2006) Niche occupation by invasive ground-dwelling predator species in Canarian laurel forests. *Biological Invasions* 8: 893–902.

Arndt E, Perner J (2008) Invasion patterns of ground-dwelling arthropods in Canarian laurel forests. *Acta Oecologica* 34: 202–213.

Arndt E, Enghoff H, Spelda J (2008) Millipedes (Diplopoda) of the Canarian Islands: Checklist and key. *Biological Invasions* 8: 893–902.

Attems C (1935) Myriopoden von Epirus. *Zoologischer Anzeiger* 110 (5–6): 141–153.

Baéz M, Oromí P (2004) Symphyla, Pauropoda. In: Izquierdo I, Martín JL, Zurita N, Arechavaleta M (Eds) Lista de especies silvestres de Canarias (hongos, plantas y animales terrestres). Consejeria de Medio Ambiente y Ordenación Territorial, Gobierno de Canarias, p. 177.

Barber AD (1995) *Lithobius lucifugus* L. Koch (Chilopoda, Lithobiomorpha), a centipede new to the British Isles from Scotland. *Bulletin of the British Myriapod Group* 11: 63–65.

Barber AD (2008) Key to the identification of British centipedes. Shrewsbury: FSC Publications. 96 pp.

Barber AD (2009a) Centipedes. *Synopses of the British Fauna (New Series)*. Shrewsbury: Field Studies Council, FSC Publications. 228 pp.

Barber T (2009b) Centipedes, millipedes and woodlice in the Eden project. *Bulletin of the Peninsular Invertebrate Forum* 19: 1–4.

Barber AD, Eason EH (1986) A redescription of *Lithobius peregrinus* Latzel, new record, a centipede new to Britain (UK) (Chilopoda Lithobiomorpha). *Journal of Natural History* 20: 431–438.

Barber T, Gregory S, Read H (2010) Field Meeting Reports: Ladock, Cornwall: combined report. *Bulletin of the British Myriapod & Isopod Group* 24: 65–74.

Barber AD, Keay AN (1988) Provisional atlas of the centipedes of the British Isles. Biological Records Centre, Natural Environment Research Council, Institute of Terrestrial Ecology; Monks Wood Experimental Station Huntington. 127 pp.

BBC News: Giant centipede legs it to the UK. http://news.bbc.co.uk/go/em/fr/-/1/hi/england/london/4201634.stm [accessed 31 August 2005].

Bergersen R, Olsen KM, Djursvoll P, Nilssen AC (2006) Centipedes (Chilopoda) and millipedes (Diplopoda) in North Norway. *Norwegian Journal of Entomology* 53: 23–38.

Blower JG (1985) Millipedes. Keys and notes for the identification of the species. *Synopses of the British Fauna* 35: 1–242.

Blower JG, Rundle AJ (1980) *Prosopodesmus panporus*, an interesting new species of polydesmoid millipede from the Royal Botanic Gardens, Kew, England. *Myriapodologica* 1 (4): 27–34.

Blower JG, Rundle AJ (1986) *Poratia digitata*, a new British hothouse millipede. *Bulletin of the British Myriapod Group* 3: 11–16.

Bocher J, Enghoff H (1984) A centipede in Groenland: *Lamyctes fulvicornis* Meinert, 1868 (Chilopoda, Lithobiomorpha, Henicopidae). *Entomologiske Meddelelser* 52: 49–50.

Bonato L, Capul-Magaña F, Minelli A (2009) *Mecistocephalus guildingii* Newport, 1843, a tropical centipede with amphi-Atlantic distribution (Chilopoda: Geophilomorpha). *Zootaxa* 2271: 27–42.

Borges PAV (2008a) Symphyla, Pauropoda. In: Borges PAV, Cunha R, Gabriel R, Martins AF, Silva L, Vieira V (Eds) A list of the terrestrial fauna (Mollusca and Arthropoda) and flora (Bryophyta, Pteridophyta and Spermatophyta) from the Azores. Direcção Regional do Ambiente and Universidade dos Açores, Horta, Hangra do Heroísmo an Ponta Delgada, p. 183.

Borges PAV (2008b) Symphyla, Pauropoda. In: Borges PAV, Abreu C, Aguiar AMF, Carvalho P, Jardim R, Melo I, Oliveira P, Sérgio C, Serrano ARM, Vieira P (Eds) A list of the terrestrial fungi, flora and fauna of Madeira and Selvagens Archipelagos. Direcçao Regional do Ambiente da Madeira and Universidade dos Açores, Funchal and Anga do Heroísmo, pp. 288–289.

Borges PAV, Enghoff H (2005) Chilopoda. In: Borges PAV, Cunha R, Gabriel R, Martins AF, Silva L, Vieira V (Eds) A list of the terrestrial fauna (Mollusca and Arthropoda) and flora (Bryophyta, Pteridophyta and Spermatophyta) from the Azores. Direcção Regional do Ambiente and Universidade dos Açores, Horta, Hangra do Heroísmo an Ponta Delgada, p. 184.

Brölemann H (1889) Contributions à la faune myriapodologique méditerranéenne. *Annales de la Société Linnéenne de Lyon* 35: 273–285.

Brolemann HW (1930) Eléments d'une faune des myriapodes de France. Chilopodes. *Faune de France* 25. Toulouse: Imprimerie Toulousaine; Paris: P. Lechevalier. 405 pp.

Carl J (1914) Die Diplopoden von Columbien nebst Beiträgen zur Morphologie der Stemmatoiuliden. *Mémoires de la Société neuchâteloise des Sciences naturelles* 5: 821–993.

Ceuca T (1974) Noi contributii la cunoaşterea diplopodelor din fauna României. *Studia Universitatis Babeş-Bolyai, Seria Biologia* 19: 91–97.

Chornyi NG, Golovatch SI (1993) Dvuparnonogie mnogonozhky ravninnych territorij Ukrainy. [Millipedes (Diplopoda) of the plain areas of the Ukraine]. Kiev: Kiev University. 56 pp.

Christian E (1996) Die Erdlaufer (Chilopoda: Geophilida) des Wiener Stadtgebietes. *Verhandlungen der Zoologisch-Botanischen Gesellschaft in Österreich* 133: 107–132.

Christian E, Szeptycki A (2004) Tausendfüβer und Bodeninsekten aus dem Botanischen Gartens der Universität Wien. In: Pernstich A, Krenn HW (Eds) Die Tierwelt des Botanischen

Gartens der Universität Wien. Wien: Eigenverlag Institut für Angewandte Biologie und Umweltbildung, 53–64.

Clarke WJ (1938) Dispersal species by commerce. (*S. subspinipes*). *Naturalist*, London, p. 136.

Condé B (1961) Diplopodes Pénicillates des Açores et de Madère. *Boletim do Museu Municipal do Funchal* 14 (43): 7–10.

DAISIE (2009) Introduction to the List of Alien Taxa. In: Handbook of Alien Species in Europe, DAISIE, Springer Science + Business Media B.V., 133–263.

Eason EH (1964) Centipedes of the British Isles. New York: Frederick Warne. 294 pp.

Eason EH (1970) The Chilopoda and Diplopoda of Iceland. *Entomologica Scandinavica* 1: 47–54.

Eason EH, Enghoff H (1992) The lithobiomorph centipedes of the Canary Islands (Chilopoda). *Entomologica Scandinavica* 23 (1): 1–9.

Edgecombe G (2003) A new species of the Gondwanan centipede *Anopsobius* (Chilopoda: Lithobiomorpha) from New South Wales, Australia. *Zootaxa* 204: 1–15.

Edgecombe G, Giribet G (2007) Evolutionary biology of centipedes (Myriapoda: Chilopoda). *Annual Review of Entomology* 52: doi:10.1146/annurev.ento.52.110405.091326.

Enghoff H (1975a) Notes on *Lamyctes coeculus* (Brölemann), a cosmopolitic, parthenogenetic centipede (Chilopoda: Henicopidae). *Entomologia Scandinavica* 6: 45–46.

Enghoff H (1975b) *Paraspirobolus dictyonotus* (Latzel, 1895) et vaeksthustusindben nyt for Danmark (Diplopoda, Spirobolida, Spirobolellidae). *Entomologiske Meddelester* 43: 17–20.

Enghoff H (1978) *Cylindrodesmus laniger* Schubart, a widespread, probably parthenogenetic millipede (Diplopoda, Polydesmida: Haplodesmidae). *Entomologia Scandinavica* 9: 80.

Enghoff H (1987) *Amphitomeus attemsi* (Schubart, 1934) endnu et væksthustusindben nyt for Danmark (Diplopoda, Polydesmida, Oniscodesmidae). *Entomologiske Meddelester* 54: 147–148.

Enghoff H (2001) *Benoitolus flavicollis* Mauries, 1980, another tropical tramp millipede, and notes on *Pseudospirobolellus avernus* (Butler, 1876) (Diplopoda, Spirobolida, Pseudospirobolellidae). *Entomologist's Monthly Magazine* 137 (1644–1647): 167–170.

Enghoff H (2008a) A large Neotropical millipede in European flower pots. *Bulletin of the British Myriapod and Isopod Group* 23: 38–39.

Enghoff H (2008b) Chilopoda, Diplopoda. In: Borges PAV, Abreu C, Aguiar AMF, Carvalho P, Jardim R, Melo I, Oliveira P, Sérgio C, Serrano ARM, Vieira P (Eds) A list of the terrestrial fungi, flora and fauna of Madeira and Selvagens Archipelagos. Direcçao Regional do Ambiente da Madeira and Universidade dos Açores, Funchal and Anga do Heroísmo, pp. 289–291.

Enghoff H (2009) Myriapoda. In: Fauna Europaea. http://www.faunaeur.org/statistics.php [accessed January 2010].

Enghoff H, Borges PAV (2005) Diplopoda. In: Borges PAV, Cunha R, Gabriel R, Martins AF, Silva L, Vieira V (Eds) A list of the terrestrial fauna (Mollusca and Arthropoda) and flora (Bryophyta, Pteridophyta and Spermatophyta) from the Azores. Direcção Regional do Ambiente and Universidade dos Açores, Horta, Hangra do Heroísmo an Ponta Delgada, p. 184.

Enghoff H, Kebapći Ü (2008) *Calyptophyllum longiventre* (Verhoeff, 1941) invading houses in Turkey, with the first description of the male (Diplopoda: Julida: Julidae). *Journal of Natural History* 42: 2143–2150.

Enghoff H, Golovatch S, Nguyen Duc A (2004) A review of the millipede fauna of Vietnam (Diplopoda). *Arthropoda Selecta* 13 (1–2): 29–43.

Evans W (1900) Scottish Myriapoda. *The annals of Scottish natural history* 1900: 127.

Farzalieva G, Zalesskaja N, Edgecombe G (2004) A new genus and species of lithobiomorph centipede (Chilopoda: Lithobiomorpha: Anopsobiidae) from eastern Kazakhstan. *Arthropoda Selecta* 13 (4): 219–224.

Gervais P (1836) Sur l'Iulus lucifugus. *Annales de la Société entomologique de France*, Sér. 1, 5: 56–57.

Gervais P (1837) Études pour servir à l'histoire naturelle des Myriapodes. *Annales des Sciences naturelles, Zoologie* (2e série), 7: 35–60, Pl. IV.

Gibson-Carmichael TD (1883) *Scutigera coleoptrata* near Aberdeen. *Entomological Monthly Magazine* 20: 88.

Golovatch SI (2008) On three remarkable millipedes (Diplopoda) from the Crimea, Ukraine. *International Journal of Myriapodology* 1: doi: 10.1163/187525408X316767.

Golovatch SI (2009) Millipedes (Diplopoda) in extreme environments. In: *Species and Communities in Extreme Environments. Festschrift towards the 75th Anniversary and a Laudatio in Honour of Academician Yuri Ivanovich Chernov*. Sofia-Moscow: Pensoft & KMK Sci. Press, 87–112.

Golovatch SI, Sierwald P (2001) Review of the millipede genus *Poratia* Cook & Cook, 1894 (Diplopoda: Polydesmida: Pyrgodesmidae). *Arthropoda Selecta* 9 (3): 181–192.

Golovatch S, Stoev P (2010) New or poorly-known millipedes (Diplopoda) from Papua New Guinea, 1. *Arthropoda Selecta* 18 (3–4): 125–130. (for 2009)

Golovatch SI, Knapinski S, Adis J (2002) On the identity of the European hothouse millipede *Amphitomeus attemsi* (Schubart, 1934), with first biological observations of this parthenogenetic species (Diplopoda: Polydesmida: Oniscodesmidae). *Arthropoda Selecta* 10 (2): 137–146.

Golovatch SI, Hoffman R, Knapinski S, Adis J (2001) Review of the millipede genus *Cylindrodesmus* Pocock, 1889 (Diplopoda: Polydesmida: Haplodesmidae). *Fragmenta faunistica* 44: 179–201.

Golovatch SI, Gruber J, Adis J, Knapinski S, Zerm M, Hansen B (2000) Parthenogenetic populations of the millipede *Cylindrodesmus laniger* Schubart, 1945 to be recorded in Europe for the first time (Diplopoda: Polydesmida, Haplodesmidae). *Arthropoda Selecta* 9 (3): 193–198.

Golovatch SI, Geoffroy J-J, Mauriès J-P, Van den Spiegel D (2009) Review of the millipede family Haplodesmidae, with descriptions of some new or poorly-known species (Diplopoda, Polydesmida). In: Golovatch SI, Mesibov R (Eds) *Advances in the Systematics of Diplopoda* I. *ZooKeys* 7: doi:10.3897/zookeys.7.117.

Gregory SJ, Jones RE (1999) *Arenophilus peregrinus* Jones, 1989 in Cornwall: a centipede new to mainland Britain. *Bulletin of the British Myriapod and Isopod Group* 15: 28–29.

Gruber J (2002) Tausendfüßer: Doppelfüßer (Myriapoda: Diplopoda). In: Neobiota in Österreich – Tiere. Wien: Umweltbundesamt GmbH, 296–301.

Gruber J, Christian E (2002) Tausendfüßer: Hundertfüßer (Myriapoda: Chilopoda). In: Neobiota in Österreich – Tiere. Wien: Umweltbundesamt GmbH, 292–296.

Hoffman R (1999) Checklist of the Millipeds of North and Middle America. *Virginia Museum of Natural History*. Special Publication 8: 1–584.

Hoffman R, Payne J (1969) Diplopods as carnivors. *Ecology* 50 (6): doi: 10.2307/1936905.

Hollington L, Edgecombe G (2004) Two new species of the henicopid centipede *Henicops* (Chilopoda: Lithobiomorpha) from Queensland and Victoria, with revision of species from Western Australia and a synoptic classification of Henicopidae. *Records of the Australian Museum* 56: 1–28. http://publications.australianmuseum.net.au/record.cfm?ref=1392.

Hopkin S, Read H (1992) The biology of millipedes. Oxford University Press. 233 pp.

Jeekel CAW (1963) Diplopoda of Guiana. *Studies on the Fauna of Suriname and other Guyanas* 11: 1–157.

Jeekel CAW (1977) Voorlopige atlas van de verspreiding der Nederlandse duizendpoten (Chilopoda). *Verslagen en Technische gegevens Instituut voor Taxonomische Zoölogie* 13: 1–55.

Jeekel CAW (2001) *Julus lucifugus* Gervais, 1836, a long overlooked name for a wide-spread synanthrope millipede (Diplopoda, Spirobolida, Spirobolellidae). *Myriapod Memoranda* 3: 39–43.

Jones RE (1989) On a new species of centipede (Chilopoda Geophilomorpha) from the Isles of Scilly. *Journal of Natural History* 23: 627–633.

Kime D (2004) The Belgian millipede fauna (Diplopoda). *Bulletin de l'institut royal des sciences naturelles de Belgique, Entomologie* 74: 35–68.

Kime D, Golovatch S (2000) Trends in the ecological strategies and evolution of millipedes (Diplopoda). *Biological Journal of the Linnean Society* 69: doi: 10.1111/j.1095-8312.2000.tb01209.x.

Kinzelbach R, Geiter O, Homma S (2001) Bestandsaufnahme und Bewertung von Neozoen in Deutschland. Untersuchung der Wirkung von Biologie und Genetik ausgewählter Neozoen auf Ökosysteme und Vergleich mit den potentiellen Effekten gentechnisch veränderter Organismen. Berlin: Umweltbundesamt (Federal Environmental Agency). 52 pp.

Korsós Z, Enghoff H (1990) The *Cylindroiulus truncorum*-group (Diplopoda: Julidae). *Entomologica Scandinavica* 21: 345–360.

Korsós Z, Hornung E, Szlávecz K, Kontschán J (2002) Isopoda and Diplopoda of urban habitats: new data to the fauna of Budapest. *Annales historico-naturales Musei nationalis hungarici* 94: 193–208.

Latzel R (1884) Die Myriapoden der Österreichisch-Ungarischen Monarchie. 2. Bd.: Die Symphylen, Pauropoden und Diplopoden. Wien: Alfred Hölder. 414 pp., 16 Taf., 209 Figure http://www.biologie.uni-ulm.de/cgi-in/query_all/litdetails.pl?sort=taxa&sid=T&thumb=no&lang=d&id=17915&B3=Daten+anzeigen.

Latzel R (1895) Die Myriopoden aus der Umgebung Hamburgs. *Jahrbuch der Hamburgischen Wissenschaftlichen Anstalten*, Beiheft 12: 99–109.

Lee P (2006) Atlas of the Millipedes (Diplopoda) of Britain and Ireland. Sofia-Moscow: Pensoft, Series Faunistica 59. 216 pp.

Lewis JGE (1981) The biology of centipedes. New York: Cambridge University Press. 476 pp.

Lewis JGE (1988) *Scolopendra subspinipes subspinipes* Leach in a cargo of bananas. *Bulletin of the British Myriapod Group*, Miscellanea 5: 36.

Lewis JGE (2007) On *Cryptops doriae* Pocock, from the wet tropical biome of the Eden project, Cornwall (Chilopoda, Scolopendromorpha, Cryptopidae). *Bulletin of the British Myriapod and Isopod Group* 22: 12–16.

Lewis JGE, Rundle AJ (1988) *Tyggarup javanicus* (Attems), a geophilomorph centipede new to the British Isles. *Bulletin of the British Myriapod Group* 5: 3–5.

Lewis JGE, Jones RE, Keay AN (1988) On a new genus and species of centipede (Chilopoda Geophilomorpha Chilenophilidae) from the British Isles. *Journal of Natural History* 22: 1657–1663.

Manfredi P (1930) Di una grossa scolopendra catturata nei dintorni di Milano. *Natura*, Milano 21: 219–220.

Marek P, Bond J (2006) Biodiversity hotspots: Rediscovery of the world's leggiest animal. *Nature* 2006, 441(7094): 707: doi:10.1038/441707a

Meinert F (1868) Danmarks scolopender og lithobier. *Naturistorisk Tidsskrift* (3) 5: 241–268.

Minelli A (1991) I Chilopodi dell'Italia nord-orientale (Trentino-Alto Adige, Veneto, Friuli-Venezia Giulia) (Chilopoda). *Gortania - Atti del Museo Friulano di Storia Naturale* 13: 157–193.

Minelli A (2006) CHILOBASE. A web resource for Chilopoda taxonomy. http://chilobase.bio.unipd.it. [accessed January 2010].

Minelli A, Golovatch SI (2001) Myriapods. In: Levin SA (Ed) Encyclopedia of biodiversity. San Diego: Academic Press 4: doi:10.1016/B0-12-226865-2/00204-2.

Minelli A, Iovane E (1987) Habitat preferences and taxocenoses of Italian centipedes (Chilopoda). *Bollettino del Museo civico di Storia naturale di Venezia* 37: 7–34.

Minoranskii VA (1977) [Some data on (Chilopoda Myriapoda) from the Rostov Oblast]. *Vestnik Zoologii* 4: 38–43.

Negrea S (1989) Sur la présence de *Lamyctes fulvicornis* Meinert, 1868 (Chilopoda Henicopidae) en Roumanie. *Miscellanea Speologica Romanica* 1: 169–174.

Palmén E (1948) The Chilopoda of Eastern Fennoscandia. *Annales zoologici Societatis zoologico-botanicae fennicae Vanamo* 13 (4): 1–45.

Palmén E (1949) The Diplopoda of Eastern Fennoscandia. *Annales zoologici Societatis zoologico-botanicae fennicae Vanamo* 13 (6): 1–53.

Palmén E (1952) Survey of the Diplopoda of Newfoundland. *Annales zoologici Societatis zoologico-botanicae fennicae Vanamo* 15 (1): 1–31.

Pocock RI (1902) Myriapoda. *The Victoria History of the County of Surrey* 1: 176–178. http://www.archive.org/stream/historyofsurrey01malduoft#page/176/mode/2up.

Pocock RI (1906) Antennata: Myriapoda. In: The wild fauna and flora of the Royal Botanic Gardens, Kew. Royal Botanic Gardens, Kew. *Bulletin of Miscellaneous Information*, Additional Series 5: 21–22.

Read H (2008) Records of millipedes from Kew Gardens and the Eden project, including descriptions of three species. *Bulletin of the British Myriapod and Isopod Group* 23: 27–35.

Rein JO (2002) Exotic invertebrates as pets in Norway – a health problem? *Tidsskrift for den Norske Legeforening* 30, 122: 2896–2901 [in Norwegian].

Roques A, Rabitsch W, Rasplus J-Y, Lopez-Vaamonde C, Nentwig W, Kenis M (2009). Alien terrestrial invertebrates of Europe. In: Handbook of Alien Species in Europe, DAISIE, Springer Science + Business Media B.V., 63–79.

Sahli F (1996) Déplacements en masse dans le sud-est de la France chez *Ommatoiulus sabulosus* (Myriapoda, Diplopoda, Julidae) avec invasions d'habitations. In: *Acta Myriapodologica. Mémoires du Muséum National d'Histoire Naturelle* 169: 587–598.

Scheller U (2002) A new species of *Hanseniella* Bagnal (Myriapoda, Symphyla) found in hothouse. *Mitteilungen aus dem Museum für Naturkunde in Berlin*, *Zoologische Reihe* 78 (2): 269–273.

Schubart O (1925) Die Diplopodenfauna Schleswig-Holsteins. *Zoologische Jahrbücher, Abteilung für Systematik, Ökologie und Geographie der Tiere* 49: 537–610.

Schubart O (1934) Tausendfüßler oder Myriapoda. I: Diplopoda. *Die Tierwelt Deutschlands und der angrenzenden Meeresteile* 28: 1–318.

Šefrová H, Laštůvka Z (2005) Catalogue of alien animal species in the Czech Republic. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis* 53, 4: 151–170.

Sharples RW (1994) Theophrastus of Eresus. Sources for his life, writings, thought and influence. Vol. 5. *Sources on Biology*. Leiden (Netherlands): Brill. 273 pp.

Shear W, Peck S (1992) Centipeds (Chilopoda) and Symphyla of the Galápagos Islands, Ecuador. *Canadian Journal of Zoology* 70 (11): 2260–2274.

Shelley RM (1998) Occurrence of the milliped *Glyphiulus granulatus* (Gervais) in the Hawaiian Islands (Spirostreptida: Cambalidea: Cambalopsidae). Bishop Museum Occasional Papers 56: 36–37.

Shelley RM, Lehtinen PT (1999) Diagnoses, synonymies and occurrences of the pantropical millipeds, *Leptogoniulus sorornus* (Butler) and *Trigoniulus corallinus* (Gervais) (Spirobolida: Pachybolidae: Trigoniulinae). *Journal of Natural History* 33: doi: 10.1080/002229399299932

Silvestri F (1933) Nuovi contributi alla conoscenza della fauna delle isole italiane dell'Egeo. I. Descrizione di un nuovo genere di chilopodo henicopino. *Bollettino del Laboratorio di Zoologia Generale e Agraria della Regia Scuola Superiore d'agricoltura*, Portici 27: 57–60.

Stoev P (2004) Myriapoda (Chilopoda, Diplopoda) in Urban Environments in the City of Sofia. In: Penev L, Niemelä J, Kotze DJ, Chipev N (Eds) *Ecology of the City of Sofia. Species and communities in an Urban Environment*. Sofia-Moscow: Pensoft Publishers, 299–306.

Stoev P (2007) Myriapoda of Bulgaria. In: Fet V, Popov A (Eds) *Monographiae Biologicae. Biogeography and Ecology of Bulgaria*. Dodrecht: Springer Publishers, 379–403.

Strasser C (1974) I diplopodi chilognati della Sardegna. *Fragmenta Entomologica* 10: 231–293.

Tabacaru I, Giurginca A, Vanoaica L (2003) Cavernicolous Diplopoda of Romania. *Travaux de l'Institut de Spéologie "Emile Racovitza"* 41–42: 121–148.

Tömösváry Ö (1879) Néhány hazánkban előforduló Myriopodáról. *Orvos- Természettudományi Értesitő*, Kolozsvár 3: 22–25.

Verhoeff KW (1926) Über einige von Dr. I. Buresch in Bulgarien gesammelte Diplopoden. 2. Aufsatz. *Bulletin de la Société Entomologique de Bulgarie* 3: 193–210.

Verhoeff KW (1933) Symphyla (Bronn's Klassen und Ordungen Tierreiches 5(2), 3, 1). Leipzig: de Gruyter, 1–120.

Verhoeff KW (1934) Pauropoda (Bronn's Klassen und Ordungen des Tierreiches 5(2), 3, 2). Leipzig: de Gruyter, 121–200.

Vicente M, Enghoff H (1999) The millipedes of the Canary Islands. *Vieraea* 27: 183–204.

Voigtländer K (2005) Mass occurrences and swarming behaviour of millipedes (Diplopoda: Julida) in Eastern Germany. *Peckiana* 4: 181–188.

Wittenberg R (Ed) (2005) *An inventory of alien species and their threat to biodiversity and economy in Switzerland*. CABI Bioscience Switzerland Centre report to the Swiss Agency for Environment, Forests and Landscape. 417 pp.

Zapparoli M (1989) I Chilopodi delle Alpi sud-orientali. *Biogeographia, Lavori della Società Italiana di Biogeografia, N.S.* 12 (1987): 553–585.

Zapparoli M (1999) The present knowledge of the centipede fauna of Anatolia (Chilopoda). *Biogeographia, Lavori della Società Italiana di Biogeografia*, N. S. 20: 105–177.

Zapparoli M (2002) A catalogue of the centipedes of Greece (Chilopoda). *Fragmenta Entomologica* 34: 1–146.

Zapparoli M (2006) A catalogue of the centipedes (Chilopoda) of Central Apennines (Italy). *Bollettino del Museo civico di Storia naturale di Verona*, Botanica, Zoologia 30: 165–273.

Zapparoli M, Oromi P (2004) Chilopoda. In: Izquierdo I, Martin JL, Zurita N, Archavaleta M (Eds) *Lista de especies silvestres de Canarias (hongos, plantas y animales terrestres)*. Consejeria de Politica Territorial y Medio Ambiente Gobierno de Canarias, 179–180.

Zapparoli M, Minelli A (1993) Tassonomia, corologia, ecologia delle specie del genere *Pleurolithobius* Verhoeff, 1909 (Chilopoda, Lithobiomorpha). *Bollettino del Museo Regionale di Scienze Naturali di Torino* 11: 331–345.

Zapparoli M, Minelli A (2005) Chilopoda. In: Ruffo S, Stoch F (Eds) Checklist and distribution of the Italian fauna. *Memorie del Museo Civico di Storia naturale di Verona* 2. Serie, sezione Scienze della Vita 17: 123–125, with data on CD-ROM.

Zerm M (1997) Distribution and phenology of *Lamyctes fulvicornis* and other lithobiomorph centipedes in the floodplain of the Lower Oder Valley, Germany (Chilopoda, Henicopidae: Lithobiidae). *Entomologica Scandinavica*, Supplement 51: 125–132.

Table 7.2.1. List and main characteristics of the myriapod species alien to Europe. Status: **A** Alien to Europe **C** cryptogenic species. Country codes abbreviations refer to ISO 3166 (see Appendix I). Habitat abbreviations refer to EUNIS (see Appendix II). Only selected references are given. Last update 10/03/2010.

Class *Order*	**Family**	**Species**	**Status**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**References**
Pauropoda								
Tetramerocerata								
	Pauropodidae	*Allopauropus pseudomillotianus* Remy & Balland, 1958	A	Southeast Asia (India, Sri Lanka)	1958, FR	FR, NO	J100	Andersson et al. (2005)
Symphyla								
Symphylomorpha								
	Scutigerellidae	*Hanseniella caldaria* (Hansen, 1903)	A	Tropical, subtropical (North America up to Mexico, South America, sub-Saharan Africa, Sri Lanka, Galapagos Islands, and possibly New Zealand)	1903, DK	DK, FR, GB, MC, NO	J100	Andersson et al. (2005), Scheller (2002), Shear and Peck (1992)
		Hanseniella oligomacrochaeta Scheller, 2002	C	Unknown. Tropical, subtropical?	2000, DE	DE	J100	Scheller (2002)
		Hanseniella orientalis (Hansen, 1903)	A	Tropical, subtropical (South and southeastern Asia, Central and South America, islands in the Pacific)	2000, DE	DE	J100	Scheller (2002)
Chilopoda								
Geophilomorpha								
	Mecistocephalidae	*Mecistocephalus guildingii* Newport, 1843	A	Amphi-Atlantic (coasts of Tropical America, African coast from Gambia to Liberia, Atlantic islands)	1895, DE	DE, FR, GB, PT-MAD	J100	Bonato et al. (2009), Pocock (1906)
		Mecistocephalus maxillaris (Gervais, 1837)	C	Unknown, tropical?	1837, FR	DK, FR, NL	J100	Andersson et al. (2005), Bonato et al. (2009), Jeekel (1977)
		Tygarrup javanicus Atems, 1929	A	Southeast Asia (Java, Vietnam, Cambodia), The Seychelles	1975, GB	AT, GB	J100	Barber (2009b), Christian (1996), Lewis and Rundle (1988)

Class *Order*	Family	Species	Status	Native range	1st record in Europe	Invaded countries	Habitat	References
	Geophilidae	*Arenophilus peregrinus* Jones, 1989	C	Unknown, genus present in North America	1986, GB	GB	B3, I2	Barber (2009a), Gregory and Jones (1999), Jones (1989)
		Nothogeophilus turki Lewis, Jones & Keay, 1988	C	Unknown	1985, GB	GB	B3	Barber (2009a), Lewis et al. (1988)
	Oryidae	*Orphnaeus brevilabiatus* (Newport, 1845)	A	Tropical, subtropical (Australia, Central and South America, Sub-Saharan Africa, Madagascar, East Asia, Arabian Peninsula, Hawaii)	19th century, SE	SE	Unknown, J100?	Andersson et al. (2005)
	Schendylidae	*Nyctunguis persimilis* Attems, 1932	C	Unknown. Genus present in North America	1996, AT	AT	I2?	Christian (1996), Christian and Szeptycki (2004), Gruber and Christian (2002)
Chilopoda								
Scolopendromorpha								
	Cryptopidae	*Cryptops doriae* Pocock, 1891	A	Southeast Asia, Papua New Guinea, The Seychelles	2007, GB	GB	J100	Barber (2009a), Lewis (2007)
	Scolopendridae	*Scolopendra gigantea* Linnaeus, 1758	A	Central and South America	2005, GB	GB	J1	BBC News (2005)
		Scolopendra morsitans Linnaeus, 1758	A	Tropical, subtropical. North and South America, Atlantic Ocean Islands, Europe, Africa, Arabian Peninsula, Southeast Asia, Indian Ocean Islands, Australia, New Zealand, Pacific Islands	1902, GB	GB	J100	Akkari et al. (2008), Pocock (1906)
		Scolopendra subspinipes Leach, 1815	A	East and South Asia	1902, GB	GB	J100	Minelli (2006), Pocock (1906)

Class *Order*	Family	Species	Status	Native range	1st record in Europe	Invaded countries	Habitat	References
Chilopoda								
Lithobiomorpha								
	Henicopidae	*Ghilaroviella* cf. *valiachmedovi* Zalesskaja, 1975	A	Unknown. *G. valiachmedovi* occurs in Central Asia (Tajikistan)	2004, AT	AT	I2	Christian and Szeptycki (2004)
		Lamyctes (*Metalamyctes*) *albipes* (Pocock, 1895)	C	Southeast Asia (Java), Sakhalin Island, Guadeloupe, The Seychelles	1988, ES-CAN	ES-CAN	H3, H5	Eason and Enghoff (1992), Hollington and Edgecombe (2004)
		Lamyctes (*Lamyctes*) *coeculus* (Brölemann, 1889)	A	Tropical, subtropical. Known from Australia, Central and South America, Sub-Saharan Africa, Madagascar	1889, IT	DK, ES-CAN, FI, FR, GB, IT, SE	J100, J	Barber (2009a), Enghoff (1975a), Zapparoli and Minelli (2005)
		Lamyctes (*Lamyctes*) *emarginatus* (Newport, 1844)	A	Australasia (Australia+ New Zealand) is the possible areas of origin. Known also from North and South America, Africa, Asia Minor, Greenland, Iceland, New Caledonia, islands in the Pacific	1868, DK	AT, BE, BG, CZ, DE, DK, ES-CAN, FI, FR, GB, GL, GR, HU, IT, LU, NL, NO, PL, PT, PT-AZO, PT-MAD, RO, RU, SE, SK, UA	B1, D, E, F4, F9, G1, G3, J1, J2, J3, J4, J5, J6, I, I1, I2, X6, X7, X23	Barber and Keay (1988), Bocher and Enghoff (1984), Meinert (1868), Minelli and Iovane (1987), Negrea (1989), Palmén (1948, 1952), Zapparoli and Minelli (2005)
		Rhodobius lagoi Silvestri, 1933	C	Unknown, possibly tropical, subtropical. Subfamily Anapsobiinae distributed in South America, South Africa, Australia, Japan, Vietnam, Kazakhstan and Tajikistan	1933, GR-SEG	GR-SEG (Rhodes)	I ?	Silvestri (1933), Zapparoli (2002)

Class *Order*	Family	Species	Status	Native range	1st record in Europe	Invaded countries	Habitat	References
Diplopoda								
Polyxenida								
	Polyxenidae	*Polyxenus fasciculatus* Say, 1821	A	Nearctic (USA), Bermuda Islands	1961, PT-MAD	ES-CAN, PT-MAD	G	Attems (1935), Condé (1961), Vicente and Enghoff (1999)
Diplopoda								
Polyzoniida								
	Siphonotidae	*Rhinotus purpureus* (Pocock, 1894)	A	Tropical, subtropical (South and Central America, islands in Indian and Pacific oceans)	1986, GB	GB	J100	Barber (2010), Read (2008)
Diplopoda								
Callipodida								
	Schizopetalidae	*Eurygyrus ochraceus* C.L. Koch, 1847	A	Asia (Turkey)	1925, BG	BG, UA	E1, I2	Golovatch (2008), Stoev (2007), Verhoeff (1926)
Diplopoda								
Polydesmida								
	Chelodesmidae	*Chondrodesmus* cf. *riparius* Carl, 1914	A	South America	2000, SE	DE, DK, NO, SE	J	Andersson and Enghoff (2007), Enghoff (2008a)
	Haplodesmidae	*Cylindrodesmus hirsutus* Pocock, 1889	A	Tropical, subtropical (South America, Southeast Asia, Papua New Guinea, islands in Indian and Pacific oceans)	1950-1985	AT, DE, FR, GB, HU, SK	J100	Golovatch and Stoev (2010), Golovatch et al. (2001), Golovatch et al. (2009), Read (2008)
		Prosopodesmus panporus Blower & Rundle, 1980	A	Unknown, other species in the genus pantropical	1975, GB	GB	J100	Blower and Rundle (1980), Golovatch et al. (2009), Read (2008)

Class *Order*	Family	Species	Status	Native range	1st record in Europe	Invaded countries	Habitat	References
	Oniscodesmidae	*Amphitomeus attemsi* (Schubart, 1934)	A	South America (Venezuela or Colombia)	1930, DE	AT, CH, DE, DK, GB, HU, NL, PL, SK	J100	Barber and Eason (1986), Enghoff (1987), Enghoff (2009), Golovatch et al. (2002), Gruber (2002), Korsós et al. (2002)
	Paradoxosomatidae	*Asiomorpha coarctata* (De Saussure, 1860)	A	Southeast Asia	1906, GB	GB	J100	Pocock (1906)
		Chondromorpha kelaarti (Humbert, 1865)	A	India, Sri Lanka	1902, GB	GB	J100	Pocock (1906)
		Oxidus gracilis (C.L. Koch, 1847)	A	Asia (East or Southeast)	1879, HU	AT, BE, BG, BY, CH, CZ, DE, DK, ES, ES-BAL, ES-CAN, FI, FR, GB, HU, IE, IS, IT, LT, LU, LV, MC, MD, MK, MT, NL, NO, PL, PT-MAD, PT-AZO, RO, RU, SE, SI, SK, UA	J, J100, G	Blower (1985), Enghoff (2009), Enghoff et al. (2004), Evans (1900), Hoffman (1999), Pocock (1902), Read (2008), Šefrová and Laštůvka (2005), Stoev (2004)
	Pyrgodesmidae	*Cynedesmus formicola* (Cook, 1896)	C	Unknown, genus native of Central America	1896, ES-CAN	ES-CAN, HU, PT-MAD	J100	Attems (1935), Korsós et al. (2002), Vicente and Enghoff (1999)
		Poratia digitata (Porat, 1889)	A	Tropical and subtropical (Southern North and Central America)	1889, SE	AT, CH, DE, DK, FR, GB, NL, NO, SE	J100	Blower and Rundle (1986), Golovatch and Sierwald (2001), Gruber (2002), Latzel (1895)

Class *Order*	Family	Species	Status	Native range	1st record in Europe	Invaded countries	Habitat	References
		Poratia obliterata (Kraus, 1960)	A	Tropical (South and Central America: Peru, Colombia, Brazil, Costa Rica)	late 1990s, DE	DE, FR, HU	J100	Adis et al. (2000), Golovatch and Sierwald (2001), Korsós et al. (2002)
	Trichopolydesmidae	*Napocodesmus endogeus* Ceuca, 1974	C	Unknown, only female/s known; the second tentative congener occurs in Romania and Moldova	1969, RO	RO	I2?	Ceuca (1974), Tabacaru et al. (2003)
Diplopoda ***Julida***								
	Julidae	*Cylindroiulus truncorum* (Silvestri, 1896)	A	North Africa (Algeria, Tunisia)	1925, DE	AT, BE, CH, DE, DK, ES-CAN, FI, FR, GB, HU, LT, LU, NL, NO, PL, PT, PT-MAD, RO, SE, UA	J, J100, I2	Enghoff (2009), Kime (2004), Korsós and Enghoff (1990), Read (2008), Schubart (1925)
Diplopoda ***Spirobolida***								
	Pseudospirobolellidae	*Pseudospirobolellus avernus* (Butler, 1876)	A	Tropical (Southeast Asia, islands in Indian and Pacific oceans, and Caribbean Sea)	2009, GB	GB	J100	Barber et al. (2010), Enghoff (2001)
	Rhinocricidae	*Anadenobolus monilicornis* (Porat, 1876)	A	Caribbean region	1906, GB	GB	J100	Hoffman (1999), Pocock (1906)
		Anadenobolus vincenti (Pocock, 1894)	A	Saint Vincent Island, Lesser Antilles	1900, GB	GB	J100	Hoffman (1999), Pocock (1906)
	Spirobolellidae	*Paraspirobolus lucifugus* (Gervais, 1836)	A	Tropical. Area of origin most likely The Seychelles and/or Mauritius	1836, FR	DE, DK, GB, NL	J100	Enghoff (1975b), Jeekel (2001), Latzel (1895), Lee (2006), Read (2008)
	Trigoniulidae	*Trigoniulus corallinus* (Gervais, 1847)	A	Southeast Asia	1902, GB	GB	J100	Pocock (1906), Shelley and Lehtinen (1999)

Table 7.2.2 List of myriapod species intercepted in Great Britain (Barber 2009a, Clarke 1938, John Lewis, *pers. comm.*, Sharon Reid (FERA), *pers. comm.*)

Species	Native Range	Found in/ Country of dispatch/ Year of Interception
Class Chilopoda		
Order Craterostigmomorpha		
Craterostigmus sp.	New Zealand & Tasmania	*Dicksonia* (Australia or New Zealand, 2008)
Order Geophilomorpha		
?*Zelanion* (= *Steneuryton*) sp.	Australia, New Zealand, Hawaii	*Dicksonia* (Australia, 2005)
Order Scolopendromorpha		
Scolopendra cingulata Latreille, 1829	Mediterranean region	With luggage (Spain, 2003), potatoes (Greece, 1975), Turkey (2004), Palestine (pre-1992)
Scolopendra dalmatica C.L. Koch, 1847	Balkan peninsula	Found in fruit & vegetable warehouse on Isle of Wight (1983)
Scolopendra subspinipes subspinipes Leach, 1815	Asia, Africa, C. & S. America	*Trachycarpus wagnerianus* (South Korea, 2006), bananas (Jamaica, 1938)
Order Lithobiomorpha		
Lithobius forficatus (Linneaus, 1758)	Europe	*Dicksonia* (Australia, 2004)
Lithobius peregrinus Latzel, 1880	Europe, Caucasus	*Dicksonia* (New Zealand, 2004)
Class Diplopoda		
Order Polydesmida		
Polydesmida gen. spp.		*Dracaena fragans* (Belgium, 1979)
?*Gasterogramma plomleyi* Mesibov, 2003	Tasmania	*Dicksonia* (Australia, 2004)
?*Mestosoma* sp.		Bromeliad (Ecuador, 1982)
Akamptogonus novarae (Humbert & Saussure, 1869)	? Australia	*Dicksonia* (New Zealand, 2004)
Habrodesmus falx Cook, 1896	West Africa	Tete leaves (Nigeria, 1981)
Habrodesmus sp.		Orchid (Malawi, 1982)
?*Oxidus gracilis*	?East Asia	Zelkova (Netherlands, 1995)
Oxidus gracilis	East Asia	Aroid (USA,1980), *Chaemaerops* (Morocco, 2001), *Cryptomeria* (Japan, 1979), *Dracaena* (Belgium, 1979), *Ficus* (West Africa, 1979), *Hibiscus* (Canary Is.), *Lirope* (USA, 1999), Orchid (Belize, 1980; Madagascar, 1995; Malaysia,1984; India, 2000), Palm (Canary Is., 1998), *Pentas* (Canary Is., 2010), *Phoenix* (USA, 1995), *Rhododendron* (soil, Nepal, 1981), *Sanseviera* (USA, 1980), *Scindapus* (soil, Nepal, 1981), *Selaginella* (Singapore, 1999; Brazil, 1995), *Serissa* (China, 1999, 2004), *Trachycarpus* (Netherlands, 2008), *Washingtonia* (Italy, 2009), Weeping fig (USA, 1984), *Yucca* (?Netherlands, 1980), *Zamia* seed (USA, 1982), *Zelkova* (China, 1995), unknown (Chile, 1998; South Africa, 2001)

Species	Native Range	Found in/ Country of dispatch/ Year of Interception
Polydesmidae		*Dicksonia* (Australia, 2005; New Zealand, 2004), Orchid (Malaysia, 1983), Wild Plant (South Africa, 1983)
Polydesmus sp.		*Miscanthus* (Dominica, 2000), Orchid (Australia, 1985)
Order Spirostreptida		
Spirostreptida		*Cyathea* (New Zealand, 2005), *Dicksonia* (Australia, 2004–2008), *Dracaena* (Rwanda, 1980)
Spirostreptus sp.		Fig (Ivory Coast, 1983)
Plusioglyphiulus sp.		Orchids & Rhododendrons (Borneo, 1979)
Order Julida		
Blaniulidae		*Echinodorus* (Singapore, 2008), Orchid (Brazil, 2003)
Blaniulus guttulatus (Fabricus, 1798)	Europe	Orchid (Australia, 1985)
Blaniulus sp.		Unknown (South Africa, 1999)
Cylindroiulus londinensis (Leach, 1814)	Europe	*Phoenix dactylifera* (Italy, 2004)
Cylindroiulus sp.		*Dicksonia* (New Zealand, 2004)
Ommatoiulus moreletii (Lucas, 1860)	Iberian peninsula	*Dicksonia* (Australia, 2006), melon fruit (South Africa, 1983)
Ommatoiulus oxypygus (Brandt, 1841)	Italy	*Vitis* sp. (Italy, 1979)
Ophyiulus targionii Silvestri, 1898	Italy	Unknown (New Zealand, 1982)

Table 7.2.3. Relative importance of the non-native species in the myriapod fauna of the Macaronesian islands. The numbers of introduced species correspond to the total non-native species of both exotic and continental European origin (cf., Arndt et al. 2008, Baéz and Oromí 2004, Borges, 2008a,b, Borges and Enghoff 2005, Enghoff 2008b, Enghoff and Borges 2005, Zapparoli and Oromi 2004), some numbers updated according to recent records. * 7 certainly native, 6 probably native, 20 possibly native, ** all probably introduced; *** all possibly native.

	Canary Isl.		Azores Isl.		Madeira Is.		Selvages Isl.	
	Native	Introduced	Native	Introduced	Native	Introduced	Native	Introduced
Diplopoda	83	24	2	19	40	18	2	0
Chilopoda	33*	2**	8	3	2	17+2?	0	2
Symphyla	0	6**	3	0	1	2	no records	no records
Pauropoda	14***	0	1	0	10	0	no records	no records

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Spiders (Araneae)
Chapter 7.3

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Abstract

A total of 47 spider species are alien to Europe; this corresponds to 1.3 % of the native spider fauna. They belong to (in order of decreasing abundance) Theridiidae (10 species), Pholcidae (7 species), Sparassidae, Salticidae, Linyphiidae, Oonopidae (4–5 species each) and 11 further families. There is a remarkable increase of new records in the last years and the arrival of one new species for Europe per year has been predicted for the next decades. One third of alien spiders have an Asian origin, one fifth comes from North America and Africa each. 45 % of species may originate from temperate habitats and 55 % from tropical habitats. In the past banana or other fruit shipments were an important pathway of introduction; today potted plants and probably container shipments in general are more important. Most alien spiders established in and around human buildings, only few species established in natural sites. No environmental impact of alien species is known so far, but some alien species are theoretically dangerous to humans.

Keywords

Buildings, urban area, greenhouse, pathways, venomous spiders, Europe, alien

7.3.1 Introduction

Spiders are among the most diverse orders in arthropods with a world-wide distribution in all terrestrial habitats and more than 40,000 species, grouped in 109 families (Platnick 2008). The European spider fauna comprises nearly 3600 species of which 47 (= 1.3 %) are alien to Europe, i.e. their area of origin is outside Europe. An ad-

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ditional number of at least 50–100 species are alien within Europe, i.e. they originate, e.g., from the Mediterranean or from eastern parts of Europe and spread gradually into other parts of Europe. Such aliens within Europe are not considered here. Small scale spread, e.g., into an adjacent country, is also not considered here.

All spiders are predators and usually prey on arthropods, mainly insects. Since many insects are regarded as pests, spiders are often seen as beneficial. Spiders have unique features such as abdominal silk glands which are used in many ways (e.g., construction of retreat, cocoon, web or dragline) and venom glands to poison their prey (only two families deviate from this). Spiders developed many different ways to catch their prey. Roughly half of them build silken webs to subdue prey and they evolved a large variety of web types. Funnel webs are usually soil-born and closely connected to the retreat of the spider (such as Agelenidae and Amaurobiidae), sheet webs are more often found within the vegetation (examples are Linyphiidae and Theridiidae) and orb webs often bridge the open space between structures (Araneidae and Tetragnathidae). Spiders which do not build a web live as sit-and-wait predators (e.g., Clubionidae, Gnaphosidae, Lycosidae, Sparassidae, and Thomisidae) or actively hunt for prey (such as Salticidae).

For this compilation of alien spiders to Europe the DAISIE database (www.europe-aliens.org) was used. In addition a variety of further sources (cited below) was consulted. When speaking about alien species two main problems occur. (1) It may be unclear whether a species is native to Europe or not, e.g., because it is native in an area close to the European borders. This concerns primarily Mediterranean and North or East Palearctic species. We choose a very conservative attitude and did not consider such species. It may also be difficult to decide whether a Holarctic species originates in the Nearctic or in the Palearctic part of the Arctic. We tried to follow the most probable decision. (2) We included only established alien species. In some cases it may be difficult to decide on this because sometimes the discovery of an alien species is communicated but no follow-up reports on its establishment are available. Again, we tried to achieve the most probable point of view. For example, all the reports on tropical Ctenidae or Theraphosidae arriving with banana shipments in Europe never lead to an established population of these spiders and were therefore not included into our chapter.

7.3.2 Taxonomy of alien species

The 47 spider species alien to Europe belong to 17 families (Table 7.3.1) with Theridiidae (10 species) and Pholcidae (7 species) being the most species-rich families. Sparassidae comprise five species; Salticidae, Linyphiidae and Oonopidae comprise four species each. Eleven families are represented with only one or two species each. The most astonishing aspect of the composition of the alien spider fauna is that it neither reflects the structure of the global spider community nor the structure of the European spider fauna (Fig. 7.3.1).

Globally frequent families (such as Araneidae, Corinnidae, Lycosidae, Theraphosidae, and Zodariidae) are not represented at all among the alien species in Europe. This may be due to some specialisations or restrictions of most species in these families: Araneidae and Corinnidae are usually not associated with human infrastructure and have a rather low probability of becoming transported to foreign areas (see below). Most Theraphosidae ("tarantulas") depend on their specific microclimate and are among the largest spiders, thus easy to detect and avoid. Lycosidae were also not imported to Europe and the reason for this remains unknown.

Other families are overrepresented among the alien community: Sicariidae, Oonopidae, Sparassidae, Pholcidae, and Theridiidae. Their common feature is a preadaptation to human infrastructure, especially buildings. Many species from these families initially live on bark and rocks and/or in arid habitats, thus, they tolerate the dry climate in houses and in urban areas. They can easily sit at the vertical sides of containers (Sparassidae), hide at the underside of pallets or in cracks and cavities (Pholcidae, Theridiidae) or are simply so tiny that they fit everywhere in (Oonopidae).

The composition of the spider fauna in Europe will become strongly influenced by alien newcomers if the trend of the last decades continues. Eresidae, Prodidomidae, Scytodidae, and Oonopidae were so far rare families in Europe. Sparassidae and Pholcidae comprise only a few species and the alien add-on may lead to a situation where some families are dominated by alien species. Sicariidae did not even occur previously in Europe.

7.3.3 Temporal trends

In the past, there was hardly any systematic check for alien spiders in imported goods. In contrast to herbivores where damage to plants may be of economic importance, alien spiders were only occasionally recorded. Exceptions may be border controls of banana shipments and similar goods because such transports enabled large and dangerous animals to enter Europe. In general, information on arrival data of alien spiders is scarce and when using the date of a scientific publication as a proxy, this information may be considerably fuzzy because some publications compile data of a long period; e.g., for 26 years in Van Keer (2007).

12 first species records were collected in the 19th century, 24 records came from the 20th century and already 11 records were perceived in the first years of the 21st century. This in itself indicates a steep increase in recording alien species. Of course, it should not be overlooked that the public awareness of alien species and the number of experts increased in the last decades considerably. Both accelerate the probability of detecting new spider introductions.

Kobelt and Nentwig (2008) analysed the arrival of 87 alien spider species with known arrival date (alien to Europe and alien within Europe) and concluded that the known number of alien spider introductions still represents an underestimation. They predict a continuous trend of more alien species and give the figure of at least one additional alien spider species annually arriving in Europe in the near future.

7.3.4 Biogeographic patterns

One third of all alien spiders have an Asian origin. This may include Eastern Palearctic and Indo-Malayan, thus temperate and tropical areas. About one fifth of the species derive from North America and Africa each, and South America and Australia contribute only four species each. In a few cases the origin is not known or subjected to expert guess (Fig. 7.3.2). Such cosmopolitan species are not truly cosmopolitan because they have of course a defined area of origin, but due to early spread among many or all continents and due to lacking phylogeographical information, it is sometimes still impossible to solve such a puzzle. These results suggest that the closer a continent is (Palaearctic) and the more traffic and goods exchange exists (Asia, North America), the more alien species are also imported.

An analysis between temperate and tropical origins indicates that about 45 % of species may originate from temperate habitats and 55 % from tropical habitats. Uncertainty, however, is high because for many species nothing or not very much is known about the natural environment in which they live in their area of origin.

7.3.5 Main pathways to Europe

Kobelt and Nentwig (2008) analysed the origin of alien spider species in Europe and the intensity of trade between Europe and the native area of these alien spiders in a continent by continent comparison. By including trade volume, area size, and geographical distance, they clearly could demonstrate that trade volume, size of the area of origin, and the geographical distance to Europe are good indicators for the number of alien species transported to Europe. The volume per time curves of agricultural products and mining products fit the increase of alien spiders less well than the curve for manufactures, and therefore it is concluded that the first have a lower number of alien stowaways whereas manufactures have the highest potential to transport alien species (Fig. 7.3.3).

More in detail, spiders can survive shipment in or at containers or construction materials for periods long enough to reach most other continents. The rare collection notes on spiders which had been recorded during or after this voyage suggest that spiders frequently occur in container (e.g., with stones, wood, other products), in or at wooden boxes, at wooden pallets, and within shipments of logs or wood products. Consequently, many alien spiders are detected in a harbour, in buildings at or close to a harbour, and in or at warehouses (Van Keer 2007).

Up to the 1980s, many alien spiders were detected in banana or other fruit shipments (Forsyth 1962, Reed and Newland 2002). This does not only represent a pathway from a tropical area of origin to Europe, it also enables the spider to travel within Europe. With increasing technical standards to supply the fruits with optimal transport conditions (usually low temperature, oxygen reduction to 1–5 % and a carbon dioxide increase to 1–10 %, see also Hallman (2007)), spiders have less chances to survive this (but see Craemer 2006).

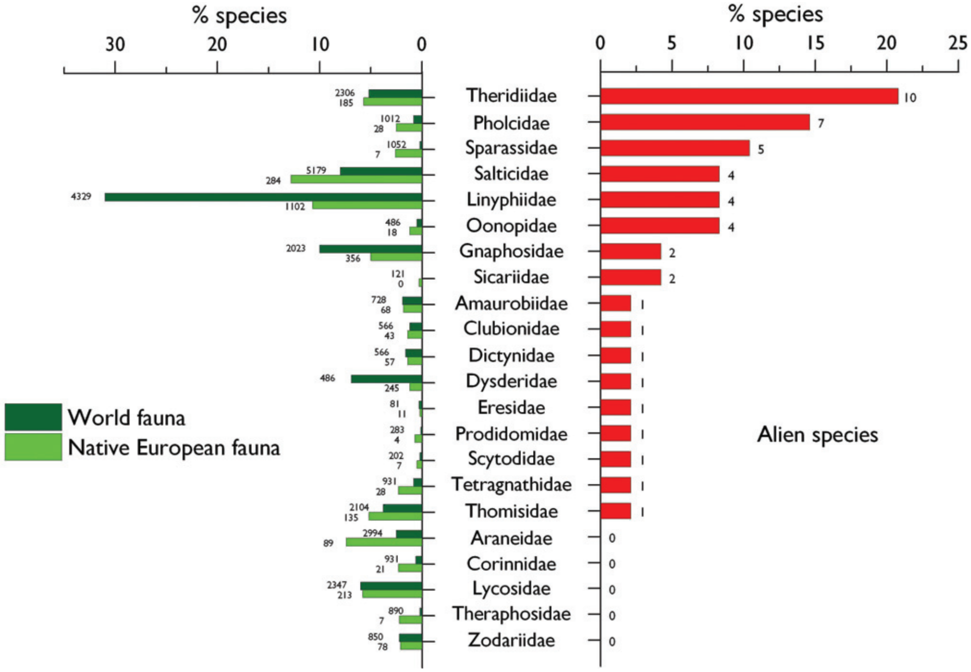

Figure 7.3.1 Taxonomic overview of the spider species alien to Europe compared to the native European fauna. Right- Relative importance of the spider families in the alien fauna expressed as the percentage of species in the family compared to the total number of alien spiders in Europe. Families are presented in a decreasing order based on the number of alien species. The number over each bar indicates the total number of alien species observed per family. Left- Relative importance of each family in the native European fauna of spiders and in the world fauna expressed as the percentage of species in the family compared to the total number of spiders in the corresponding area. The number over each bar indicates the total number of species observed per family in Europe and in the world, respectively.

Transported plants represent a very important pathway for spiders. This hardly concerns cut flowers but potted plants and plants for planting. There are numerous anecdotes that plants bought in supermarket, in a plant shop or at a plant fair contained a spider or a spider cocoon. Since a considerable amount of such potted plants is produced in China and transported through Italy to different European countries, this indicated the importance of plants as pathway from Asia to Europe.

For the further spread of alien spiders within Europe, it is assumed that transport vehicles such as trucks or trains play an important role. The spread of *Zodarion rubrum*, formerly only known from the French Pyrenees, followed in the last 100 years the main railway connections within Europe. This allowed the small spider to hitchhike over large distances (Pekár 2002). Hänggi and Bolzern (2006) discuss this phenomenon and give evidence for additional species. Spread by vehicles also may explain the fact that quite often the first record of an alien spider had been made at roadsides or in drains along roadsides (Van Keer 2007).

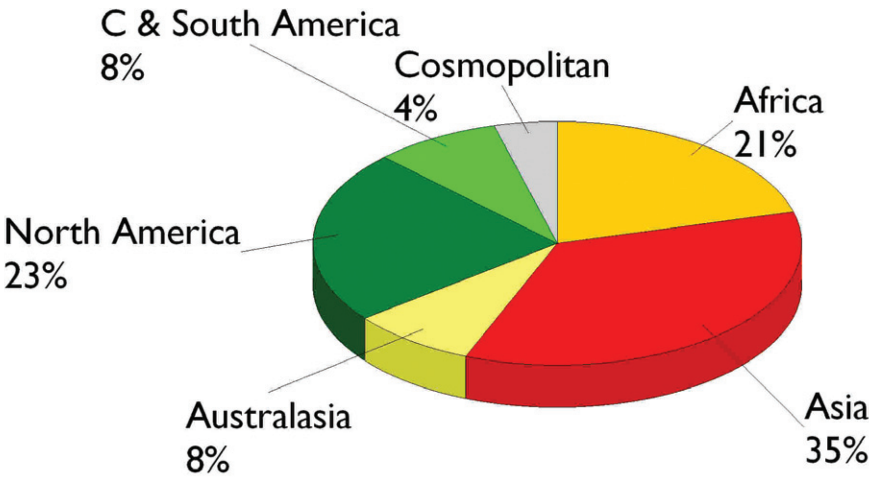

Figure 7.3.2 Geographic origin of the 47 spider species alien *to* Europe.

In a country-wise comparison within Europe, France, Belgium, The Netherlands, Germany and Switzerland possess the highest numbers of alien spider species (Fig. 7.3.4). These countries are also the ones with the highest level of imports (Fig. 7.3.5). On the other side, the Balkan countries have much lower numbers of alien spiders and Norway, the Baltic States, Belarus, and Russia have the lowest numbers of alien spiders. There is a good correlation between this type of economic activity and the number of alien species, thus, on the country level a comparable picture to the continental level of Kobelt and Nentwig (Kobelt and Nentwig 2008) is obtained.

7.3.6 Most invaded ecosystems and habitats

Nearly half of all alien spider species occur only in buildings and/or urban areas. This may be species which inhabit walls of buildings or need the specific microclimatic conditions of houses. One third of all alien species live in greenhouses, botanical gardens, in zoo buildings, or in comparably warm buildings. They rely on the specific temperature conditions but nevertheless are able to establish permanent populations (Holzapfel 1932, Van Keer 2007). In the summer season, in southern countries and under the conditions of climate change some species can colonise the vicinity of buildings and have the potential of further spread.

Only five among 47 alien spiders so far were able to establish in natural habitats. They usually are small-sized species, belonging to families which are common in Europe (Dictynidae, Linyphiidae, Tetragnathidae), and they build sheet webs or small orb webs. They originate from North America, Japan and the temperate part of Australia or New Zealand. These parameters probably indicate the conditions which an alien spider should fulfil to be able to survive in natural habitats in Europe.

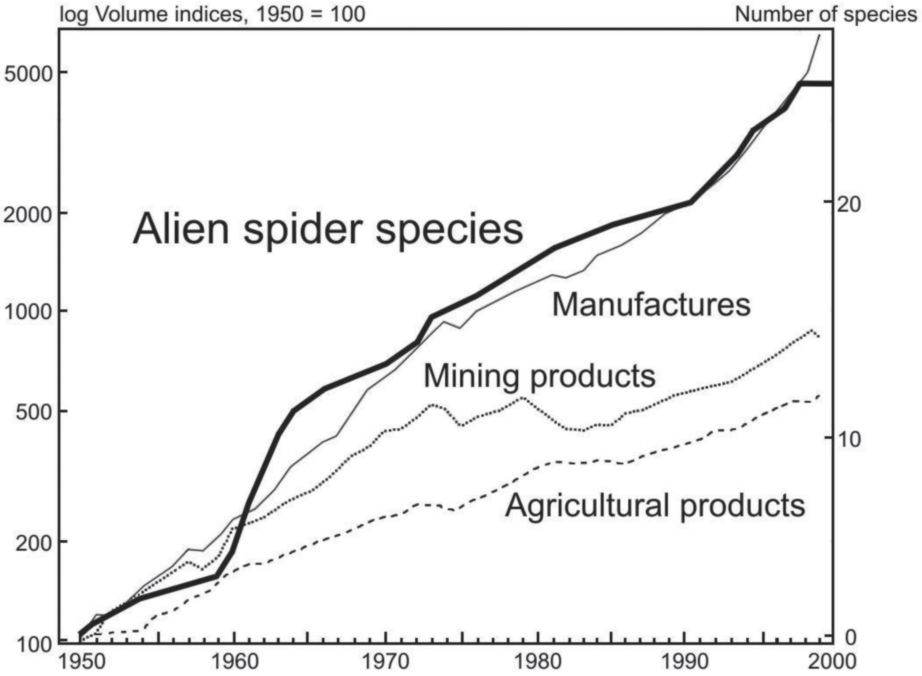

Figure 7.3.3 Increase in global trade (left scale) and the cumulative number of alien spider species introductions (right scale) during the last 50 years. Only cases with known year of introduction are included - from Kobelt and Nentwig (2008).

An interesting reason for the obvious high establishment success of alien spiders in human buildings may be found in the rarity of native species at such conditions. This could mean that alien species have much better chances to establish in habitats with no competition by native species.

7.3.7 Ecological and economic impact

A family-wise comparison of body sizes of alien and European spider species showed that alien Theridiidae imported to Europe were significantly larger than the native species, Pholcidae and Salticidae showed a trend into the same direction. Kobelt and Nentwig (2008) argue that this reflects the physical transport conditions, especially of temperature and humidity inside a standard ship container (Diepenbrock and Schieder 2006, Naber et al. 2006). These are important stress factors which primarily affect small specimen and can be more easily compensated by large spiders (Pulz 1987). So, even if spiders of all body sizes and from all continents would have more or less equal possibilities to be shipped around the globe, larger species have better chances to survive transportation than smaller ones do.

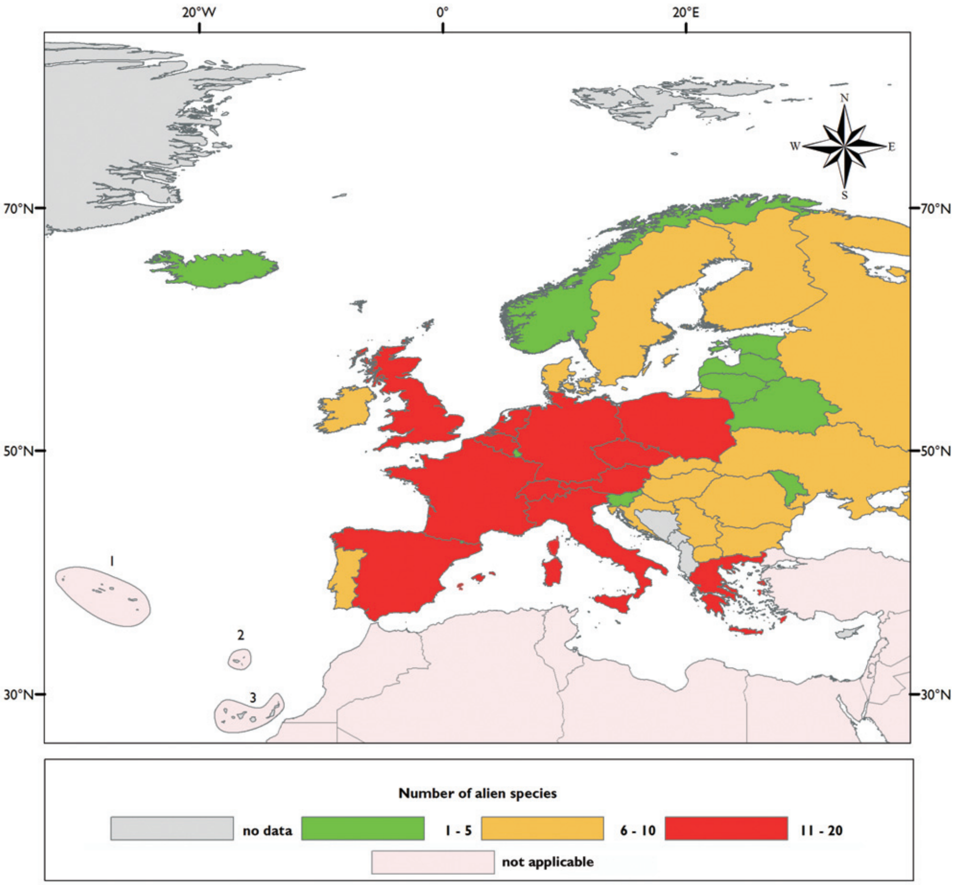

Figure 7.3.4 Number of alien spider species for each European country.

If alien species could successfully invade European spider assemblages in natural habitats, it could be argued that due to their slightly larger body size they could compete with native species and suppress or even replace them. This would change the dominance structure in natural spider communities within a few years. So far, however, most alien species do not occur in natural spider communities and / or remained rare. Therefore, in Europe no influence of alien spider species on native spiders had been observed so far. This is in agreement with a two-year-analysis of spider communities in California were the occurrence of alien spider species did not negatively affect native species. The most productive habitats contained both the highest proportion of alien and the greatest number of native spiders. No negative associations between native and alien spiders could be detected and, thus, Burger et al. (2001) concluded that the alien spiders do not impact native ground-dwelling spiders.

The most frequently occurring alien spider in Europe is probably the North American linyphiid *Mermessus trilobatus,* first detected in southern Germany in the 1980s and spreading since then. Only in the last years it had been detected that it obviously easily

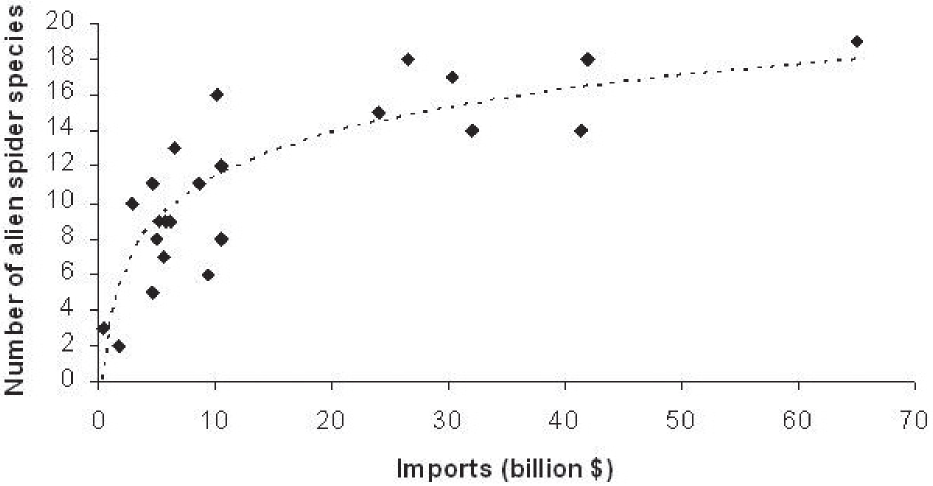

Figure 7.3.5 Relationship between the number of alien spider species and the value of imported goods in European countries (economic data for 2005).

establishes in many natural spider communities, especially in grassland and ruderal habitats (Schmidt et al. 2008). With an average body length of 1.6–2.1 mm (Nentwig et al. 2003), *M. trilobatus* belongs to the smaller linyphiids and it is unlikely that it outcompetes a native species. Competition experiments indeed proved that the invasion success of *M. trilobatus* is not facilitated by strong competitiveness. Actually it is unknown if other traits (e.g., higher reproduction effort, better dispersal abilities, or nutritional aspects) give some competitive advantage over native species (Eichenberger et al. 2009). So far, the integration success of *M. trilobatus* into native spider communities seems to confirm the assumption of Burger et al. 2001 on the resilience of native spider communities.

An economic impact of spiders may be expected from those spider species which are venomous to humans. Among the alien spiders listed here (Table 7.3.1) species which may be considered as theoretically dangerous to humans comprise the sicariids *Loxosceles laeta* and *L. rufescens* and the Australian black widow *Latrodectus hasselti* (Forster 1984). We are, however, not aware of any report from Europe referring to bites from these species. This is in line with the general assumption that the frequency of spider bites is overestimated (Vetter et al. 2003). Additionally it may be possible that these alien species did not reach relevant densities or that they even did not establish in the long term.

Spiders are also known to pollute the faces of buildings and the interior of rooms by their silk spinning activity. Spider webs often stay for long, collect dust and dirt, and are the reason for additional cleaning procedures which cause costs for hygienic reasons. There are only very few reports on this and they only refer to the Mediterranean dictynid spider *Dictyna civica* spreading since more than 50 years in Central Europe (Billaudelle 1957, Hertel 1968) which occasionally colonises the outside surface of buildings in high densities. Also many native species live inside buildings and cause

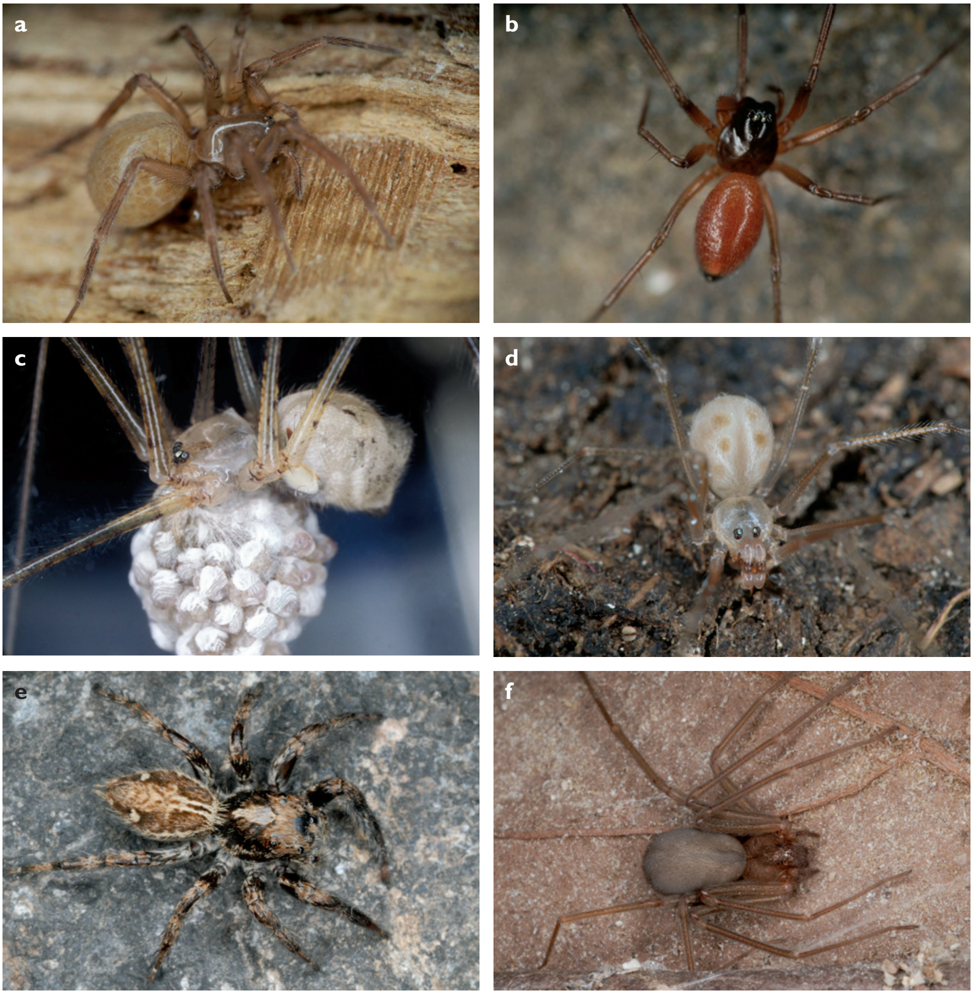

Figure 7.3.6. Alien spiders. **a** *Cicurina japonica* female (Dictynidae) **b** *Ostearius melanopygius* female (Linyphiidae) **c** *Crossopriza lyoni* female with eggsac (Pholcidae) **d** *Spermophora senoculata* male (Pholcidae) **e** *Plexipus paykulli* female (Salticidae) **f** *Loxosceles rufescens* female (Sicariidae). Reprinted with kind permission of Jǿrgen Lissner (© Jǿrgen Lissner, http://www.jorgenlissner.dk).

regular cleaning activities due to their web spinning activity but no report concerns additional cleaning costs. Since alien species are much less abundant, such additional costs are not to be expected or they will be merged with cleaning costs which anyhow have to be achieved. In addition, it should not be underestimated that many people simply fear spiders and react with insecticidal applications which involves financial costs and may cause health problems. This, however, concerns native and alien spiders likewise.

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References

Billaudelle H (1957) Zur Biologie der Mauerspinne *Dictyna civica* (H. LUC.) (Dictynidae: Araneida). *Zeitschrift für angewandte Entomologie* 41: 475–512.

Blick T (ed) (2004) *Checklist of the spiders of Central Europe (Arachnida: Araneae)*. http://www.arages.de/checklist.html#2004_Araneae

Blick T, Hänggi A (2003) *Invasive Spinnentiere (Arachnida ohne Acari) in der Schweiz*. Delémont, Switzerland: CABI Bioscience Switzerland Centre.

Bosmans R, Vanuytven H (2002) Een herziene soortenlijst van de Belgische spinnen (Araneae). *Nieuwsbrief Belgische Arachnologische Vereniging* 16: 44–80.

Burger JC, Patten MA, Prentice TR, Redak RA (2001) Evidence for spider community resilience to invasion by non-native spiders. *Biological Conservation* 98: 241–249.

Craemer C (2006) Spiders a problem on export grapes. *Plant Protection News* 67: 10

Deeleman-Reinhold CL, Deeleman P (1988) Révision des Dysderinae (Araneae, Dysderidae), les espèces méditerranéennes occidentales exceptées. *Tijschrift Voor Entomologie* 131: 141–269.

Diepenbrock B, Schieder U (2006) Transport information service, Version 1.8.0.06. Gesamtverband der Deutschen Versicherungswirtschaft, Berlin. http://www.tis-gdv.de

Eichenberger B, Siegenthaler E, Schmidt-Entling MH (2009) Body size determines the outcome of competition for webs among exotic and native sheetweb spiders (Araneae: Linyphiidae). *Ecological Entomology* 34: 363–368.

Entling W, Schmidt MH, Bacher S, Brandl R, Nentwig W (2007) Niche properties of Central European spiders: shading, moisture and the evolution of the habitat niche. *Global Ecology and Biogeography* 16: 440–448.

Fauna Europaea (2005) *Fauna europaea, Version 1.2 from 7 March 2005*. http://www.faunaeur.org

Forster LM (1984) The Australian redback spider (*Latrodectus hasselti*): its introduction and potential for establishment and distribution in New Zealand. In: Laird M (Ed) *Commerce and the spread of pests and disease vectors*. New York: Praeger, 273–289.

Forsyth M (1962) Spiders introduced with fruit to Northern Ireland during 1961. *Irish Naturalists' Journal* 14: 63.

Hallman GJ (2007) Phytosanithary measures to prevent the introduction of invasive species. in Nentwig W (Ed) *Biological invasions*. Berlin: Springer, 367–384.

Hänggi A (2003) Nachträge zum 'Katalog der schweizerischen Spinnen' 3. Neunachweise von 1999 bis 2002 und Nachweise synanthroper Spinnen. *Arachnologische Mitteilungen* 26: 36–54.

Hänggi A, Bolzern A (2006) *Zoropsis spinimana* (Araneae: Zoropsidae) neu für Deutschland. *Arachnologische Mitteilungen* 32: 8–10.

Harvey R, Nellist DR, Telfer MG (eds) (2002) *Provisional atlas of British spiders (Arachnida, Araneae)*. Huntingdon, UK: Biological Records Centre. 214 pp.

Hertel R (1968) Über das Auftreten der südeuropäischen Spinne *Dictyna civica* (H.LUC.) in Dresden (Dictynidae, Araneida). *Abhandlungen des Naturkundemuseums Görlitz* 44: 89–94.

Holzapfel M (1932) Die Gewächshausfauna des Berner Botanischen Gartens. *Revue Suisse de Zoologie* 39: 325–374.

Huhta V (1972) *Loxosceles laeta* (Nicolet) (Araneae, Loxoscelinae), a venomous spider established in a building in Helsinki, Finland, and notes on some other synanthropic spiders. *Annales Entomologici Fennici* 38: 3.

Jäger P (2005) *Zimiris doriai* (Araneae: Prodidomidae) – erstmals nach Deutschland eingeschleppt. *Arachnologische Mitteilungen* 29: 17–19

Kobelt M, Nentwig W (2008) Alien spider introductions to Europe supported by global trade. *Diversity and Distributions* 14: 273–280.

Komposch C (2002) Spinnentiere: Spinnen, Weberknechte, Pseudoskorpione, Skorpione (Arachnida: Araneae, Opiliones, Pseudoscorpiones, Scorpiones). In: Essl F, Rabitsch W (Eds) *Neobiota in Österreich*. Wien: Umweltbundesamt. 432 pp.

Koponen S (1997) *Triaeris stenaspis* Simon (Araneae, Oonopidae) found in the botanical garden of the University of Turku, Finland. *Entomologica Fennica* 8: 7.

Lee P (2005) An imported pholcid in Felixstowe. *Newsletter of the British Arachnological Society* 102: 7.

Montardi Y (2006) *Catalogue of French Salticidae*. http://saitis.club.fr/montardi/salticidae/catalogue/catalogue_frame.html

Naber G, Duken U, Mast EW, Schieder UP (2006) *Container handbook*. Gesamtverband der Deutschen Versicherungswirtschaft, Berlin. http://www.containerhandbuch.de [accessed 28 June 2006]

Nentwig W, Hänggi A, Kropf C, Blick T (2003) *Central European spiders determination key*. www.araneae.unibe.ch [accessed 8.12.2003]

Pekár S (2002) Revision of the genus *Zodarion* (Araneae: Zodariidae) in the Czech and Slovak Republics. *Acta Societatis Zoologicae Bohemiensis* 66: 51–66.

Platnick NI (2008) The world spider catalog, Version 9.0. http://research.amnh.org/entomology/spiders/catalog/INTRO1.html

Pulz R (1987) Thermal and water relations. In: Nentwig W (Ed) *Ecophysiology of spiders*. Berlin: Springer, 26–55.

Reed C, Newland S (2002) Spiders associated with table grapes from United States of America (State of California), Australia, Mexico and Chile. Wellington, New Zealand: MAF Biosecurity Authority, Ministry of Agriculture and Forestry. 90 pp.

Ruzicka V (1995) The spreading of *Ostearius melanopygius* (Araneae: Linyphiidae) through Central Europe. *European Journal of Entomology* 92: 723–726.

Saaristo MI (2003) Tetragnathid spiders of Seychelles (Araneae, Tetragnathidae). *Phelsuma* 11: 13–28.

Sacher P (1983) Spinnen (Araneae) an und in Gebäuden. Versuch einer Analyse der synanthropen Spinnenfauna in der DDR, 1.Teil. *Entomologische Nachrichten und Berichte* 27: 97–104.

Schmidt MH, Rocjer S, Hanafi J, Gigon A (2008) Rotational fallows as overwintering habitat for grass-land arthropods: the case of spiders in fen meadows. *Biodiversity and Conservation* DOI 10.1007/s10531–008–9412–6

Slawson C (2000) Staffordshire biodiversity action plan, Araneae (Arachnida) – spiders. 2nd edn. http://www.sbap.org.uk/focal/checklst/araneae.htm

Terhivuo J (1993) Novelties to the Finnish spider fauna (Araneae) and notes on species having bitten man. *Memoranda Societatis Fauna Flora Fennica* 69: 53–56.

Valesova-Zdarkova E (1966) Synanthrope Spinnen in der Tschechoslowakei. *Senckenbergiana Biologica* 47: 73–75.

Van Keer K (2007) Exotic spiders (Araneae): Verified reports from Belgium of exported species (1976–2006) and some notes on apparent neozoan invasive species. *Nieuwsbrief Belgische Arachnologische Vereniging* 22: 45–54.

Vetter RS, Cushing PE, Crawford RL, Royce LA (2003) Diagnoses of brown recluse spider bites (loxoscelism) greatly outnumber actual verifications of the spider in four western American states. *Toxicon* 42: 413–418.

Wunderlich J, Hänggi A (2005) *Cicurina japonica* (Araneae: Dictynidae) eine nach Mitteleuropa eingeschleppte Kräuselspinnenart. *Arachnologische Mitteilungen* 29: 20–24.

Table 7.3.1 List and main characteristics of the spider species alien to Europe. Area of origin: since the area of origin is quite often not well known, this refers to the most probable origin. "cosmopolitan" means that the area of origin is outside Europe but not known, "cosmopolitan" in brackets gives an alternative explanation, South America refers to the tropical part of America. Country codes abbreviations refer to ISO 3166 (see appendix I). Only selected references are given. Last update 30.09.2008.

Family *Species*	**Area of origin**	**First record in Europe**	**Invaded countries**	**Habitats**	**Refs**
Amaurobiidae					
Amaurobius similis (Blackwall 1861)	North America (cosmopolitan)	1915, DK	AD, BE, CH, DK, DE, ES, FR, GB, IE, MD, NL, NO, PL, RO, SE, UA	J1	Fauna Europaea (2005), Harvey (2002), Sacher (1983), Jonsson pers. comm. (2005), Scharff pers. comm. (2005)
Clubionidae					
Clubiona facilis O. P.-Cambridge 1910	Australia	1932, GB	GB	U	Fauna Europaea (2005), Platnick (2008)
Dictynidae					
Cicurina japonica (Simon 1886)	Asia	1990, DE	DE, CH, DK	E, F, G, H, I	Blick and Hänggi (2003), Wunderlich and Hänggi (2005)
Dysderidae					
Dysdera aculeata Kroneberg 1875	Asia	1988 HR	HR	U	Deeleman-Reinhold and Deeleman (1988)
Eresidae					
Seothyra perelegans Simon 1906	Africa	1906 FR	FR	U	Fauna Europaea (2005)
Gnaphosidae					
Sosticus loricatus (L. Koch 1866)	Asia	1879, SK	AT, BG, BY, CS, CZ, DE, EE, FI, FR, GR, HU, IT, LV, LT, MK, PL, RO, RU, SK	J1	Fauna Europaea (2005), Sacher (1983), Terhivuo (1993), Pekar pers. comm. (2005)
Zelotes puritanus Chamberlin 1922	North America	1966, CZ	AT, CH, CR, CZ , DE, LI, NO, RU, SE, SK	J1	Fauna Europaea (2005), Komposch (2002), Pekar pers. comm. (2005)
Linyphiidae					
Erigone autumnalis Emerton 1882	North America	1990, CH	CH, IT	E, F, G, H, I	Blick and Hänggi (2003), Fauna Europaea (2005)
Mermessus denticulatus (Banks, 1898) (=*Eperigone eschatologica*)	North America	1995, BE	BE, CH, DE, ES, NL	J1, J2.43	Blick (2004), Blick and Hänggi (2003), Fauna Europaea (2005)
Mermessus trilobatus (Emerton 1882)	North America	1980, DE	AT, BE, CH, DE, IT, PL	E, F, G, H, I	Blick and Hänggi (2003), Fauna Europaea (2005)
Ostearius melanopygius (O. P.-Cambridge 1879)	Australia	1906, GB	AT, BE, BG, CH, CZ, DE, DK, ES, FR, FI, GB, IT, NL, PT, PL, RO, SE, SK	E, F, G, H, I	Blick and Hänggi (2003), Fauna Europaea (2005), Komposch (2002), Ruzicka (1995), Pekar pers. comm. (2005), Scharff pers. comm. (2005)

Family *Species*	**Area of origin**	**First record in Europe**	**Invaded countries**	**Habitats**	**Refs**
Oonopidae					
Diblemma donisthorpei O. P.-Cambridge 1908	Asia	1914, GB	GB	J1	Platnick (2008), Saaristo (2003)
Ischnothyreus lymphaseus Simon 1893	Asia	2005, FR	FR	U	Fauna Europaea (2005)
Ischnothyreus velox Jackson 1908	Asia	2003, DE	DE, GB, NL	J2.43	Blick (2004), Fauna Europaea (2005), Saaristo (2003)
Triaeris stenaspis Simon 1891	North America	1896, FR	BE, FI, FR, IE, SK	J1, J100	Blick (2004), Fauna Europaea (2005), Holzapfel (1932), Koponen (1997), Van Keer (2007), Pekar pers. comm. (2005)
Pholcidae					
Artema atlanta Walckenaer 1837	Africa	2001 BE	BE, GB, GR	J1	Blick (2004), Blick and Hänggi (2003), Fauna Europaea (2005), Lee (2005), Platnick (2008), Van Keer (2007)
Crossopriza lyoni (Blackwall 1867)	Africa	2004, BE	BE	E, F, G, H, I, J1	Blick (2004), Van Keer (2007)
Micropholcus fauroti (Simon 1887)	Africa	2001, BE	BE, CH	J1	Blick (2004), Blick and Hänggi (2003), Platnick (2008), Van Keer (2007)
Pholcus opilionoides (Schrank 1781)	Asia	1859, CZ	AD, AT, BG, CH, CS, CZ , DE, ES, FR, GR, HR, HU, IT, LI, LU, MD, MK, MT, PL, PT, RO, RU, SK, UA	J1	Fauna Europaea (2005), Sacher (1983), Pekar pers. comm. (2005)
Pholcus phalangioides (Fuesslin 1775)	Asia	1857, SK	AT, BE, BG, BY, CH, CS, CZ , DE, DK, ES, FI , FR, GB, GR, HU, IE, IS, IT, LI, LT, LU, MD, MK, MT, NO, NL, PL, PT, RO, RU, SE, SK, UA	J1	Fauna Europaea (2005), Holzapfel (1932), Komposch (2002), Sacher (1983), Terhivuo (1993), Valesova-Zdarkova (1966), Jonsson pers. comm. (2005), Pekar pers. comm. (2005), Scharff pers. comm. (2005)
Smeringopus pallidus (Blackwall 1858)	Africa	2004, NL	NL	J1, J2.43	Blick (2004)
Spermophora senoculata (Dugès 1836)	Africa	1976, SK	BE, BG, CH, CS, ES, FR, GR, HR, IT, MK, MT, PT, SI, SK, UA	J1, J100	Blick (2004), Fauna Europaea (2005), Platnick (2008), Pekar pers. comm. (2005)

Family *Species*	**Area of origin**	**First record in Europe**	**Invaded countries**	**Habitats**	**Refs**
Prodidomidae					
Zimiris doriai Simon 1882	Asia	2005, DE	DE	J1	Jäger (2005)
Salticidae					
Hasarius adansoni (Audouin 1826)	Africa	1901, FR	BE, CH, CZ, DE, DK, ES, FR, GR, IE, IT, MT, NL, PL	J2.43	Blick and Hänggi (2003), Bosmans and Vanuytven (2002), Fauna Europaea (2005), Hänggi (2003), Holzapfel (1932), Pekar pers. comm. (2005), Scharff pers. comm. (2005)
Menemerus bivittatus (Dufour 1831)	Africa	1831, ES	CZ, ES, FR, GB, IT, PT	J1	Fauna Europaea (2005), Montardi (2006)
Panysinus nicholsoni (O. P.-Cambridge 1899)	Asia	2005, FR	FR	J1	Fauna Europaea (2005)
Plexippus paykulli (Audouin 1826)	Asia	1819, FR	ES, FR, GB, GR, IT, MT	J1	Fauna Europaea (2005), Montardi (2006)
Scytodidae					
Scytodes venusta (Thorell 1890)	Asia	2004, NL	NL	J1	Blick (2004), Fauna Europaea (2005), Platnick (2008), Pekar pers. comm. (2005)
Sicariidae					
Loxosceles laeta (Nicolet 1849)	South America	1963, FI	FI, IT	J1	Fauna Europaea (2005), Huhta (1972)
Loxosceles rufescens (Dufour 1820)	North America (cosmopolitan)	1820, ES	ES, FR, GR, HR, IT, NL, MT, PT	J1, J2.43	Blick (2004), Fauna Europaea (2005)
Sparassidae					
Barylestis scutatus (Pocock 1903)	Africa	1961, IE	IE	J1	Forsyth (1962)
Barylestis variatus (Pocock 1899)	Africa	1961, IE	GB, IE	J1	Forsyth (1962), Slawson (2000)
Heteropoda venatoria (Linnaeus 1767)	Asia	1960, CZ	CH, CZ, DE, DK, ES, NL, NO, PL	J2.43	Blick and Hänggi (2003), Fauna Europaea (2005), Hänggi (2003), Ruzicka (1995), Valesova-Zdarkova (1966), Ruzicka pers. comm. (2005), Scharff pers. comm. (2005)
Olios sanctivincentii (Simon 1897)	Asia	1961, IE	GB, IE	J1	Forsyth (1962), Slawson (2000)
Tychicus longipes (Walckenaer 1837)	Asia	1837, NL	NL	J2.43	Platnick (2008)

Family *Species*	**Area of origin**	**First record in Europe**	**Invaded countries**	**Habitats**	**Refs**
Tetragnathidae					
Tetragatha shoshone (Levi 1981)	North America	1992, DE	AT, CZ, DE, HU, MK, RO, SK	E, F, G, H, I	Fauna Europaea (2005)
Theridiidae					
Achaearanea tabulata Levi 1980	South America	1991, AT	AT, CH, DE, PL, RU, BG, UA	J1	Blick and Hänggi (2003), Fauna Europaea (2005)
Achaearanea acoreensis (Berland 1932)	North America	2002, BE	BE	J1, J2.43	Van Keer (2007)
Achaearanea tepidariorum (C.L. Koch 1841)	South America (cosmopolitan)	1867, AT	AT, BE, BG, CH, CZ, DE, DK, ES, FI, FR, GB, GR, HU, HR, IE, IS, IT, LV, LI, MK, MT, NL, NO, PL, PT, RO, RU, SK, SE, UA	J1	Fauna Europaea (2005), Komposch (2002), Sacher (1983), Valesova-Zdarkova (1966), Koponen pers. comm. (2005), Pekar pers. comm. (2005), Scharff pers. comm. (2005)
Achaearanea veruculata (Urquhart 1885)	Australia	1885, BE	BE, GB	J1, J2.43	Blick (2004), Platnick (2008), Van Keer (2007)
*Chrysso spiniventr*is (O. P.-Cambridge 1869)	Asia	1949, NL	NL	J2.43	Blick (2004)
Coleosoma floridanum Banks 1900	Asia	1981, GB	AT, CH, DE, FI, GB, NL	J1, J2.43	Blick (2004), Blick and Hänggi (2003), Fauna Europaea (2005), Hänggi (2003), Harvey (2002), Komposch (2002)
Latrodectus hasselti Thorell 1870	Australia	2001, BE	BE, DK	J2.43	Blick (2004), Platnick (2008), Scharff pers. comm. (2005)
Nesticodes rufipes (Lucas 1846)	South America	1996, AT	AT, BE, CZ, ES, MT, PT	J2.43	Blick (2004), Komposch (2002), Van Keer (2007)
Steatoda grossa (C.L. Koch 1838)	Cosmopolitan	1850, SE	AT, BE, BG, BY, CS, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LT, LV, MD, MK, MT, NL, PL, PT, RO, RU, SE, SI, SK , UA	J1	Fauna Europaea (2005), Komposch (2002), Sacher (1983), Valesova-Zdarkova (1966), Jonsson pers. comm. (2005), Pekar pers. comm. (2005), Scharff pers. comm. (2005)
Steatoda triangulosa (Walckenaer 1802)	Cosmopolitan	1852, AT	AD, AT, BE, BG, CH, CS, CZ, DE, ES, FR, GB, GR, HR, HU, LV, MK, MT, NL, PT, RO, RU, SI, SK, UA	J1	Fauna Europaea (2005), Harvey (2002), Komposch (2002), Valesova-Zdarkova (1966), Scharff pers. comm. (2005)
Thomisidae					
Bassaniana versicolor Keyserling 1880	North America	1932, FR	FR	U	Fauna Europaea (2005)

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Mites and ticks (Acari)
Chapter 7.4

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Abstract

The inventory of the alien Acari of Europe includes 96 species alien to Europe and 5 cryptogenic species. Among the alien species, 87 are mites and 9 tick species. Besides ticks which are obligate ectoparasites, 14 mite species belong to the parasitic/predator regime. Among these species, some invaded Europe with rodents (8 spp.) and others are parasitic to birds (2 spp). The remaining 77 mite species are all phytophagous and among these 40% belong to the Eriophyidae (37 spp.) and 29% to the Tetranychidae (27 spp.) families. These two families include the most significant agricultural pest. The rate of introductions has exponentially increased within the 20th century, the amplification of plant trade and agricultural commodities movements being the major invasion pathways. Most of the alien mite species (52%) are from North America, Asia (25%), and Central and South America (10%). Half of the ticks (4 spp.) alien *to* Europe originated from Africa. Most of the mite species are inconspicuous and data regarding invasive species and distribution range is only partially available. More research is needed for a better understanding of the ecological and economic effects of introduced Acari.

Keywords

Europe, alien, mite, tick, Acari, Eriophyidae, Tetranychidae, biological control, *Tetranychus evansi*, *Oligonychus perseae*, *Polyphagotarsonemus latus*, *Brevipalpus californicus*, *Aceria sheldoni*, *Aculops pelekassi*, *Dermatophagoides evansi*, *Varroa destructor*

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7.4.1. Introduction

The subclass Acari, which includes mites and ticks, forms an important part of the class Arachnida, with a worldwide distribution and with over 55,000 (Krantz and Walter 2009) species described to date. An estimate of up to half a million to a million more species await discovery (Krantz and Walter 2009). Mites and ticks are a very diverse group ranging in size from about 0.08 mm up to 1 centimetre long. Acari differ from others Arachnida by the fusion of the abdominal segments as in Araneae (spiders) and from spiders by the presence of a gnathosoma containing mouthparts, the fusion of the posterior part of the prosoma (the podosoma, bearing legs) and fusion of an opisthosoma into an idiosoma (Evans et al. 1996). Most species are free living and have different trophic modes, including phytophagous, predators feeding on a variety of small invertebrates, fungivores and detritivores. Some species have developed complex parasitic relationships with both vertebrate and invertebrate animals. A number of acarine groups are injurious to crops and to livestock, both because of their feeding activities and because of their capacity as vectors for a variety of disease organisms to their plant or animal host. While the Oribatida is an important group (more than 6,000 species) having a key role in soil equilibrium, data regarding invasive species and distribution range remain largely unavailable. Ticks are very peculiar acarines, since they are obligate ectoparasites. In this sense they form a very homogenous group, with the order Ixodida composed of only three families. In this chapter, the two groups of Acari, mites and ticks, will be treated separately. The ticks will be presented through the description of a few significant case studies. By contrast, mites being much diversified in their biology and habitat use, and being truly ubiquitous, will be presented systematically.

Mites have successfully colonized nearly every known terrestrial, marine, and freshwater habitat. The most studied and observed invaders are found among the phytophagous mites of the families Tetranychidae and Eriophyidae, which include important agricultural pests. There is a growing awareness of the economic relevance of eriophyids as crop pests, including their importance as vectors of plant viruses, their role as alternative food for predators of plant pests, and their potential as weed control agents (Sabelis and Bruin 1996). A description on spider mite biology and their control is presented in the extensive review by Helle and Sabelis (1985). In addition to plant-feeding mites, a second group includes the alien parasitic mites. Among them, some invaded Europe with rodents such as muskrats (six alien species of mites), and brown rats (two aliens), while others are bird parasites (two species). *Dermatophagoides evansi* (Pyroglyphidae) is not associated with rodents and it has probably been accidentally introduced by humans (Bigliocchi and Maroli 1995,Hughes 1976,Thind and Clarke 2001). A single species in the family Varroidae, *Varroa destructor,* is alien to Europe (De Rycke et al. 2002, Griffiths and Bowman 1981).

Ticks are important parasites of livestock, wild animals, and humans. After their parasitic phase, they spend most of their life cycle outside their hosts, where prevailing climate conditions may constrain their ability to colonize a given territory. While some tick species are highly restricted to particular combinations of climatic variables, or have defined host species, others may occur in widely variable climate conditions and have catholic feeding habits. Some species of ticks can be considered as invasive species, since the uncontrolled movements of domestic animals may introduce alien species into Europe or disperse some species outside their native distribution ranges. The introduction via large-bodied host vectors (such as passerine birds) and the uncontrolled importation of reptiles, are important means for colonizing newly available areas. Furthermore, one species of tick, *Rhipicephalus sanguineus,* is spreading in parts of Europe out of its current range because of the movements of domestic dogs.

7.4.2 Taxonomy of the mite species alien *to* Europe

A total of 101 mite species have been considered as alien to Europe, including 96 species shown to have originated from other continents and 5 cryptogenic species (Table 7.4.1). These species involve 16 different families of mites (Figure 7.4.1). In addition, Table 7.4.2 provides some examples of mite species alien *in* Europe; i.e., European species introduced from one part of Europe to another where they are not native.

Alien mites belong to two super orders, **Acariformes (Actinotrichida)** and **Parasitiformes (Anactinotrichida)**. Most of these species belong to two orders of Acariformes, **Prostigmata** and **Astigmata**. Prostigmata includes the three most important superfamilies:

* **Tetranychoidea** comprises two main families containing alien mites. The Tetranychidae family, or spider mites, includes 1,250 described species (http://www1.montpellier.inra.fr/CBGP/spmweb/). Among them, 100 can be considered as pests and 10 as major pests of agricultural crops. All stages are phytophagous and feed on parenchyma cells. No viruses associated with spider mites have been observed. The most widely distributed species is the highly polyphagous and ubiquitous *Tetranychus urticae* (two spotted spider mite), found on nearly 1,000 plant species. In Europe, alien spider mites are generally more specialized and occur on a single genus or family of plants. Due to their minute size (200 to 900 µm) typical of many species of Acari, spider mites remain undetected until major plant damage occurs. The members of another family, Tenuipalpidae, or false spider mites, are important obligate phytophagous mites. They are elongate, dorsoventrally flattened and usually have a reddish colour.

* **Eriophyoidea** includes three families:

– Eriophyidae, to which belong ca. 88% of all known Eriophyoidea in the fauna of Europe (Fauna Europaea 2009). These are vermiform, four legged mites. The family includes important economic pests of broadleaved plants. All known mite vectors of plant pathogens and nearly all gall-forming species belong to this family. About half are vagrants. Most of the species in the genera *Aceria* and *Eriophyes* cause specific galls on the leaves, green twig, flower buds, vegetative buds, or fruit of the hosts (Oldfield 1996). Others, especially *Epitrimerus, Phyllocoptes, Aculops* and *Aculus* cause discolouration and other non-distortive damage to their hosts.

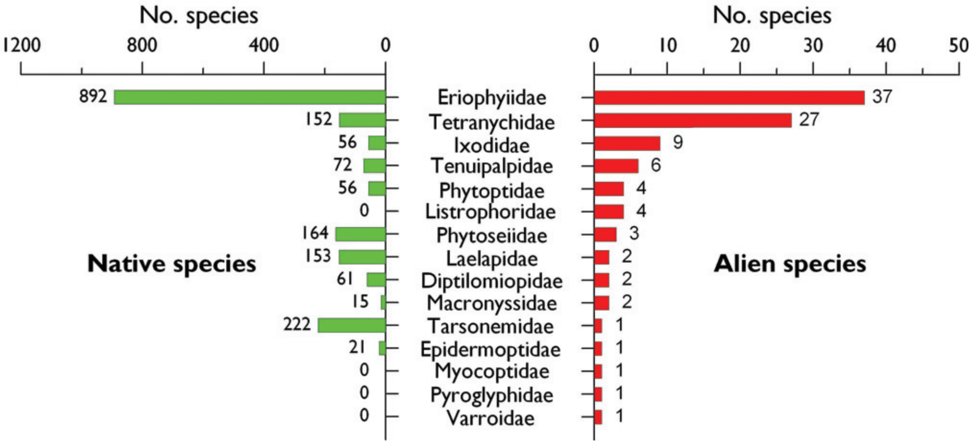

Figure 7.4.1. Relative importance of the mite families in the alien and native fauna in Europe. Families are presented in a decreasing order based on the number of alien species. Species alien *to* Europe include cryptogenic species. Only the most important families of native species (> 50 spp.) have been considered. The number over each bar indicates the number of species observed per family.

– Phytoptidae, which are obligate phytophagous and gall mites, with a high degree of specificity. They are also vermiform and four-legged. The family Phytoptidae is well represented on conifers (half of the described phytoptid species) and monocots. Phytoptidae is less represented than Eriophyidae or Diptilomiopidae on dicotyledons. Four alien species out of a total of 56 species have been reported in the fauna of Europe.

– Diptilomiopidae, which are predominantly leaf vagrants, only inhabiting leaves of dicotyledons, and rarely causing notable damage to their hosts (Keifer 1975). Two monotypic genera are known from only two families of monocotyledons (Poaceae and Palmae) occurring in the tropics. *Rhyncaphytoptus* species are mainly represented on several families of deciduous trees in the Holarctic region. Two alien species have been reported, out of the total 61 in the European fauna.

* **Tarsonemoidea** represented by the family Tarsonemidae includes economically important mites. Most of them are mycophagous. Some species are phytophagous, whereas others are parasites of bark beetle eggs, or predators of tetranychid eggs. The most redoubtable pest species in the family is the broad mite, *Polyphagotarsonemus latus* (=*Hemitarsonemus latus*), which was described in 1890 and has recently been redefined and considered as being a species complex (Gerson 1992).

The order **Astigmata** is less represented in the alien fauna. A few species belong to the super-family **Sarcoptoidea**, and especially to families Listrophoridae and Myocopidae. Members of Listrophoridae are usually small, elongate mites and are skin or hair parasites of mammals. The palpae and/or legs I-II are often highly modified for grasping hairs. Four species of Listrophoridae mites have invaded Europe, grasped to the fur of muskrats: *Listrophorus americanus*, *L. dozieri*, *L. faini* and *L. validus* (Šefrová and Laštůvka 2005). Myocopids, or hair mites, live on skin of marsupial and rodents (Bauer and Whitaker 1981, Šefrová and Laštůvka 2005, Whitaker 2007). *Myocoptes ondatrae* is an ectoparasite that has invaded Europe by grasping the fur of muskrats (Bauer and Whitaker 1981, Šefrová and Laštůvka 2005, Whitaker 2007). Other species belong to the super-family **Acaroidea** and families Epidermoptidae and Pyroglyphidae. Epidermoptidae are skin parasites of birds. *Epidermoptes bilobatus* causes avian scabies. Pyroglyphidae are external parasites living on bird feathers or are nidicolous. *Dermatophagoides evansi* feeds on human detritus, and lives in house dust as well as within bird nests (Piotrowski 1990, Razowski 1997).

Among the super-order **Parasitiformes (Anactinotrichida)**, aliens belong to orders **Ixodida** and **Mesostigmata**. Ixodida is represented by the species in the family Ixodidae, which is treated in a separate section at the end of the chapter. Alien Mesostigmata belong to superfamilies **Ascoidea** and **Dermanyssoidea**. The first superfamily is represented by a single family with aliens, Phytoseiidae, which are predators of spider mites. In Europe, species such as *Phytoseiulus persimilis, Amblyseius* (*Neoseiulus*) *californicus* and *Iphesius* (*Amblyseius*) *degenerans* are used as biological control agents against phytophagous pests (Bartlett 1992, Croft et al. 1998, Easterbrook 1996, EPPO 2002, Garcia Mari and Gonzalez-Zamora 1999, Helle and Sabelis 1985, McMurtry and Croft 1997). Three families of Dermanyssoidea contain alien species. Varroidae mites are ectoparasites of honeybees. *Varroa destructor* is at present the most important parasite of *Apis mellifera* (L.). *Varroa* feeds on the haemolymph of adult, larval and pupal bees. Laelapidae mites live in soil, are nidicoles or parasitize small mammals and insects. *Ondatralaelaps multispinosus* is an ectoparasite of muskrats (Šefrová and Laštůvka 2005). *Laelaps echidninus is* a common worldwide ectoparasite of spiny rats, wild brown rats and is occasionally found on the house mouse and cotton rat (Wharton and Hansell 1957). Macronyssidae mites are haematophagous, have a large dorsal shield, prominent chelicerae and inconspicuous body setae (Easterbrook et al. 2008). *Ornithonyssus bacoti* is a parasite of rats, living in rat nests and their surroundings (Cole et al. 2005, Easterbrook et al. 2008, Fan and Petit 1998, Whitaker 2007). *Ornithonyssus bursa* is a natural parasite of common birds including pigeons, starlings, sparrows, Indian mynahs, poultry, and some wild birds, such as the robin (Berggren 2005).

7.4.3 Temporal trends of introduction in Europe of alien mite species

The rate of arrival of alien mites in Europe is increasing exponentially (Figure 7.4.2). An average of 2.1 alien species was newly recorded per year in Europe during 2000–2007 whereas only half this number was recorded during the period 1950–1974 (1 species/year). However, large differences were found between families.

The first records for Europe of all alien Tetranychidae are extensively documented in this chapter. There are no records reported before 1950; however, only few taxonomists were specialized on the family before this date. Since the second half of the 20th century, tetranychid species have been reported at an average rate of one new species every two years, with an acceleration of reports (one species per year) since 2000.

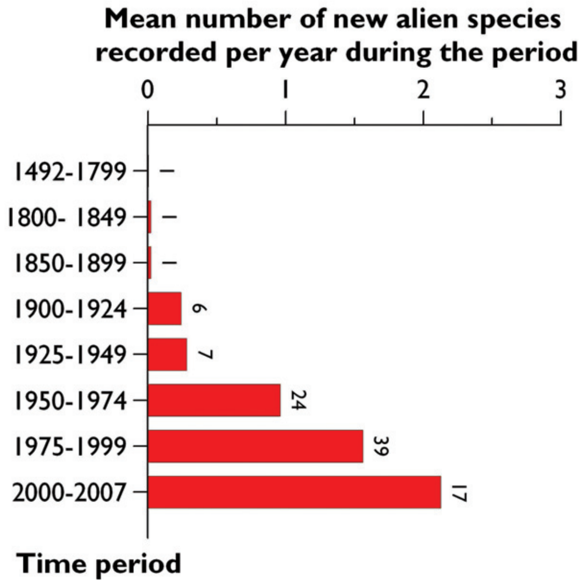

Figure 7.4.2. Temporal changes in the mean number of records per year of mite species alien *to* Europe from 1800 to 2009. The number over each bar indicates the absolute number of species newly recorded per time period.

Most of these mites represent agricultural pests, and therefore have been widely studied which explains the overrepresentation of crop pest species as Tetranychidae aliens.

The mean number of records of Eriophyoidae species alien to Europe increased rapidly during the third quarter of the 20th century. Only one species *Aceria alpestris*, which is alien in Europe, was recorded within the period 1850–1899. This species was described from the host plant *Rhododendron ferrugineum* L. from Tirol (Austria). The species was later recorded in mainland Italy, Czech Republic, Slovenia and Serbia, but it is not clear if it was associated with cultivated *Rhododendron*. Species recorded intensively between 1900–1924 (although described from Germany in 1857) are categorized as cryptogenic (*Eriophyes pyri,* the pear blister mite) or alien in Europe, like *Aculus hippocastani* (recorded in 1907, but probably introduced in Europe from the 17th century when its host plant *Aesculus hippocastanum* L. was intensively cultivated), and *Aceria loewi* (probably introduced in the 16th century when lilac started to be cultivated in France). *Aculops allotrichus*, which is alien to Europe, was recorded in 1912 but was probably, introduced with its host *Robinia pseudoacacia* L. which was for the first time introduced into France at the beginning of 17th century. *Aceria erinea* and *A. tristriata* were suspected to have an Asian origin and have been designated as aliens. They were recorded on 1903, but probably were present on its host, Persian walnut, in the Balkans and South Europe much earlier. Only one species in the Eriophyoidae was recorded between 1925–1949, e.g. *Aceria petanovicae,* the lilac rust mite. Being for long time known under the name of *Aculops massalongoi* the species is alien in Europe.

Six alien species to Europe were recorded between 1950–1974. Two pests of citrus, *Aceria sheldoni* (citrus bud mite) and *Aculops pelekassi* (citrus rust mite) and the azalea mite *Phyllocoptes azaleae*, are suspected to have been introduced from Asia. Characteristic symptoms of deformed lemon fruits caused by *A. sheldoni* were drawn by Battista Ferrari in Italy in 1664 (Ragusa 2002). Three pests have been reported from North American maple trees (*Acer negundo* L., *A. saccharinum* L. and *A. rubrum* L.), i.e. *Shevtchenkella brevisetosa, Vasates quadripedes* and *Rhyncaphytoptus negundivagrans*. The 25 species recorded during the period 1975–1999 almost all have a North American origin (only *Epitrimerus cupressi* is designated as cryptogenic, because of the Mediterranean origin of its host *Cupressus sempervirens* L.). During the period from 2000 to 2007, one species alien *to* Europe, *Rhyncaphytoptus bagdasariani,* has been recorded as being introduced from Asia and the serious pest *Aceria fuchsiae* (a species on the European quarantine list) was introduced from South America. As for other phytophagous mites, the most probable explanation for the acceleration in the pace of introductions of alien eriophyids is intensification of international trade. Most of these alien species inhabit ornamental trees and shrubs, flowers and potted ornamental plants.

Some alien parasitic mites have invaded Europe with rodents such as muskrats and brown rats. The muskrat (*Ondatra zibethicus* L.) is an invasive rodent native to North America. It was introduced around 1905, by humans as a fur resource in several parts of Europe, as well as in Asia and South America. Six species of mites, native from North America (Bauer and Whitaker 1981, Whitaker 2007), have invaded Europe grasping its fur (Glavendekić et al. 2005, Šefrová and Laštůvka 2005). The first report of muskrat mites was recorded in 1955, and a second in 2000, both in Czech Republic. Two other parasitic species, *Laelaps echidninus* and *Ornithonyssus bacoti*, are also alien ectoparasites of rodents that have invaded Europe and were identified in the 1950's (Šefrová and Laštůvka 2005), but the exact pathway of introduction is not known. One possible vector is the wild brown rat, *Rattus norvegicus* (Berkenhout). Thought to have originated in northern China, this rodent spread in Europe in the middle ages and is now the dominant rat in the continent.

Birds are vectors of a second group of alien parasitic mites, that include *Epidermoptes bilobatus* and *Ornithonyssus bursa*, both identified in the 1950's, in the Czech Republic (Šefrová and Laštůvka 2005). The exact route of introduction is not known with confidence, but a possible vector is the chicken (*Gallus gallus domesticus* L.). In the 20thcentury, with the intensifications of poultry production, concerns have been raised about the increasing risk of transfer of diseases and mites (from chickens to native bird species).

Whereas the exact date of arrival of alien mites is generally unknown, deliberately released biological control agents are the exception to this rule. Among them, three phytoseiids are mainly used as predatory species against pests (McMurtry and Croft 1997). *Phytoseiulus persimilis* was introduced for the first time in the 1970's in Bulgaria and Czech Republic (EPPO 2002, Šefrová and Laštůvka 2005). *Neoseiulus californicus* was introduced for the first time in 1991 in Great Britain (EPPO 2002). It was also introduced at the same period in the Czech Republic (EPPO 2002, Šefrová and Laštůvka

2005). The third introduced mite is *Iphiseius degenerans*. It is native from the Mediterranean region and was introduced for the first time in 1993 in Czech Republic (EPPO 2002, Šefrová and Laštůvka 2005). Nowadays, these three biological agents have been introduced in most European countries.

7.4.4 Biogeographic patterns of the mite species alien *to* Europe

7.4.4.1 Origin of the mite species alien to Europe

Figure 7.4.3. presents the region of origin of the 101 alien species of mites. Most of the alien mite species (52%) came from North America, then from Asia (25%), and Central and South America (10%). The origin of phytophagous alien mites can usually be inferred from the origin of the host plant. These mites are dispersed over long distances mainly by the introduction of plant material and spread further by plant cultivation in newly colonized regions. Aerial distribution is possible and most frequent, but mainly over short distances (Margolies 1993, Margolies 1995). In the case of highly polyphagous species such as several Tetranychidae, their ubiquity and highly diverse host uses might be misleading and the origin can be difficult to ascertain. Twelve out of 27 alien Tetranychidae originated in North America, nine in Asia and only five in Central and South America. Temperate regions provide the majority of the alien species (16 vs. 11 for tropical areas).

The majority of eriophyoid species are mono- or oligophagous and are distributed within the host range. North America appears to be the dominant source of the alien eriophyoid fauna with half of the species originating from this continent. Around 26% of species originate from Asia, and less than 10% from South America. A few species are designated as cryptogenic or with questionable origin. For example, *Rhyncaphytoptus negundivagrans,* although described from Hungary, probably originated from North America with its host plant, *Acer negundo*. Whereas the camellia rust mite, *Cosetacus cameliae* (described from California) was probably introduced to Europe from the USA, it probably has an Asian origin considering that *Camelia japonica* L. comes from subtropical and tropical regions of Southeast Asia. The pouch gall mite of plum leaves, *Eriophyes emarginatae,* first discovered in the USA, has also been recorded in Serbia and Japan. This mite is very closely related to the European *E. padi* (Nalepa) (Petanović 1997) and may even be the same species, with synonymous names (Keifer 1975). *Epitrimerus cupressi* was described from North America, but according to the origin of its host plant *Cupressus sempervirens*, which is from the Mediterranean region, the mite probably has an European origin too. The gall mite *Phytoptus hedericola* (Phytoptidae) is native from South Africa (Glavendekić et al. 2005), and *Trisetacus chamaecypari* (Phytoptidae) from North America (Ostojá-starzewski and Halstead 2006, Smith et al. 2007).

Among the false spider mites (Tenuipalpidae), *Brevipalpus californicus, B. obovatus* and *Tenuipalpus pacificus* originated from Central and South America, and Florida

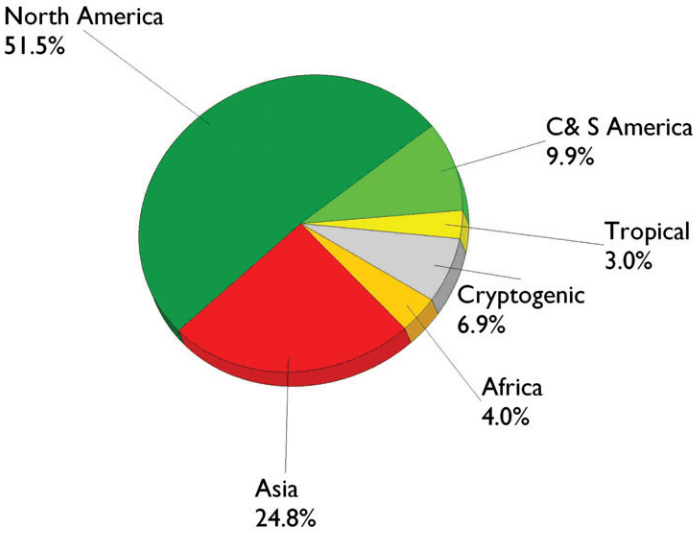

Figure 7.4.3. Origin of the mite species alien *to* Europe.

(USA) (Denmark 1968, Manson 1967). Six alien species of rodents bear parasitic mites originating from North America, and belong to the families Listophoridae (four species), Laelapidae (one species), and Myocoptidae (one species). In their native country, they are all ectoparasites of murskrats. There are also some bird parasites: one species of Epidermoptidae, *Epidermoptes bilobatus*, is an ectoparasite native from South Asia, and *Ornithonyssus bursa* is probably native from Trinidad.

A single *Varroa* species, *V. destructor,* is alien to Europe (Griffiths and Bowman 1981). Its native range is South East Asia, where it was originally confined on its original host, the Asian honeybee, *Apis cerana* F. This mite came to be a parasite of the European honeybee, *Apis mellifera,* in the mid-twentieth century. Importation of commercial *A. mellifera* colonies into areas with *A. cerana* brought the previously allopatric bee species into contact and allowed *V. destructor* to switch to the new host

7.4.4.2 Distribution in Europe of the alien mite species

Alien mite species are not evenly distributed throughout Europe. Large differences in the number of aliens are noticed between countries (Figure 7.4.4) but it may reflect differences in sampling efforts and in the number of local taxonomic specialists.

Among the Tetranychidae, 19 alien species are found around the Mediterranean Basin and 12 in the rest of Europe. With relatively warm winters, the Mediterranean region provides suitable climatic living conditions for many species of temperate climates, but also for the establishment of many species of tropical or sub-tropical origin. Except for *Panonychus citri* and the cryptic species *Tetranychus ludeni*, which can be found in glasshouses in Europe, all tropical alien spider mites are restricted to the area around the Mediterranean Sea.

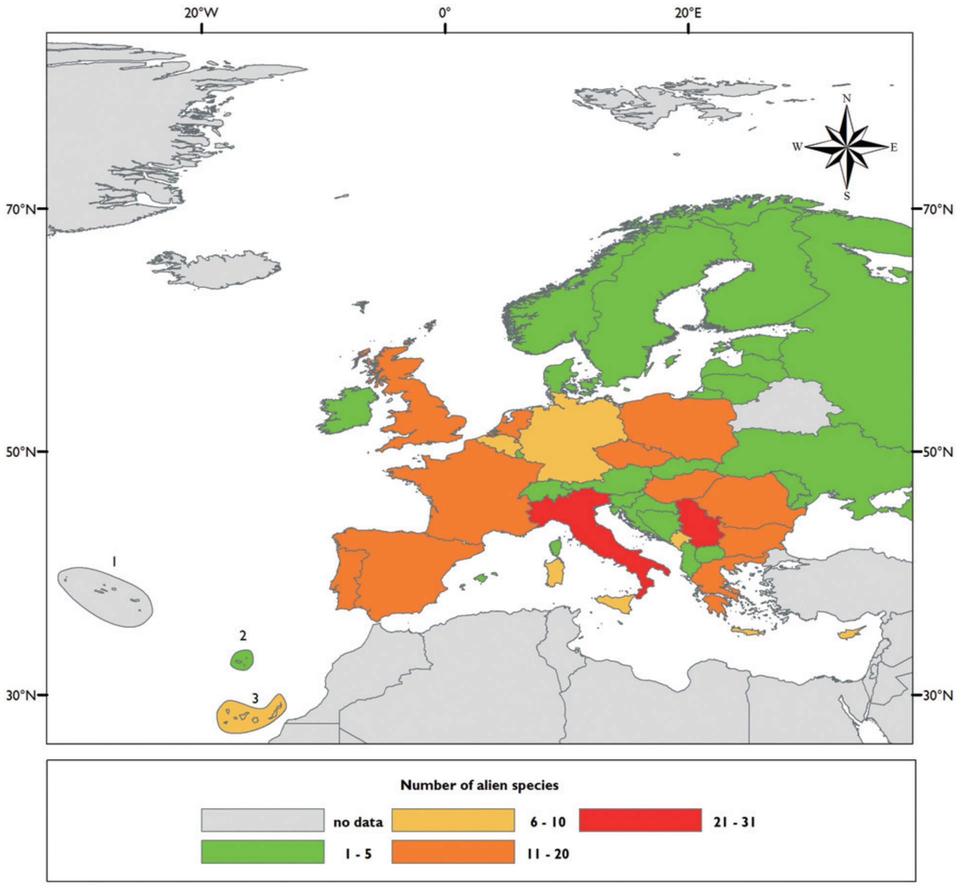

Figure 7.4.4. Comparative colonization of continental European countries and islands by mite species alien *to* Europe. Archipelago: **1** Azores **2** Madeira **3** Canary Islands.

Most alien Eriophyids have a very restricted distribution. More than 40% of the species have been observed in only one country (17 species), more than 40% (21 species) in 2–5 countries, and approximately 20% (7 species) in 6–11 countries. Eight European countries have no recorded occurrence of alien eriophyoids to date. Only one species, the pear blister mite *Eriophyes pyri* (which has cryptogenic status), has been recorded from 32 European countries. Besides *E. pyri,* the more widely distributed eriophyoid species are: *Aceria erinea, A. loewi, A. sheldoni, Aculops pelekassi* and *Eriophyes canestrini.* The gall mite *Phytoptus hedericola* (Phytoptidae) entered Europe in 2002 and has been observed in Serbia (Glavendekić et al. 2005). *Trisetacus chamaecypari* (Phytoptidae) entered Europe in 2002 (Ostojá-starzewski and Halstead 2006, Smith et al. 2007). The status of *Typhloctonus squamiger* (Phytoseiidae), a poorly known phytophagous mite found on trees in Italy since 1991 (Rigamonti and Lozzia 1999), is questionable.

The distribution of biological agents belonging to the Phytoseiidae family is well-known. *Phytoseiulus persimilis* is now present in nearly all of Europe (Table 7.4.1)

(EPPO 2002). *Neoseiulus californicus* has been found in the same countries except Austria, Hungary, Morocco, Slovakia, Sweden and Turkey. The third introduced phytoseid mite, *Iphesius degenerans*, is also present in several countries (Table 7.4.1).

The broad mite *Polyphagotarsonemus latus* (Tarsonemidae) is now cosmopolitan. In Europe, it was reported for the first time in 1961 and since then the mite has invaded almost all countries (Table 7.4.1) (CAB-International 1986, Fan and Petit 1998, Natarajan 1988, Parker and Gerson 1994); it is potentially now in all parts of Europe.

Three species of false spider mites (Tenuipalpidae) are major invaders in Europe. *Brevipalpus californicus*, found in 316 orchid and tree species of 67 genera and 33 families, was first recorded in 1960 and is mainly observed in citrus trees around the Mediterranean basin (Denmark 1968, Manson 1967). The privet mite, *Brevipalpus obovatus* is found in 451 herb, ornamental and shrub species (19 genera, 55 families) (Manson 1967) has been recorded from Austria, Cyprus, France, Germany, Israel, Netherlands, Serbia and Spain (Manson 1967). *Tenuipalpus pacificus* (the Phalaenopsis mite) is found in greenhouses of *Phalaenopsis* orchids in Germany, Great Britain, Netherlands and Serbia (Denmark 1968, Manson 1967).

The introduced range of *Varroa destructor* is practically worldwide. It was first reported in Eastern Europe in the mid- 1960s and it has spread rapidly all over the continent. Two different genotypes, characterized by mitochondrial DNA sequences, have spread as independent clonal populations (Solignac et al. 2005), the Korean and the Japanese haplotypes, the latter having been found, besides Asia, in the Americas only.

7.4.5. Pathways of introduction in Europe of alien mite species

Although colonisation routes are poorly documented for the Tetranychidae, it is known that many species travel with their host plant. Small organisms like tetranychids are easily transported with plant material (leaves and in bark crevices). Only five species feed mainly on herbaceous plants (*Tetranychus evansi*, *T. macfarleni*, *T. sinhai*, *Schizotetranychus parasemus*, and *Petrobia lupini*), whereas all other alien species in the family feed on perennial shrubs.

As for tetranychids, the horticultural and ornamental trade is probably the most important factor for accidental introductions of almost all species of alien Eriophyoidae. Just a few species of Eriophyoids are on European quarantine lists, as plants are rarely inspected for presence of these mites. Infested plant material is not regularly intercepted at borders even in the case of important pests such as the grape rust mite *Calepitrimerus vitis* (Nalepa) or the blackberry fruit mite *Acalitus essigi* (Hassan), which are frequently disseminated with plant seedlings. During recent decades more than 50% of aliens were imported with ornamental plants. Among eriophyids, which are obligate plant parasites, only one trophic group which is associated with weeds, can be subject to intentional introduction. Although these mites were recently nominated as potential agents for classical biological control of weeds (few species are imported for this purpose), they have not yet been used for this purpose in Europe. Four species of alien eriophyoids which were probably introduced along with their host plants may have the potential as biological control agents of serious alien weed pests. In particular, *Aceria ambrosiae* can be used against the allergenous weed *Ambrosia artemisifolia* L. that was imported into Europe from North America.

As for other phytophagous species, the broad mite *Polyphagotarsonemus latus* (Tarsonemidae) has mainly been dispersed by human activities, but also by wind or insect transfer. Movement by insects should not be neglected: this concerns almost only females that get attached to the legs of aphids and the whiteflies *Bemisia argentifolii* (Bellows and Perring), *Bemisia tabaci* (Gennadius) and *Trialeurodes vaporariorum* (Westwood) (Homoptera: Aleyrodidae) (Fan and Petit 1998, Natarajan 1988, Parker and Gerson 1994).

Although including important crop pest species, the dispersal potential of false spider mites (*Brevipalpus* spp.), Tenuipalpidae, remains unclear (Childers et al. 2003a, 2003b).

Intentional introductions of mites represent a low proportion of alien arrivals. Only three phytoseeid predators were introduced purposely for biological control and have established. Some of these biological control agents were released in the field but others were first released in glasshouses, and then escaped and became established outdoors.

International travel and commerce has facilitated the dispersal of *Varroa destructor*. Once established in a new region, the mite spreads using drifting, robbing, and swarming behaviour of the host. Human mediated varroa dispersion also occurs via apicultural practices.

7.4.6. Ecosystems and habitats invaded in Europe by alien mite species

Alien mites established in Europe predominantly live in agrosystems or anthropogenic environments (ca. 92%; Figure 7.4.5). This is especially verified in Tetranychidae and Eriophyidae. Among eriophyoids, some are present in man-made habitats, parks and gardens (22 species), agricultural lands (13 species), and greenhouses (10 species); very few species inhabit woodland and forest, costal, alpine or sub alpine habitats. Most alien species in this superfamily are leaf vagrants (13 species). Twelve species cause leaf galls, *erinea** and leaf rolling, 11 cause leaf and/or fruit russeting or other type of discolouration, six live predominantly in buds causing bud galls, three species cause stunting of whole plants and/or plant organs and two cause flower and/or fruit deformations. Among the leaf gall makers, the most important horticultural pests are distributed in many European countries, such as *E. pyri, A. erinea, A. tristriata* or, such as *A. fuchsiae* which is on quarantine lists. Among the rust mites, only a few are important horticultural pests like *A. theae, A. pelekassi* and *C. carinatus.* Most species are pests of ornamental trees, shrubs or flowering plants, having an important aesthetic impact on plants in parks and streets in most European towns and cities (i.e. *A. gleditsiae, A.ligustri, A. petanovicae, S. strobicus, P. chrysanthemi*), an exception being *A. sawatch-*

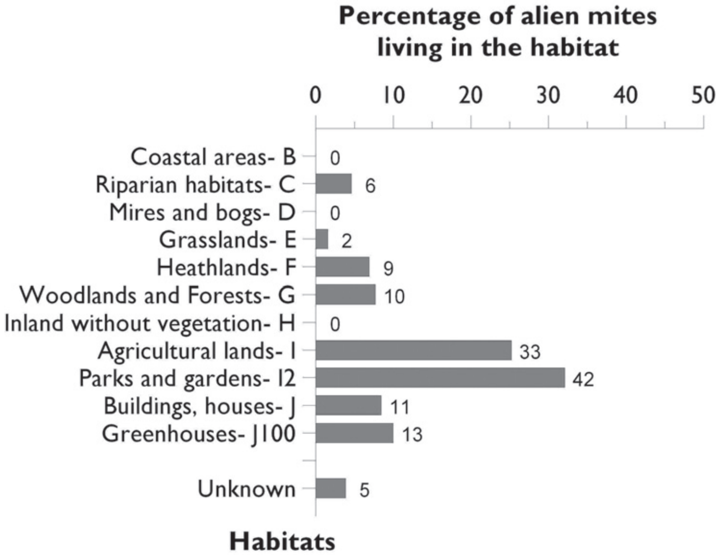

Figure 7.4.5. Main European habitats colonized by the established alien species of mites. The number over each bar indicates the absolute number of alien dipterans recorded per habitat. Note that a species may have colonized several habitats.

ensae which inhabits weeds. Two Eriophyoids which cause plant stunting, *A. paradianthi* and *T. califraxini,* are important pests of ornamental plants and one species, *A. ambrosiae,* is a potential biocontrol agent against the alien weed *Ambrosia artemisifolia.* Two species which cause flower and/or fruit deformations, *A. alpestris* and *A. sheldoni,* are respectively pests of *Rhododendron* and citrus trees.

The gall mite *Phytoptus hedericola* lives on ivy (*Hedera helix* L.) and *Trisetacus laricis* switched from American larch to European larch (*Larix decidua* Mill.).

The broad mite *Polyphagotarsonemus latus* (Tarsonemidae) has a very short life cycle of a few days, damaging crops abruptly. Being highly polyphagous, the species has been reported on 57 plant families (Gerson 1992) both in open field crops and in greenhouses. This is an important pest of crops and ornamental plants such as azaleas, castor bean, chillies, citrus fruits, cotton, cucumber, mango, papaya, pepper, potato, sweet potato, tea, tomato and winged bean (Gerson 1992, Glavendekić et al. 2005, Heungens 1986, Raemaekers 2001). Nevertheless, in Europe this mite is found mainly in greenhouses because the mite cannot survive winter conditions outdoors.

False spider mites (*Brevipalpus* spp.; Tenuipalpidae) present a risk of invasion in greenhouses. *Brevipalpus obovatus* (the privet mite) is found on ornamentals and shrubs like citrus and azaleas and could become of great importance in glasshouses for ornamentals (Childers et al. 2003a, 2003b). *Tenuipalpus pacificus* (the Phalaenopsis mite) is one of the rare monophagous mites in the family, but it is a very destructive pest of orchids under greenhouses, mainly because it has several generations per year and has a two-month life cycle (Denmark 1968, Manson 1967).

A Pyroglyphidae mite, *Dermatophagoides evansi*, is a cosmopolitan free-living species, often encountered in synanthropic situations and has probably been accidentally introduced by humans (Bigliocchi and Maroli 1995, Hughes 1976).

7.4.7. Ecological and economic impact of alien mite species

Seven species of alien Tetranychidae are important pests. On citrus, four alien species are found: *Panonychus citri*, *Eotetranychus lewisi* (also on grapes) *Eutetranychus banksi* and *E. orientalis,* the last presently spreading to Southern Portugal and Spain from Huelva to Murcia and Alicante. *Oligonychus perseae* is found on avocado and produces very severe damage in southern Spain (Malaga, Granada and Huelva) and in the Canary Islands. *Stigmaeopsis celarius* is found on bamboos and causes important visual damage to these ornamental plants. *Tetranychus evansi* is found on solanaceous crops and can reach very high density as observed in France, Spain and Canary Islands. All these mites are present in the Mediterranean Basin, which appears to be the region most threatened by alien species. Only two of these species can be found outside the Mediterranean area: *Panonychus citri*, especially in glass-houses, and *Stigmaeopsis celarius*.

In humid citrus-growing regions of the world, eriophyoid mites are considered to be the major mite pests (Jeppson et al. 1975, McCoy 1996). Two alien species, *Aceria sheldoni* and *Aculops pelekassi*, distributed worldwide, are among the most important pests infesting citrus. The pear blister mite, *Eriophyes pyri,* widely distributed in Europe, probably does little harm to the tree, but in severe infestations, the tree leaves may become disfigured, and most importantly the mite may damage fruits (Easterbrook et al. 2008). Besides fruit orchards, species in the superfamily inhabiting wild trees in natural forests are: *Aceria tristriata* and *A. erinea* which appear to be the most common and most injurious eriophyoids found on *Juglans regia* L. (Castagnoli and Oldfield 1996). Among the five species of eriophyoid mites reported from commercially important beverage crops in different parts of the world, wherever tea is grown, the purple tea mite *Calacarus carinatus* and the pink tea mite *Acaphylla theae* are economically important in Southeast Asian countries, and in India (Channabasavanna 1996). Both species are aliens to Europe, reported from mainland Italy (*A. theae*) and from Hungary, Poland and Spain (*C. carinatus*). Records concerning host plant range in the case of *C. carinatus* are, besides tea, *Viburnum opulus* L. and *Capsicum annuum* L. (Amrine and Stasny 1994). Bearing in mind that congeneric *Calacarus citrifolii* has an extremely wide host range (Oldfield 1996), this might be also the case for *C. carinatus,* which would convey on the latter serious pest status in Europe. Economic impact of alien pest species of eriophyoids on ornamentals has been observed for *Aculops gleditsiae* on honey locust, *Aceria petanovicie* on lilac, *Aculops ligustri* on privet hedges, *Aculops allotrichus* on black locust, *Reckella celtis* on *Celtis australis* L., *Shevtchenkella brevisetosa* on *Acer negundo, Vasates quadripes* on silver maple, *Phytoptus hederae* on English ivy, and *Setoptus strobicus* on *Pinus strobus* L. (Petanović 2004). Flower and foliage aesthetic impact has been observed indoors (business centers, restaurants, shopping centers, hotels, etc.) for a few alien eriophyoids, *Cecidophyopsis hendersoni* causing a powdery

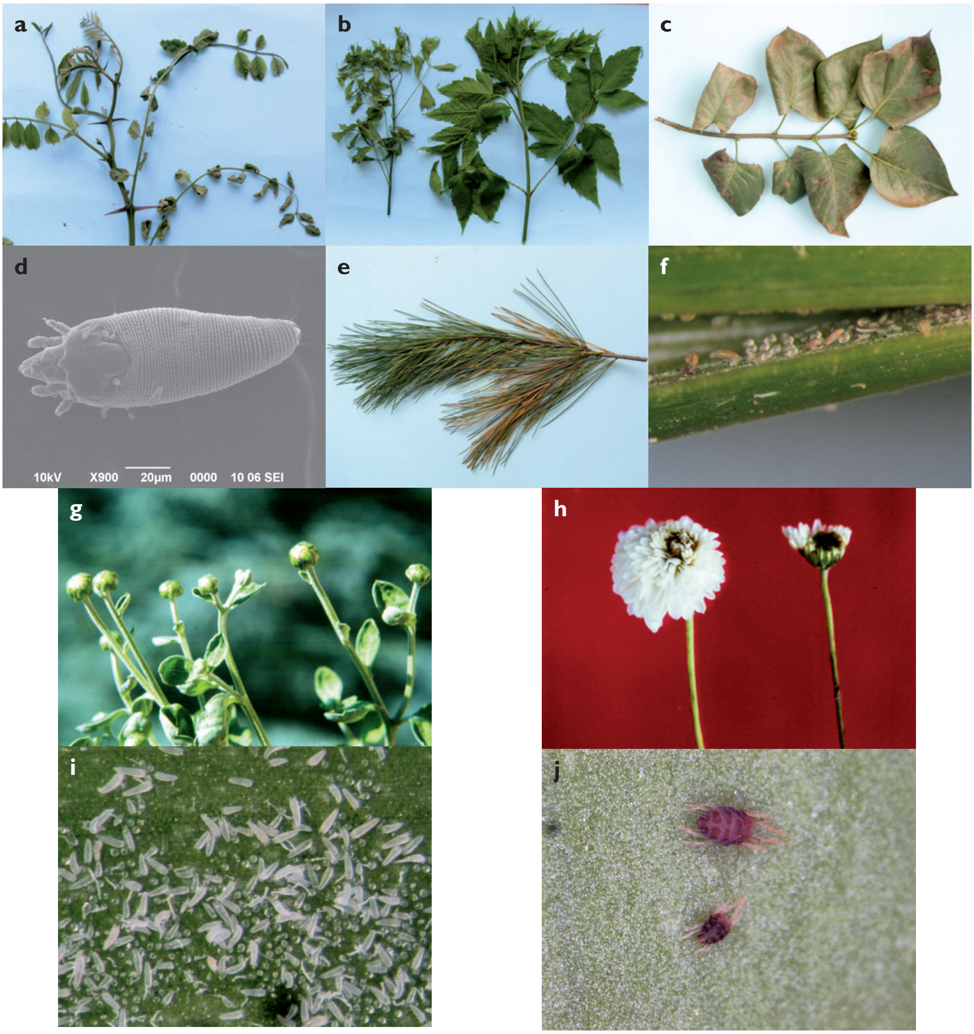

Figure 7.4.6. Alien mites and their damage. **a** Curling and rusting of black locust leaves caused by *Aculops allotrichus* **b** Chlorotic and misshapen leaves of *Acer negundo* caused by *Shevtchenkella brevisetosa* (left) and uninfested leaves (right) **c** Leaf rusting of lilac leaves caused by *Aceria petanovicae* **d** *Aceria petanovicae*, dorsal view-SEM photograph **e** Rusting of *Pinus strobus* needles caused by *Setoptus strobacus* **f** *Setoptus strobacus* eggs, juveniles and adults between needles of *Pinus strobus* **g** Leaf distortion and unopened damaged flower buds of chrysanthemum caused by *Paraphytoptus chrysanthemi* **h** Deformed flower heads of chrysanthemum caused by *Paraphytoptus chrysanthemi* **i** Colony of *Cecidophyopsis hendersoni* on *Yucca* leaf **j** *Panonychus citri*. (**a–i** Credit: Radmila Petanović; **j** Credit: Alain Migeon).

appearance on *Yucca* leaves, *Cosetacus cameliae* causing bud rust and abortion on flower buds of *Camelia* plants, and *Paraphytoptus chrysanthemi* causing deformed buds, hairy leaves and rust on *Chrysanthemum* (Petanović 2004).

The broad mite *Polyphagotarsonemus latus* (Tarsonemidae) and the false spider mites (*Brevipalpus* spp.) (Tenuipalpidae) are major pests of great agronomical importance because of their broad host range, worldwide distribution and economic impact (CAB-International 1986, Fan and Petit 1998, Gerson 1992, Heungens 1986, Natarajan 1988, Parker and Gerson 1994, Raemaekers 2001). The most important threat for *Brevipalpus* spp. is the spread of citrus viruses (Childers et al. 2003b).

Among parasitic mites, the hair mites (muskrat mites) are currently considered non-pathogenic for humans although they are sometimes found in the fur of other mammals. *Laelaps echidninus* (Laelapidae) is a common worldwide ectoparasite of the spiny rats (hystricognath rodents), wild brown rat and is occasionally found on the house mouse, cotton rat and other rodents. It is a bloodsucking mite and the natural vector of *Hepatozoon muris* Balf. (Protozoa, Adeleidae), a haemogregarine parasite pathogenic for white rats (Smith et al. 2007) but which should not be overlooked as a possible vector of disease to humans (Wharton and Hansell 1957). *Ornithonyssus bacoti* (Macronyssidae) is a parasite of rats and inhabits the area in and around the rat's nesting area. This mite is the only one of the common rat mites which frequently deserts domestic rats to bite man or his domestic and laboratory animals (Cole et al. 2005). It is also a bloodsucking mite and its bite is painful and causes skin irritation, itching and skin dermatitis in humans (James 2005). *Ornithonyssus bacoti,* is a known vector of the murine filarial nematode *Litomosoides carinii* Travasaos. In addition, it is susceptible to the transmission of endemic typhus, *Rickettsia typhi* (Wolbach and Todd) 1943 (= *R. mooseri* Monteiro) to humans (Berggren 2005, Bowman et al. 2003).

Epidermoptes bilobatus (Epidermoptidae) is a bird parasite causing avian scabies. This endoparasite burrows into the skin causing inflammation and itchiness. The skin thickens with brownish-yellow scabs, which may become secondarily infected with a fungus. It is difficult to control and can cause death. Culling infested birds is usually required (Department of the Environment and Heritage 2006). *Ornithonyssus bursa* (Macronyssidae) is an haematophagous natural parasite of common birds including pigeons, starlings, sparrows, Indian mynahs, poultry, robin (Berggren 2005). These pest mites and parasites are and will remain a long term problem for poultry housing (Gjelstrup and Møller 1985). Although none of these two species of mites are truly parasitic on humans and pets, they readily bite humans and are liable to cause allergies and dermatitis in human (Denmark and Cromroy 2008, James 2005). *Dermatophagoides evansi* (Pyroglyphidae), and a species alien *in* Europe, *Glycyphagus domesticus* (Glycyphagidae), have been accidentally introduced by humans and often encountered in synanthropic situations (Bigliocchi and Maroli 1995, Hughes 1976, Thind and Clarke 2001). *Glycyphagus domesticus* also occurs in bird, bat and mammal nests. It is associated with moist and humid conditions that promote the growth of mould on which they feed (Thind and Clarke 2001). *Dermatophagoides evansi* (Pyroglyphidae) feeds on detritus and is also found in house dust, birds' nests and poultry houses (Piotrowski 1990, Razowski 1997). *Dermatophagoides evansi* represents a source of airborne allergens in indoor house dust (Eriksson 1990, Musken et al. 2000) that may cause sensitization, dermatitis, rhinopharyngitis and asthma especially among farmers.

The honeybee ectoparasite *Varroa destructor* causes serious losses through feeding injury in apiaries in Europe but also almost worldwide. While the populations of the

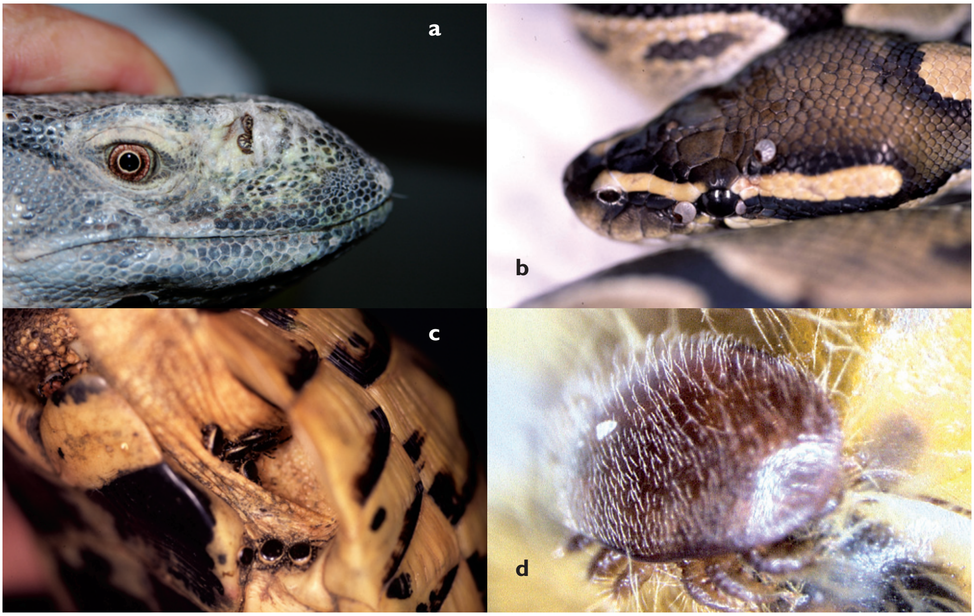

Figure 7.4.7. Ixodidae ticks on tortoises and snakes. **a** Hyalomma aegyptium on tortoise **b** Amblyomma exornatum semi-engorged on Python head **c** Amblyomma sp. on snake head (Credits: Nicasio Brotons) **d** Female of *Varroa destructor* on abdomen of *Apis mellifera* (Credit: Alain Migeon).

parasite reach only a small size within colonies of *A. cerana* and do not damage the colony, infested *A. mellifera* colonies die. The problems with varroa control are typical of those encountered in curbing arthropod pest population. Varroas are becoming resistant to the acaricides used by beekeepers to control them. The recent discovery in several parts of the world (notably the United States of America (Harbo and Harris 2005) and Europe (Le Conte et al. 2007)) of honeybee bee colonies able to tolerate heavy infestations of *V. destructor* opens the door to lasting solutions for controlling the parasite.

A positive impact is recognized for the three mite species deliberately introduced to Europe for biological control of house flies and tetranychid mites. *Phytoseiulus persimilis* and *N. californicus* are two well-known biological control agents used against spiders mites such as *Tetranychus urticae* Koch (Garcia Mari and Gonzalez-Zamora 1999, Helle and Sabelis 1985) and *Phytonemus pallidus* (Banks) (James 2005). The third introduced mite, *Iphiseius degenerans,* targets numerous species of thrips (van Houten and van Stratum 1993, van Houten and van Stratum 1995), e.g. *Thrips tabaci* Lindeman and *Frankliniella occidentalis* (Pergande) (Albajes et al. 1999, Bartlett 1992, McMurtry and Croft 1997, Sengonca et al. 2004).

7.4.8. Alien tick species: case studies

It is difficult to ascertain if a tick may have permanent populations outside of its native range or, to the contrary, they are just isolated records. In some cases, a few examples of a given species have been reported for a small area or found over non-resident hosts. This may result from the introduction of a few specimens, commonly immature stages. The most important means of introduction and expansion of ticks (provided that suitable climate and host is available) is by means of engorged females, because of their huge potential to lay thousands of eggs.

The movements of domestic ungulates have introduced some tick species, that may be considered to produce permanent and viable populations out of their native range. An example is the introduction of *Hyalomma dromedarii* into the Canary Islands, by the importation of dromedaries (*Camelus bactrianus* L.). The native range of this tick is northern Africa where *C. bactrianus* is the main adult host, and *H. dromedarii* is abundant in wide areas of Mauritania and Morocco. The current population of dromedaries in the Canary Islands was introduced from Morocco at the end of 18th Century, and it seems that this tick came into these islands using dromedary hosts. *H. dromedarii* may use a wide range of hosts in immature stages, thus increasing risk of spread and permanent establishment (Apanaskevich and Horak 2008, Apanaskevich et al. 2008). It is difficult, however, to assess the reliability of records of *Hyalomma anatolicum excavatum*. A recent review of the original two subspecies (*H. a. anatolicum* and *H. a. excavatum*), concluded that they should be considered as separate species, although the matter is hard to decide as both taxa have a well defined allopatric range (Apanaskevich 2003). *H. excavatum* is restricted to central and eastern Asia and *H. anatolicum* colonizes wide areas of northern Africa. The records of *H. excavatum* from Bulgaria, Albania, Greece, and Italy should be cautiously treated, as they may probably represent *H. anatolicum* imported from northern Africa with domestic ungulates, as is the case for *Hyalomma detritum*. The formerly recognized species *H. detritum*, restricted to northern Africa, is now considered to be a synonym of the European *H. scupense*, which occurs not only in scattered localities of mainland Europe but is present in wide areas of northern Africa. Similarly, caution should be also applied for the single record of *Hyalomma truncatum* in the Canary islands. This tick is currently known to be restricted to parts of Asia, while a close species, *H. rufipes*, is common in sub-saharan Africa. While the adults of *H. rufipes* feed on a variety of hosts, including domestic ungulates, the immature stages commonly attach to diverse passerine birds. Most of these birds perform long distance travel in their migratory flights from Africa to Europe, and they have been found carrying hundreds of immature ticks (Hoogstraal 1956). However, as mentioned above, it is difficult for a population of nymphs to produce a viable and permanent population of resident ticks. To our knowledge, *H. rufipes* has been recorded only in Cyprus and Macedonia (Apanaskevich and Horak 2008), and we still do not know if these are permanent populations or only accidental records on their passerine hosts on migration to lower latitudes from sub-saharan Africa.

The scenario for the tortoise tick, *Hyalomma aegyptium*, is however different. Its presence outside northern Africa has been reported in countries such as Romania, Spain, Italy, Greece, Bulgaria, Croatia, and even farther north in Belgium (Siroky Pet al. 2007). The tick has permanent populations in areas of southern Russia (Robbins et al. 1998). There have been also introductions of this tick by tortoises imported form northern Africa or eastern Europe, where this tick is common. The only record of a permanent population of *H. aegyptium* as a consequence of an accidental importation recorded for eastern Spain (Brotóns and Estrada-Peña 2004). Since the ticks attach to portions of the neck and legs of the host body, it may be difficult to find feeding stages even after careful observation of the hosts. In the reported case of introduction of several specimens of *Testudo graeca* infested by ticks, the hosts were kept in a large private garden with a Mediterranean-type climate and vegetation. After some years of recurrent tick parasitism in the tortoises without new importations and repeated treatments, it was realized that the tick had permanent populations in the garden, and the hosts became infested according to the seasonal activity of the ticks.

An interesting case of tick introduction into mainland Europa are ticks commonly found on snakes, like *Amblyomma latum* and *A. exornatum* (both formerly in the genus *Aponomma*). These ticks feed for a long period on the host, and owing to their small size and preference to feed under host scales, they are commonly unrecognized while importing a host out of its native range. *Amblyomma latum* is a very common parasite of *Python spp*., which is becoming increasingly popular as a pet in Europe. The only known case of an importation of *A. exornatum* was noticed on specimens of *Varanus niloticus* that arrived into Spain (Estrada-Peña (Unpubl.)). These imported ticks founded a permanent population in the terrarium where the lizards live, under suitable conditions of high relative humidity and controlled temperature.

A very peculiar case of tick introduction is an alien *in* Europe, the brown dog tick, *Rhipicephalus sanguineus*. While feeding on domestic dogs, this tick is endophilic and is normally restricted to the Mediterranean region, being abundant in kennels, human constructions and private gardens where dogs remain unprotected against tick bites. Because of its endophilic behaviour, this tick may survive independently of prevailing environmental conditions, since human habitations buffer harsh climate. Therefore, unprotected pets travelling may harbor feeding ticks, and introduce them to uninfested areas which might be far from their native range. Such cases of introduction have been commonly recorded in the United Kingdom and northern European countries (Garben et al. 1980, Sibomana et al. 1986), as well as in Czech Republic (Černý 1985). Although there are as yet no reports of its establishment outdoors, this tick could become established out of its former native range as a consequence of global warming.

References

Albajes R, Gullino ML, van Lenteren JC, Elad Y (1999) Biological control of thrips. In: *Integrated Pest and Disease Management in Greenhouse Crops*. The Netherlands: Springer. pp. 244–253.

Alcázar MD, Aranda G, Márquez AL, Sánchez L, Ruiz C (2005) *Oligonychus persea* (Acari: Tetranychidae); una nueva plaga en el aguacate en el Sur de España. *IV Congresso Nacional de Entomología Aplicada - X Jornadas Científicas de la SEEA - I Jornadas Portuguesas de Entomologia Aplicada*, Bragança - Portugal: 213.

Amrine JW Jr, Stasny TAH (1994) *Catalog of the Eriophyoidea* (*Acarina, Prostigmata*) *of the World*. West Bloomfield, Michigan: Indira Publishing House. 531 pp.

Anagnou-Veroniki M, Papaioannou-Souliotes P, Karanastasi E, Giannopolitis CN (2008) New records of plant pests and weeds. *Hellenic Plant Protection journ*al, 1: 55–78.

Apanaskevich DA (2003) Differentiation of closely related species *Hyalomma anatolicum* and *H. excavatum* (Acari, Ixodidae) based on a study of all life cycle stages, throughout their entire geographical range. *Parazitologiya* 37: 259–280.

Apanaskevich DA, Horak IG (2008) The genus *Hyalomma* Koch, 1844: V. Re-evaluation of the taxonomic rank of taxa comprising the *H.* (*Euhyalomma*) *marginatum* Koch complex of species (Acari: Ixodidae) with redescription of all parasitic stages and notes on biology. *International Journal of Acarology* 34: 13–42.

Apanaskevich DA, Santos-Silva M, Horak I (2008) The genus *Hyalomma*, Koch 1844. IV. Redescription of all parasitic stages of *H.* (*Euhyalomma*) *lusitanicum* Koch, 1844 and the adults of *H.* (*E.*) *franchinnii* Tonelli Rondelli, 1932 (Acari: Ixodidae) with a first description of its immature stages. *Folia Parasitologica* 55: 61–74.

Aucejo S, Foo M, Gimeno E, Gomez-Cadenas A, Monfort R, Obiol F, Prades E, Ramis M, Ripolles JL, Tirado V, Zaragoza L, Jacas JA, Martinez-Ferrer MT (2003) Management of *Tetranychus urticae* in citrus in Spain: acarofauna associated to weeds. *Bulletin OILB/SROP* 26: 213–220.

Auger P, Migeon A (2007) Les tétranyques des bambous en France. *PHM Revue Horticole* 488: 17–19.

Balevski A (1967) [Tetranychid mites occuring on fruit crops] (in Bulgarian). *Izvestija na Instituta za Zastita na Rastenijata*, *Gara Kostinbrod*: 157.

Bartlett PW (1992) Experience of polyphagous pests of protected crops in Great Britain. *EPPO Bulletin* 22: 337–346.

Battelli C, Catteruccia G, Sobrero L (1977) *Hyalomma excavatum* Koch in Italia. *Atti Societá italiana di Scienze veterinarie* 31: 741–743.

Bauer CA, Whitaker JOJ (1981) Ectoparasites of muskrats from indiana with special emphasis on spatial distribution of coexisting mites of the genus *Listrophorus*. *American Midland Naturalist* 105: 112–123.

Bebić N (1955) [Pests in Kosmet during 1953 and 1954] (in Serbian). *Plant protection*, 30: 85–91.

Berggren Å (2005) Effect of the blood-sucking mite *Ornithonyssus bursa* on chick growth and fledging age in the North Island robin. *New Zealand Journal of Ecology* 29: 2430–2500.

Bernini F, Castagnoli M, Nannelli R (1995) Arachnida Acari. In Minelli A, Ruffo S, La Posta S (Eds) *Checklist delle specie della fauna italiana, 24*. Bologna: Calderini, 24–66.

Bigliocchi F, Maroli M (1995) Distribution and abundance of house-dust mites (Acarina: Pyroglyphidae) in Rome, Italy. *Aerobiologia* 11: 35–40.

Boczek J (1964) Studies on mites (Acarina) living on plants in Poland. IV *Bulletin de l'Académie des Sciences Polonaises* 12: 365–369.

Boczek J, Kropczynska D (1964) Studies on mites (Acarina) living on plants in Poland I. *Fragmenta Faunistica Warszawa* 11: 161–188.

Bolland HR, Gutierrez J, Flechtmann CHW (1998) *World catalogue of the spider mite family* (*Acari: Tetranychidae*). Leiden: Brill Academic Publishers. 392 pp.

Bowman CE, Bartlett PW (1978). *Panonychus citri* (McGregor) (Acari: Tetranychidae) infesting imported Citrus mitis in England. *Plant Pathology* 27: 201.

Bowman DD, Lynn RC, Eberhard ML (2003) *Georgi's Parasitology for Veterinarians*. 8.ed. St. Louis: Saunders. 422p.

Bozai J (1970) Determination key for spider mites. *Növényvédelen* (*Plant protection*) 10: 455–460

Bozai J (1974) Contributions to the knowledge of the Tetranychoid fauna of Hungary (Acari). *Folia Entomologica Hungarica* 27: 5–7.

Brotóns NJ, Estrada-Peña A (2004) Survival of tick colonies on captive imported reptiles in Spain. In *Abstracts of the 7th International Symposium on pathology and medicine of reptiles and amphibians*. Berlin, Germany.

CAB-International (1986) *Distribution maps of plant pests*. Wallingford, UK.

Carmona MM (1992) Acaros fitofagos e predadores da Ilha da Madeira – II. *Boletín de Sanidad Vegetal, Plagas* 18: 469–482.

Castagnoli M, Oldfield GN (1996) Other Fruit Trees and Nut Trees. In: Lindquist EE, Sabelis MW, Bruin J (Eds) *Eriophyoid Mites, Their Biology, Natural Enemies and Control, 6*. Amsterdam: Elsevier, 543–559.

Castagnoli M, Nannelli R, Simoni S (2006) Un nuovo temibile fitofago per la fauna italiana: *Tetranychus evansi* (Baker e Pritchard) (Acari Tetranychidae). *Informatore Fitopatologico* 2006: 50–52.

Černý V (1985) First case of introduction of the tick *Rhipicephalus sanguineus* to Czechoslovakia. *Folia Parasitologica* 32: 162.

Channabasavanna GP (1996) Sugarcane, coffee and tea. In: Lindquist EE, Sabelis MW, Bruin J (Eds) *Eriophyoid Mites, Their Biology, Natural Enemies and Control, 6*. Amsterdam: Elsevier, 631–640.

Childers CC, French JV, Rodrigues JCV (2003). *Brevipalpus californicus, B. obovatus, B. phoenicis,* and *B. lewisi* (Acari: Tenuipalpidae): a review of their biology, feeding injury and economic importance. *Experimental and Applied Acarology* 30: 5–28.

Childers CC, Rodrigues JCV, Welbourn WC (2003) Host plants of *Brevipalpus californicus, B. obovatus,* and *B. phoenicis* (Acari: Tenuipalpidae) and their potential involvement in the spread of one or more viruses. *Experimental and Applied Acarology* 30: 29–105.

Ciampolini M, Rota P (1972) Presenza in Italia di *Panonychus citri* (McGregor) (Acarina, Tetranychidae). *Bollettino di Zoologia Agraria e di Bachicoltura* 11: 195–205.

Ciglar I, *Barić* B (1998) Pernicious insects and mites fauna in Croatian orhards. *Entomologia Croatica* 4: 63–69.

Cole JS, Sabol-Jones M, Karolewski B, Byford T (2005) *Ornithonyssus bacoti* infestation and elimination from a mouse colony. *Contemporary Topics in Laboratory Animal Science* 44: 27–30.

Colin ME (1982) “La Varroatose.” *Le Point Vétérinaire* 14: 21–28.

Croft BA, Pratt PD, Koskela G, Kaufman D (1998) Predation, reproduction, and impact of phytoseiid mites (Acari: Phytoseiidae) on cyclamen mite (Acari: Tarsonemidae) on strawberry. *Journal of Economic Entomology* 91: 1307–1314.

Dautel H, Kahl O (1999) Ticks (Acari: Ixodoidea) and their medical importance in the urban environment. In: Robinson WH, Rettich F, Rambo GW (Eds) *Proceedings of the Third International Conference on Urban Pests*,19–22 July 1999, Prague, Czech Republic, 73–82.

De Rycke PH, Joubert JJ, Hossein Hosseinian S, Jacobs FJ (2002) "The possible role of Varroa destructor in the spreading of American foulbrood among apiaries." *Experimental and Applied Acarology* 27: 313–318.

Delrio G, Ortu S, Prota R (1979) Aspects of integrated control in the citrus cultures of Sardinia. *Studi Sassaresi* 27: 205–232.

Denmark HA (1968) (revised 2006) Phalaenopsis mite, *Tenuipalpis pacificus* Baker (Acarina: Tenuipalpidae). *Entomology Circular* 74: 1p.

Denmark HA (1978) A mite, *Brevipalpus russulus* (Boisduval 1867) in Florida (Acarina: Tenuipalpidae). *Entomology Circular* 188: 1–2.

Denmark HA, Cromroy HL (2008) Tropical Fowl Mite, *Ornithonyssus bursa* (Berlese) (Arachnida: Acari: Macronyssidae). Bulletin EENY-297. Gainesville, Florida: University of Florida. 3 pp.

Deutsche Dahlien, Fuchsien, Gladiolen und Kübelpflanzen. *Fuchsiengallmilbe*. http://www.ddfgg.de/Allgemein/aktuell/Archiv/index_Fuchsiengallmilbe_2.html.

Dobosz R, Skorupska A, Blaszak C (1995) The appearance of spider mites (Tetranychidae) in parks of Poznan. In: Boczek J, Ignatowicz S, *Materialy z Sympozjum na temat: "Osiagniecia Akarologii w Polsce"*, Komitet Ochrony Roslin Polska Akademia Nauk, Siedlce, 39–42.

Drenski P (1955) Săstav i razprostranenie na kărležite (Ixodoidea) v Bălgarija (s ogled na medicinskoto i veterinarnoto im značenie [Artbestand und Verbreitung der Zecken (Ixodoidea) in Bulgarien (im Hinblick auf ihre medizinische und tierärtztliche Bedeutung)].(in Bulgarian, Russian and German summary). *Bulletin* of the *Institute* of *Zoology* (Sofija) 4–5: 109–168.

Easterbrook MA 1996. Damage and Control of Eriophyoid Mites in Apple and Pear. In: Lindquist EE, Sabelis MW, Bruin J (Eds) *Eriophyoid Mites, Their Biology, Natural Enemies and Control, 6*. Amsterdam: Elsevier, 527–541.

Easterbrook JD, Kaplan JB, Glass GE, Watson J, Klein SL (2008) A survey of rodent-borne pathogens carried by wild-caught Norway rats: a potential threat to laboratory rodent colonies. *Laboratory Animals* 42: 92–98.

Emmanouel NG, Papadoulis GT (1987) *Panonychus citri* (MacGregor) (Tetranychidae) and *Eriophyes medicaginis* K. (Eriophyidae): two important phytophagous mites recorded for the first time in Greece. *Entomologia Hellenica* 5: 3–6.

EPPO (2002) List of biological control agents widely used in the EPPO region. *EPPO Bulletin* 32: 447–461.

Eriksson NE (1990) Allergy screening with Phadiatop and CAP Phadiatop in combination with a questionnaire in adults with asthma and rhinitis. *Allergy* 45: 285–292.

Estación Fitopatolóxica do Areeiro. *Cosetacus camelliae* (*Keifer*). *Camellia flower bud drop*. http://www.efa-dip.org/en/Publicaciones/FTecnicas/Ficha9_1.htm.

Estrada-Peña A, unpublished observations.

Evans WD, Krantz G, Lindquist E (1996) *Acari. The Mites.* Version 13 December 1996. http://tolweb.org/Acari/2554/1996].12.13 in The Tree of Life Web Project, http://tolweb.org/.

Fan Y, Petit FL (1998) Dispersal of the broad mite, *Polyphagotarsonemus latus* (Acari: Tarsonemidae) on *Bemisia argentifolii* (Homoptera: Aleyrodidae). *Experimental and Applied Acarology* 22: 411–415.

Fauna Europaea. http://www.faunaeur.org.

Fauna Italia. *Eriophyidae*. http://www.faunaitalia.it/checklist/invertebrates/families/Eriophyidae.html.

Feider Z (1965) Arachnida, Volumul V, Fascicula 2. Acaromorpha, Suprafamilia Ixodoidea (Capuse). In: *Fauna Republicii Populare Romane*. Bucarest: Editura Academiei Republicii Populare Romane, Romania, 89–104.

Ferragut F, Escudero LA (1999) *Tetranychus evansi* Baker & Pritchard (Acari, Tetranychidae), una nueva araña roja en los cultivos horticolas españoles. *Boletín de Sanidad Vegetal*, *Plagas* 25: 157–164.

Ferragut F, Escudero LA, Olmeda T (1997) *Tetranychus evansi* Baker & Pritchard (Acari: Tetranychidae), una nueva araña roja en los cultivos hortícolas españoles. *Resúmenes de las VI Jornadas Científicas de la Sociedad Española de Entomología Aplicada*. Leida, Spain: Edicións Universitat de Lleida: 66.

Ferragut F, Santonja MC (1989) Taxonomia y distribucion de los acaros del genero *Tetranychus* Dufour 1832 (Acari: Tetranychidae), en Espana *Boletín de Sanidad Vegetal*, *Plagas* 15: 271–281.

Ferreira MA, Carmona MM (1995) Acarofauna do tomateiro em Portugal. *Avances en Entomologia Ibérica, Museo Nacional Ciencias Naturales y Universidad de Madrid*: 385–392.

Garben AF, Bosman BT, Bronswijk JEMH v (1980) [The brown dog tick *Rhipicephalus sanguineus* Latreille 1806 in the Netherlands, an analysis of imported cases, including their veterinary and medical significance] (in Dutch). *Tijdschrift voor Diergeneeskunde* 105: 192–203.

Garcia E, Marquez AL, Orta S, Alvarado P (2003) Caracterizacion de la presencia de *Eutetranychus banksi* (McGregor) y *Eutetranychus orientalis* (Klein) en el Sur de Espana. *Phytoma - España* 153: 90–96.

Garcia Mari F, de Rivero JM (1981) El acaro rojo *Panonychus citri* (McGregor), nueva plaga de los citricos en Espana. *Boletin del Servicio de Defensa contra Plagas e Inspeccion Fitopatologica* 7: 65–77.

Garcia Mari F, Gonzalez-Zamora JE (1999) Biological control of *Tetranychus urticae* (Acari: Tetranychidae) with naturally occurring predators in strawberry plantings in Valencia, Spain. *Experimental and Applied Acarology* 23: 487–495.

Gerson U (1992) Biology and control of the broad mite, *Polyphagotarsonemus latus* (Banks) (Acari: Tarsonemidae). *Experimental and Applied Acarology* 13: 163–178.

Gjelstrup P, Møller AP (1985) A tropical mite, *Ornithonyssus bursa* (Berlese, 1888) (Macronyssidae, Gamasida) in Danish Swallow (*Hirundo rustica*) nests, with a review of mites and ticks from Danish birds. *Entomologiste Meddelelser* 53: 119–125.

Glavendekić M, Mihajlović LJ, Petanović R (2005) Introduction and spread of invasive mites and insects in Serbia and Montenegro In Plant protection and plant health in Europe. In: *Abstracts of the Conference Plant Protection and Plant Health in Europe, 'Introduction and spread of invasive species'*, Berlin, Germany: Humboldt University, June 2005.

González Núñez M, Budia F, Viñuela E, Esteban Durán JR, Adan A, Medina P, Schneider M, Del Estal P (2002) Primera cita en España del eriófido de la alcachofa *Aceria neocynarae* (Keifer). *Boletín de Sanidad Vegetal, Plagas* 28: 415–418.

Griffiths DA, Bowman CE (1981) "World distribution of the mite *Varroa jacobsoni*, a parasite of honeybee." *Bee World* 62: 154–163.

Guttierez J, Kreiter S, Brain F, Cotton D (1986) Les acariens, ravageurs mal connus du cypress. *Phytoma-La défense des végétaux* 376: 47–48.

Hadžistević D (1955) [Occurence of agricultural pests during twenty years (1934–1953) in Yugoslavia]. *Plant protection* (in Serbian) 27: 89–120.

Harbo JR, Harris JW (2005) Suppressed mite reproduction explained by the behavior of adult bees. *Journal of Apicultural Research* 44: 21–23.

Hance T, Neuberg P, Noel-Lastelle C (1998) The use of fecundity, lobe biometry and the RAPD-PCR technique in order to compare strains of *Tetranychus sp. Experimental & Applied Acarology*, 22: 649–666.

Hatzinikolis EN (1968) Liste d'acariens de la sous-famille Tetranychinae trouvés sur les plantes cultivées en Grèce. *Annales de l'Institut Phytopathologique Benaki* 8: 193–194.

Hatzinikolis EN (1970) Neuf espèces d'acariens signalées pour la première fois en Grèce. *Annales de l'Institut Phytopathologique Benaki* 9: 238–241.

Hatzinikolis EN (1986) The genus *Tetranychus* Dufour, 1832, in Greece (Acari : Tetranychidae). *Biologia Gallo-hellenica* 12: 383–388.

Helle W, Sabelis MW (eds.) 1985. *Spider mites: their biology, natural enemies and control. Vol. 1A*. Amsterdam, The Netherlands: Elsevier. 405 pp.

Hetenyi E (1954) A gyapoton é lö takacsatkak (*Tetranychus urticae* Koch) és az ellen ük valo védekezés. *Növényvédelen* (*Plant protection*) 1: 11–19.

Heungens A (1986) Soft-skinned mites in azalea culture and comparable control results on other host plants. *Verbondsnieuws voor de Belgische Sierteelt* 30: 257–269.

Hoogstraal, H. (1956) *African Ixodoidea. Ticks of the Sudan*. Cairo, Egypt: U.S. Naval Medical Research Unit., 1099 pp.

Hoogstraal H (1979) The epidemiology of tick-borne Crimean-Congo hemorrhagic fever in Asia, Europe and Africa. *Journal of Medical Entomology* 15: 307–417.

Hughes AM (1976) *The mites of stored foods and houses. Technical bulletin of the ministry of agriculture*. London: Technical Bulletin of the Ministry of Agriculture, Fisheries & Food, No. 9. 400 pp.

James DK (2005) *Biting mites in homes of Alameda county*. Alameda County Vector Control Services District. http://www.acvcsd.org/ biting_mites.pdf.

Jeppson LR, Keifer HH, Baker EW (1975) *Mites injurious to economic plants*. Berkeley, California: University of California Press. 614 pp.

Keifer HH (1975) Injurious eriophyoid mites. In Jeppson LR, Keifer HH, Baker EW (eds.) *Mites injurious to economic plants*. Berkeley, California: University of California Press, 397–533.

Krantz GW, Walter, D.E. (eds.) 2009. *A manual of Acarology, 3rd Edition*. Lubbock, Texas: Texas Tech University Press, 807 pp.

Kropczynska D (1984) The role of predaceous mites (Phytoseidae) as natural enemies of *Eotetranychus tiliarium* (Hermann) in town conditions. *Publications of Warsaw Agricultural University, SGGW-AR* (*Treatises and Monographs*): 1–68.

Labanowski GS (1999) Occurrence and chemical control of introduced ornamental glasshouse pests in Poland. OEPP/*EPPO Bulletin*, 29, 73–76.

Le Conte Y, de Vaublanc G, Crauser D, Jeanne F, Rousselle JC, Bécard JM (2007) Honey bee colonies that have survived *Varroa destructor*. *Apidologie* 38: 566–572.

Manson DCM (1967) Mites of the families Tenuipalpidae and Tetranychidae intercepted entering New Zealand from overseas. *New Zealand Journal of Science 10*: 664–674.

Margolies DC (1993) Adaptation to spatial variation in habitat: spatial effects in agroecosystems. In Ke Chung K, McPheron BA (eds.) *Evolution of insects pests: patterns of variation*. New York: John Wiley & Sons Inc., 129–144.

Margolies DC (1995) Evidence of selection on spider mite dispersal rates in relation to habitat persistence in agroecosystems. *Entomologia Experimentalis et Applicata* 76: 105–108.

Mc Coy CW (1996) Damage and control of Eriophyoid mites in crops. Stylar feeding injury and control of Eriophyoid in citrus. Evolutionary ecology: life history patterns, food plant choice and dispersal. In: Lindquist EE, Sabelis MW, Bruin J (Eds) *Eriophyoid Mites, Their Biology, Natural Enemies and Control, 6*. Amsterdam: Elsevier, 513–526.

McMurtry JA, Croft BA (1997) Life-styles of phytoseiid mites and their roles in biological control. *Annual Review of Entomology* 42: 291–321.

Migeon A (2003) *Eurytetranychus admes*: un nouvel acarien tétranyque sur les cyprès en France. *Phytoma - La Défense des Végétaux*, 561: 30–31.

Migeon A (2005) Un nouvel acarien ravageur en France: *Tetranychus evansi* Baker et Pritchard. *Phytoma - La Défense des Végétaux*, 579: 38–43.

Migeon A (2007) Acarien rouge de la tomate: nouvelles observations et perspectives. *PHM Revue Horticole*, 488: 20–24.

Migeon A, Cros-Arteil S, Navajas M (2004) The use of taxonomical and ecological databases combined with the genetic approach for tracking spidermite invasions. In: Weigman G, Alberti G, Wolhtmann A, Ragusa S Acarine biodiversity in the natural and human sphere. *Phytophaga Berlin,* 14: 757–765.

Mijušković M (1953) [Quelques maladies et insectes nuisibles aux agrumes au Montenegro] (in Serbian). *Zaštita Bilja*, 19: 47–60.

Mijušković M (1973) [*The study of mites on the Citrus trees on the Yugoslav littoral - final technical report*] (in Serbian). Titograd (Podgorica), Montenegro: Agriculture Research Institute, 239.

Mijušković M, Tomašević B (1975) [*The mites on the citrus trees on the Yugoslav littoral*] (in Serbian). Titograd (Podgorica), Montenegro: Society for Sciences and Art of Montenegro. 204 pp.

Morel P-C, Battelli C, Sobrero L (1977) *Hyalomma detritum scupense* Schulze in Italia. *Atti Societá italiana di Scienze veterinari* 31: 739–740.

Morse RA, Goncalves LS (1979) Varroa disease, a threat to world beekeeping. *Gleanings in Bee Culture* 107: 179–181.

Musken H, Franz JT, Wahl R, Paap A, Cromwell O, Masuch G, Bergmann KC (2000) Sensitization to different mite species in German farmers: Clinical aspects. *Journal of Investigational Allergology and Clinical Immunology* 10: 346–351.

Natarajan K (1988) Transport of yellow mite *Polyphagotarsonemus latus* by cotton whitefly. *Current Science* 57: 1142–1143.

Neumann LG (1911) *Ixodidae. Tierreich 26*. Berlin: R. Friedlander und Sohn. 169 pp.

Oldfield GN (1996) Diversity and host plant specificity. I In: Lindquist EE, Sabelis MW, Bruin J (Eds) *Eriophyoid Mites, Their Biology, Natural Enemies and Control, 6*. Amsterdam: Elsevier, 195–216.

Ostoja-Starzewski JC (2000) *Schizotetranychus celarius* (Banks) (Acari: Prostigmata) a mite pest of bamboo; first records for Britain and two new host records. *British Journal of Entomology & Natural History* 13: 95–97.

Ostojá-Strazewski JC, Eyre D, Cannon RJ, Bartlett P (2007) *Update on Fuchsia gall mite* Aculops fuchsiae *Keifer*. Sand Hutton, York, UK: CSL, Plant pest notice. No.5I.

Ostojá-starzewski JC, Halstead AJ (2006) *Trisetacus chamaecypari* Smith (Acari: Phytoptdiae) damaging Leyland Cypress in Britain: a new host and country record for this mite. *British Journal of Entomology and Natural History* 19: 201–205.

Pande YD, Carnero A, Hernandez M (1989) Notes on biological observations on some unrecorded species of phytophagous and predatory mites in Canary. *Islands Investigación agraria, Producción y protección vegetales* 4: 275–281.

Papaioannou-Souliotis P, Tsagarakou A, Dermatas P (1993) Integrated pest control in citrus-groves, evaluation on new acaricides used in the treatment of citrus red mite (*Panonychus citri* Koch.). *Bulletin Oilb/Srop* 16: 125–131.

Parker R, Gerson U (1994) Dispersal of the broad mite, *Polyphagotarsonemus latus* (Banks) (Heterostigmata: Tarsonemidae), by the greenhouse whitefly, *Trialeurodes vaporariorum* (Westwood) (Homoptera: Aleyrodidae). *Experimental and Applied Acarology* 18: 581–585.

Pérez Otero R, Mansilla Vázquez P, Salinero Corral MC, Sainz Oses J (2003) Occurrence of Mites in CamelliaTrees Grown in Parks and gardens in Northwest Spain. *American Camellia Yearbook* 45–50.

Petanović R (1980) Some morphological characteristics of importance in the differentiation of *Panonychus ulmi* Koch. and *Panonychus citri* McGregor (Tetranychidae, Acarina). *Interim report Arhiv Za Poljoprivredne Nauke* 41: 517–522.

Petanović R (1988) *Eriofidne grinje u Jugoslaviji* (*Monografija*). Beograd: Naučna knjiga. 159 pp.

Petanović R (1993) Pregled vrsta eriofida (*Acari: Eriophyoidea*) šumskih i ukrasnih biljaka na prostorima južnoslovenskih zemalja. XXI skup entomologa Jugoslavije. Beograd, 17–18.11.1993. Zbornik rezimea, str. 22.

Petanović R (1997) Allochthonous mite species (Acari) in the fauna of Yugoslavia. *Zastita Bilja* 48: 211–224.

Petanović R (1998) New data to the knowledge on the eriophyoid fauna (Acari: Eriophyoidea) in Yugoslavia. *Acta Entomologica Serbica* 3: 149–157.

Petanović R (1999) Three New Species of Eriophyid Mites (Acari: Eriophyoidea) from Serbia with the Notes on New Taxa for the Fauna of Yugoslavia. *Acta Entomologica Serbica* 4: 127–137.

Petanović R (2004) [*Atlas - Mite pests of decorative plants*] (in Serbian). Beograd: Beografik. 99 pp.

Petanović R (in prep.) *Database of Eriophyoid mite fauna of Serbia*. Still not available on the internet.

Petanović R, Boček J, Jovanović S, Stojnić B (1996) [*Eriophyoidea* (*Acari: Prostigmata*) *Fauna Durmitora, 5*] (in Serbian). CANU, Posebna izdanja, knjiga 32, Odjeljenje prirodnih nauka, knjiga 18, Podgorica.

Petanović R, Dobrivojević K (1987) Kompleks galikolnih eriofida lista šljive. *Zaštita bilja* 38: 145–156.

Petanović R, Dobrivojević K, Boczek J, Lazić S (1983) Eriofidne grinje (*Eriophyoidea: Acarina*) na korovskim biljkama u okolini Beograda. *Arhiv za poljoprivredne nauke* 44, 156 (1983/4): 455–460.

Petanović R, Mihajlović LJ, Mihajlović N, Magud B (1997) *Reckella celtis* Bog. and *Aceria bezzi* (Corti) (Acari: Eriophyoidea). Two new Species in the Balkan Fauna. *Acta Entomologica Serbica* 2: 95–106.

Petanović, R. i S. Stanković (1999) Catalogue of the Eriophyoidea (Acari: Prostigmata) of Serbia and Montenegro. *Acta Entomologica Serbica*, special issue: 1–143.

Piotrowski F (1990) *Zarys entomologii parazytologicznej*. Warszawa: PWN 5. 301 pp.

Raemaekers RHE (2001) *Agriculture en Afrique Tropicale.* Bruxelles: Direction Générale de la Coopération Internationale. 1634 pp.

Ragusa S (2002) As time goes by: a profile of Italian acarology. In Bernini F, Nannelli R, Nazzaci G, De Lillo E (eds) *Acari Phylogeny and Evolution. Adaptations in mites and ticks.* Dordrecht, The Netherlands: Kluwer Academic Publishers, 1–20.

Rambier A (1958) Les acariens nuisibles en cultures fruitières. *Comptes-Rendus des Journées Fruitières et Maraichères, Avignon*: 59–64.

Rambier AM (1982) Un acarien, sur vigne en Champagne, nouveau en France: *Tetranychus mcdanieli* McGregor 1931 du groupe *pacificus. Le Progrès Agricole et Viticole* 99: 261–263

Razowski J (1997) (Ed) *Wykaz zwierząt Polski IV. [Checklist of animals of Poland]* (in Polish). Kraków, Poland: Wydawnictwa Instytutu Systematyki i Ewolucji Zwierząt. 303 pp.

Rigamonti IE, Lozzia GC (1999) Injurious and beneficial mites on urban trees in Northern Italy. *Acta Horticulturae* 496: 177–182.

Ripka G (2007) Checklist of the eriophyoid mite fauna of Hungary (Acari:.Prostigmata: Eriophyoidea). *Acta Phytopathologica et Entomologica Hungarica* 42:59–142.

Ripka G, De Lillo E (1997) New data to the knowledgeon the eriophyoid fauna in Hungary (Acari: Eriophyoidea). *Folia Entomologica Hungarica* 58, 147–157.

Robbins RG, Karesh CPP, Leontyeva OA, Pereshkolnik SL, Rosenberg S (1998) First records of *Hyalomma aegyptium* (Acari: Ixodida; Ixodidae) from the Russian spur-thighed tortoise, *Testuda graeca nikolskii*, with an analysis of tick population dynamics. *Journal of Parasitology* 84: 1303–1305.

Rosicky B, Cerny V, Luli M (1960) Contribution à l'étude sur la présence, la distribution et al bionomie des tiques (Ixodoidea) en Albanie. *Ceskoslov Parasit* 7: 159–188.

Rota P, Biraghi C (1987) *Oligonychus ilicis* (Mc Gregor): a tetranychid mite new to Europe, phytophagous on azaleas, camellias and rhododendrons. *L'Informatore Agrario* 43: 105–107

Ruttner F (1983) *Varroatosis in honeybees: Extent of infestation and effects*. Meeting of the EC Experts' Group, The Netherlands, Wageningen.

Ruttner F, Marx G (1984) "Beobachtungen über eine mögliche Anpassung von *Varroa jacobsoni* an *Apis mellifera* L. in Uruguay." *Apidologie* 15: 43–62.

Sabelis MW, Bruin J (1996) Evolutionary ecology: life history patterns, food plant choice and dispersal. In: Lindquist EE, Sabelis MW, Bruin J (Eds) *Eriophyoid Mites, Their Biology, Natural Enemies and Control, 6*. Amsterdam: Elsevier, 329–365.

Schulze P (1927) Beitrage zur Kentniss der Zecken Europas. *Sitzungsberichte der Gesellschaft Naturforschender Freunde zu Berlin* 1: 109–126.

Schulze P, Schlottke E (1929) Bestimmungstabellen fuer das Zeckengenus *Hyalomma* Koch s. str. *Sitzungsberichte und Abhandlungen der Naturforschenden Gesellschaft zu* Rostock 3: 32–46.

Šefrová H, Laštůvka Z (2005) *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis* 53: 151–170.

Sengonca C, Zegula T, Blaeser P (2004) The suitability of twelve different predatory mite species for the biological control of *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae). *Zeitschrift für Pflanzenkrankheiten und Pflanzenschutz* 111: 388–399.

Shetchenko VG, Rupais AA (1964) Four Leggd Mites (Acarina:Eriophyidae)- pests of parks in Latvia. *Fauna Latviskoi SSR,IV, Riga*: 203–239.

Sibomana G, Geerts S, De Vries T (1986) L'établissement de *Rhipicephalus sanguineus* (Latreille, 1806) à l'intérieur des maisons en Belgique. *Annales de la Société belge de médecine tropicale* 66 : 79–81.

Siroky P, Petrzelkova KJ, Kamler M, Mihalca A, Modry D (2007) *Hyalomma aegyptium* as dominant tick in tortoises of the genus *Testudo* in Balkan countries, with notes on its host preferences. *Experimental and applied Acarology* 40: 279–290.

Smith TG (1996) The genus *Hepatozoon* (Apicomplexa: Adeleina). *Journal of Parasitology* 82: 565–585.

Smith RM, Baker RHA, Malumphy CP, Hockland S, Hammon RP, Ostojá-Starzewski JC, Collins DW (2007) Recent non-native invertebrate plant pest establishments in Great Britain: origins, pathways, and trends. *Agricultural and Forest Entomology.* 9, 307–326.

Soika G, Labanowski GS (1998) Nowe gayunki szpecieli (Eriophyoidea) w szkolkach roslin ozdobnych. *Progress in Plant Protection* 38: 416–418.

Soika G, Labanowski GS (1999) Szpeciele-sprawcy wyrosli I zneikszta lcen na roslinach ozdobnych. *Progress in Plant Protection* 39: 537–540.

Solignac M, Cornuet J, Vautrin D, Le Conte Y, Anderson D, Evans J, Cros-Arteil S, Navajas M (2005) The invasive Russian and Japanese types of *Varroa destructor*, ectoparasite mite of the Western honey bee (*Apis mellifera*), are two partially isolated clones. *Proceedings of the Royal Society of London B,* 272: 411–419.

Thind BB, Clarke P (2001) The occurrence of mites in cereal-based foods destined for human consumption and possible consequences of infestation. *Experimental and Applied Acarology* 25: 203–215.

Trotter A (1903) Galle della Penisola Balcanica e Asia Minore. *Nuovo Giornale botanico Italiano N.S.X.* 5–54: 210–233.

Vacante V (1983) Prima raccolta di Acari Tetranichidi in Sicilia. *Phytophaga* 1: 41–114.

Van Houten YM, van Stratum P (1993) Biological control of western flower thrips in greenhouse sweet peppers using nondiapausing predatory mites. *Experimental and Applied Acarology* 4: 229–234.

Van Houten YM, van Stratum P (1995) Control of western flower thrips on sweet pepper inwinterwith *Amblyseius cucumeris* (Oudemans) and *A. degenerans* Berlese. *NATO ASI series A, Life Sciences* 276: 245–248.

Vappula NA (1965) Pest of cultivated plants in Finland. *Acta Entomologica Fennica* 19: 1–239.

Vierbergen G (1989) *Panonychus citri* - na vele malen geïmporteed, tenslotte geïntroduceerd. *Verslagen en Medelingen Plantenziektenkundige Dients Wageningen* 167: 52–53.

Vierbergen G (1990) The spider mites of the Netherlands and their economic significance (Acarina: Tetranychidae). *Proceedings of the Section Experimental & Applied Entomology of the Netherlands Entomological Society* 1: 158–164.

Vierbergen G (1994) Entomology. *Panonychus citri*: a pest in the subtropics, found in the Netherlands in the open. Wageningen: Medelingen, Plant Protection Service, Diagnostic Centre, Annual Report 173: 28–30.

Wharton GW, Hansell FC (1957) Studies on the feeding habits of three species of Laelaptid mites. *Journal of Parasitology* 43: 45–50.

Whitaker JOJ, Walters BL, Castor LK, Ritzi CM, Wilson N (2007) Host and distribution lists of mites (acari), parasitic and phoretic, in the hair or on the skin of North American wild mammals North of Mexico: Records since 1974. *Faculty Publications from the Harold W. Manter Laboratory of Parasitology,* 1–173.

Witters J, Casteels H, de Bondt G (2003) Diagnostic acarological research at the Department of Crop Protection in 2002–2003. *Parasitica* 59, 107–111.

Table 7.4.1. List and characteristics of the mite species alien to Europe. Status: A: Alien to Europe; C: cryptogenic species. Country codes abbreviations refer to ISO 3166 (see Appendix I). Habitat abbreviations refer to EUNIS (see Appendix II).

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Diptilomiopidae								
Rhinophytoptus bagdasariani Shev. et Pog.,1985	A	Phytophagous	Asia South West	2002, RS	RS	I2, X11	*Ulmus, Quercus macranthera, Salix caprea*	Petanović (2004)
Rhyncaphytoptus negundivagrans Farkas,1966	C	Phytophagous	North America?	1960, HU	HU, RS	I2, X11	*Acer negundo*	Petanović (in prep.), Ripka (2007)
Epidermoptidae								
Epidermoptes bilobatus Rivolta, 1876	A	parasitic/predator	Asia- Tropical	1948, CZ	CZ	I, J	*Gallus*	Šefrová and Laštůvka (2005)
Eriophyidae								
Acaphylla theae (Watt & Mann, 1903)	A	Phytophagous	Asia	1983, IT	IT, ES	I2	*Camellia*	Fauna Europaea (2009), Pérez Otero et al. (2003)
Acaricalus hederae Keifer,1939	A	Phytophagous	North America	1997, RS	RS	I2, X11	*Hedera helix*	Petanović and Stanković (1999)
Aceria ambrosiae Wilson, 1959	A	Phytophagous	North America	1999, RS	RS	J(J1–J4)	*Ambrosia psilostachya, Ambrosia artemisifolia*	Petanović (1999)
Aceria byersi Keifer,1961	A	Phytophagous	North America	1981, RS	RS	X24, X25	*Cucumis sativus*	Petanović (1988), Petanović (1997)
Aceria caliberberis Keifer, 1952	A	Phytophagous	Asia South West	1998, RS	RS	I2, X11	*Berberis californica, Mahonia dyctiota*	Petanović (1998)
Aceria erinea (Nalepa, 1891)	A	Phytophagous	Asia South West	1903, BG	BE, BG, CZ, GB, LU, ME, RO, RS	I1, I2, X11, X13	*Juglans regia*	Petanović (1988)

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Aceria ligustri (Keifer,1943)	A	Phytophagous	North America	1995, RS	BE, HU, PL, RS	I2,FB, X11	*Ligustrum ovalifolium* , *Ligustrum* sp.	Petanović (1997), Petanović (1998), Soika and Labanowski (1998), Witters et al. (2003)
Aceria neocynarae (Keifer,1939)	A	Phytophagous	North America	1998, ES	GR, IT-SIC, PT, ES	I	*Cynara scolimus*	Fauna Europaea (2009), González Núñez et al. (2002)
Aceria paradianthi (Keifer,1952)	A	Phytophagous	North America	1987, GR	IT, PL, GR	J100	Dianthus sp.	Anagnou-Veroniki et al. (2008), Fauna Europaea (2009)
Aceria petanovicae Nalepa, 1925	A	Phytophagous	Medi-terranean East	1939, IT	FI, GB, HU, IT, RS	I2, X11	Syringa	Fauna Europaea (2009), Fauna Italia, Petanović and Stanković (1999), Ripka (2007)
Aceria sawatchense Keifer, 1965	A	Phytophagous	North America	1981, RS	RS	J (J1–J4)	Polygonum douglasii ssp. johnstoni, Polygonum lapatifolium	Petanović et al. (1983)
Aceria sheldoni (Ewing, 1937)	A	Phytophagous	Asia ?	17th, IT	ES, GR, IT, IT-SAR, IT-SIC, ME, PT	I, X13	*Citrus*	Mijušković and Tomašević (1975)
Aceria tristriata (Nalepa, 1890)	A	Phytophagous	Asia South West	1903, RS	BG, CZ, GB, LU, ME, RS	X13	*Juglans*	Petanović (1996), Trotter (1903)
Aculops allotrichus (Nalepa, 1894)	A	Phytophagous	North America	1912, RO	BG, CZ, RO			
Aculops fuchsiae Keifer,1972	A	Phytophagous	South America	2003, FR	DE, FR, GB	I1,I2	*Fuschia*	Deutsche Dahlien, Fuchsien, Gladiolen und Kübelpflanzen, Ostojá-Strazewski (2007)
Aculops gleditsiae (Keifer, 1959).	A	Phytophagous	North America	1993 RS	HU, IT, RS	X11	*Gleditsia triacanthos*	Fauna Italia, Petanović (1993), Petanović (1997), Ripka (2007), Ripka and De Lillo (1997)

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Aculops pelekassi (Keifer, 1959)	A	Phytophagous	Asia	1958, GR	ES, GR, IT, IT-SAR, IT-SIC, ME, MT	I, X13	*Citrus*	Mijušković and Tomašević (1975)
Aculops rhodensis (Keifer,1957)	A	Phytophagous	North America	1997, HU	HU, IT	X11, X13	*Salix alba, Salix elegnos*	Fauna Italia
Aculus ligustri Keifer, 1938	A	Phytophagous	North America	1993, IT	HU, IT, RS	X11, X13	*Ligustrum ovalifolium* , *Ligustrum* sp.	Fauna Italia, Petanović and Stanković (1999), Ripka (2007)
Anthocoptes punctidorsa Keifer, 1943	A	Phytophagous	North America	1991, IT	IT	I2, FB	*Ulmus laevis, U. pumila*	Rigamonti and Lozzia (1999)
Anthocoptes transitionalis Hodgkiss,1913	A	Phytophagous	North America	1989, RS	RS	X13	*Acer rubrum, A. monspessulanum*	Glavendekić et al. (2005), Petanović (1997)
Calacarus carinatus (Green, 1890)	A	Phytophagous	Asia	1983, IT	ES, HU, IT, PL	I2	*Camellia, Capsicum, Viburnum*	Fauna Europaea (2009)
Cecidophyes malifoliae Parrot, 1906	A	Phytophagous	North America	1991, RS	RS	X13	*Malus* x *domestica, Aremonia agrimonoides*	Petanović and Stanković (1999)
Cecidophyopsis hendersoni (Keifer,1954)	A	Phytophagous	North America	1991, RS	RS, PL	J100, J1	*Yucca glauca, Yucca gloriosa*	Glavendekić et al. (2005), Labanowski (1999), Petanović (2004)
Coptophylla lamimani (Keifer, 1939)	A	Phytophagous	North America	1981, RS	IT, RS, ME	I2, FB, X13	*Corylus avellana, Corylus colurna*	Petanović (1988), Rigamonti and Lozzia (1999)
Cosetacus camelliae Keifer,1945	A	Phytophagous	North America	1990, ME	ES, ME	I2, J100	*Camelia japonica*	Estación Fitopatolóxica do Areeiro (1998), Petanović (1997), Petanović and Stanković (1999)

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Epitrimerus cupressi Keifer,1939	C	Phytophagous	California?	1986, ME	FR, ME	I2	*Cupressus sempervirens*	Guttierez et al. (1986), Petanović (1993)
Eriophyes emarginatae Keifer,1939	A	Phytophagous	North America	1978, RS	RS	I, X13,G1	*Prunus emarginata, P. americana, P.domestica*	Petanović (1997), Petanović and Dobrivojević (1987)
Eriophyes pyri (Pagenstecher, 1857)	C	Phytophagous	Cryptogenic	1903, ME	AT, BA, BE, BG, CH, CY, CZ, DE, DK, ES, FI, FR, GB, GR, GR-CRE, HR, HU, IE, LT, LV, MD, MK, MT, NL, NO, PL, PT, RO, RU, SE, SI, YU	I	Pear, apple, plum	Bebić (1955), Fauna Europaea (2009), Hadžistević (1955), Trotter (1903)
Paraphytoptus chrysanthemi Keifer,1940	A	Phytophagous	North America	1997, RS	RS	X25,J100	*Chrysanthemum morifolium*	Petanović (1997), Petanović and Stanković (1999)
Phyllocoptes amaranthi (Corti, 1917)	A	Phytophagous	South America	1981, RS	RS	J (J1–J4)	*Amaranthus muricatus, A. retroflexus*	Petanović et al. (1983)
Phyllocoptes azaleae Nalepa, 1904	A	Phytophagous	Asia- East	1952, CZ	BG, CZ, DE, IT, NL	G	*Rhododendron*	Fauna Europaea (2009), Šefrová and Laštůvka (2005)
Reckella celtis Bagdasarian,1975	A	Phytophagous	Armenia	1995, RS	MK, RS	G1, X13	*Celtis caucasiaca, Celtis australis*	Petanović et al. (1997)

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Shevtchenkella brevisetosa (Hodgkiss,1913)	A	Phytophagous	North America	1999, RS	HU, PL, RS	X11, X24	*Acer negundo. A. negundo* var. *californicum, A.campestre*	Petanović (in prep.)
Shevtchenkella erigerivagrans (Davis, 1964)	A	Phytophagous	North America	1989, RS	RS	J (J1–J4)	*Erigeron strigosus , Taraxacum officinale, Artemisia absinthium*	Petanović and Stanković (1999)
Tegolophus califraxini (Keifer, 1938)	A	Phytophagous	North America	1988, IT	HU, IT	I2, X10–X13, X20	*Fraxinus angustifolia*	Fauna Italia, Ripka (2007), Ripka and De Lillo (1997)
Vasates quadripedes Shimer 1869	A	Phytophagous	North America	1957, LV	HU, LV, RS, PL	I2,FB	*Acer saccharinum, A.pseudo-platanus, A. rubrum*	Petanović and Stanković (1999), Ripka (2007), Shetchenko and Rupais (1964), Soika and Labanowski (1999)
Ixodidae								
Amblyomma latum Koch, 1844	A	parasitic/predator	Africa	2004, ES	ES	E	Reptile, python	Brotóns and Estrada-Peña (2004)
Amblyomma exornatum Koch, 1844	A	Parasitic/predator	Africa	2004, ES	ES	E	Reptile, phyton	Estrada-Peña (Unpubl.)
Dermacentor variabilis (Say, 1821)	A	parasitic/predator	North America	?, DK	DK	G	Dog (transmit Lyme disease)	
Hyalomma aegyptium (L., 1758)	A	parasitic/predator	Africa	1911, DE	AL, BE, BG, CY, DE, ES, FR, GB, GR, GR-CRE, IT, PT, RO, RU	I	Tortoises (transmit *Borellia*)	Brotóns and Estrada-Peña (2004), Feider (1965), Neumann (1911), Robbins et al. (1998), Schulze (1927), Siroky Pet al. (2007)

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Hyalomma anatolicum Koch 1844	A	parasitic/predator	Cryptogenic	1929, CY	CY	F4, F5, F6, F7	Cattle	Apanaskevich (2003), Schulze and Schlottke (1929)
Hyalomma dromedarii Koch 1844	A	parasitic/predator	Africa	1929	BG, ES-CAN	F4, F5, F6, F7	Camels	Drenski (1955), Schulze and Schlottke (1929)
Hyalomma excavatum Pomerantsev 1946	A	parasitic/predator	Cryptogenic	1940	AL, BG, CY, ES-CAN, GR, GR-CRE, IT	F4, F5, F6, F7	Cattle	Apanaskevich (2003), Battelli et al. (1977), Drenski (1955), Rosicky et al. (1960)
Hyalomma truncatum Koch 1844	A	parasitic/predator	Cryptogenic	1956 ES-CAN	ES-CAN	F4, F5, F6, F7	Cattle	Hoogstraal (1956)
Rhipicephalus rossicus Yakimov & Kolyakimova, 1911	A	parasitic/predator	Cryptogenic	1965, RO	RO	F4, F5, F6, F7	Domestic animals, hedgehogs, occasionally humans (transmit Crimean congo haemorragic fever)	Feider (1965)
Laelapidae								
Laelaps echidninus Berlese, 1887	A	parasitic/predator	Asia- Tropical	1955, CZ	CZ	G	spiny rat	Šefrová and Laštůvka (2005), Smith et al. (2007), Wharton and Hansell (1957)
Ondatralaelaps multispinosus (Banks, 1909)	A	parasitic/predator	North America	1955, CZ	CZ	C	Muskrat	Šefrová and Laštůvka (2005)
Listrophoridae								
Listrophorus americanus Radford, 1944	A	parasitic/predator	North America	1955, CZ	CZ	C, I	muskrat	Bauer and Whitaker (1981), Šefrová and Laštůvka (2005), Whitaker (2007)

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Listrophorus dozieri Redford, 1994	A	parasitic/predator	North America	2004, CZ	CZ	C, I	muskrat	Bauer and Whitaker (1981), Šefrová and Laštůvka (2005),Whitaker (2007)
Listrophorus faini Dubinina, 1972	A	parasitic/predator	North America	2004, CZ	CZ	C, I	muskrat	Bauer and Whitaker (1981), Šefrová and Laštůvka (2005),Whitaker (2007)
Listrophorus validus Banks, 1910	A	parasitic/predator	North America	2004, CZ	CZ	C, I	muskrat	Bauer and Whitaker (1981), Šefrová and Laštůvka (2005),Whitaker (2007)
Macronyssidae								
Ornithonyssus bacoti (Hirst, 1913)	A	parasitic/predator	Asia- Tropical	1952, CZ	CZ	G, I, J	tropical rat, rat, mices, little rodents	Bowman et al. (2003), Cole et al. (2005), Easterbrook et al. (2008), James (2005), Šefrová and Laštůvka (2005), Whitaker (2007)
Ornithonyssus bursa (Berlese)	A	parasitic/predator	C & S America	1948, CZ	CZ, DK	G, I, J	birds, mammals	Berggren (2005), Denmark and Cromroy (2008), Gjelstrup and Møller (1985), James (2005)
Myocopidae								
Myocoptes ondatrae Lukoschus & Rouwet, 1968	A	parasitic/predator	North America	2004, CZ	CZ	C, 1	Muskrat	Bauer and Whitaker (1981), Šefrová and Laštůvka (2005),Whitaker (2007)
Phytoptidae								
Phytoptus hedericola Keifer, 1943	A	Phytophagous	South Africa	2002, RS	RS	I2, X11	*Hedera helix*	Glavendekić et al. (2005)
Setoptus strobicus Keifer,1966	A	s	North America	2005, RS	RS	G3F, X25, X11	*Pinus strobus*	Petanović (in prep.)
Sierraphytoptus alnivagrans Keifer, 1939	A	Phytophagous	North America	2007, RS	RS	G1	*Alnus glutinosa*	Petanović (in prep.)

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Trisetacus chamaecypari Smith, 1977	A	Phytophagous	North America	2002	GB	I2	*Chamecyparis, lawsonianna, C. nootkaensis, Cupressus macrocarpa, Juniperus virginiana*	Ostojá-starzewski and Halstead (2006), Smith et al. (2007)
Phytoseiidae								
Phytoseiulus persimilis Athias-Henriot 1957	A	parasitic/predator	South America	1974,CZ	BG, CZ, BE, DE, ES, GB, IT	I	Predator of *Tetranychus*	Bartlett (1992), Croft et al. (1998), Easterbrook (1996), EPPO (2002), Garcia Mari and Gonzalez-Zamora (1999), Helle and Sabelis (1985), McMurtry and Croft (1997), Šefrová and Laštůvka (2005)
Amblyseius (Neoseiulus) californicus (McGregor 1954)	A	parasitic/predator	North America	1991, GB	BG, CZ, GB, IT	I	Predator of *Tetranychus*	Croft et al. (1998), Easterbrook (1996), EPPO (2002), Garcia Mari and Gonzalez-Zamora (1999), Helle and Sabelis (1985), McMurtry and Croft (1997), Šefrová and Laštůvka (2005)
Typhloctonus squamiger Wainstein 1960	A	Phytophagous	Cryptogenic	1991, IT	IT	I	*Acer platanoides, Prunus serratulata*	Rigamonti and Lozzia (1999)
Pyroglyphidae								
Dermatophagoides evansi Fain, Hughes et Johnston, 1967	A	parasitic/predator	North America	Unknown	NL, NO, PL, IT	J	house dust	Bigliocchi and Maroli (1995), Eriksson (1990), Hughes (1976), Musken et al. (2000), Piotrowski (1990), Razowski (1997), Thind and Clarke (2001)

Family *Species*	Status	Regime	Native range	1st record in Europe	Invaded countries	Habitat	Hosts	References
Tarsonemidae								
Polyphagotarsonemus latus (Banks, 1904	A	Phytophagous	Sri Lanka	IT, 1965	DK, ES, GB, IT, IT-SAR, IT-SIC, NL, RO, RS, BE, DE	I	polyphagous: crops, vegetables, fruits and leaves	CAB-International (1986), Fan and Petit (1998), Gerson (1992), Heungens (1986), Natarajan (1988), Parker and Gerson (1994), Raemaekers (2001)
Tenuipalpidae								
Brevipalpus californicus (Banks, 1904)	A	Phytophagous	North America	IT, 1998	CY, FR, GR-CRE, GR, IT, IT-SAR, IT-SIC, PT, IL	I2, J100	*Citrus, Camellia sinensis*	CAB-International (1986), Childers et al. (2003a), Childers et al. (2003b)
Brevipalpus lewisi (McGregor 1949)	A	Phytophagous	North America	Unknown	BG, FR, GR, RO	I2, J100	*Citrus*, ornamentals	Childers et al. (2003a)
Brevipalpus phoenicis (Geijskes 1939)	A	Phytophagous	Tropical	IT, 1998	ES, GR, IT, NL	I2, J100	Polyphagous, *Citrus, Gardenia, Hibiscus, Ilex, Ligustrum; Ficus, Phoenix, Prunus*	Childers et al. (2003a), Childers et al. (2003b)
Brevipalpus obovatus Donnadieu, 1875	A	Phytophagous	North America	IT, 1986	AT, FR, DE, IL, NL, SP, RS, BE, BA, BG, HR, CY, GR, IT, PT, RO, UA	I2	*Citrus, Camellia, Coffea, Mentha, Solanum*	CAB-International (1986), Childers et al. (2003a), Childers et al. (2003b), Glavendekić et al. (2005), Manson (1967)
Brevipalpus russulus (Boisduval 1867)	A	Phytophagous	C & S America	1867, FR	BE, DE, FR, GB, GR, NL, PT, UA	J100	Cactaceae	Denmark (1978)

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Tenuipalpus caudatus (Dugès 1834)	A	Phytophagous	Tropical	Unknown	FR, GR, IT, PT	I2, J100	*Citrus*	Manson (1967)
Tenuipalpus pacificus Baker 1945	A	Phytophagous	C & S America	Unknown	DE, GB, NL, RO, RS	J100	Orchids: *Phalaenopsis*, etc..	Denmark (1968), Glavendekić et al. (2005), Manson (1967)
Tetranychidae								
Eotetranychus lewisi (McGregor, 1943)	A	Phytophagous	C & S America	1990, PT-MAD	PT-MAD	I	*Citrus, Carica*	Carmona (1992)
Eotetranychus weldoni (Ewing, 1913)	A	Phytophagous	North America	2004, RS	AL, MK, RS	I	*Populus*	Glavendekić et al. (2005)
Eurytetranychus admes Pritchard & Baker, 1955	A	Phytophagous	North America	1970, HU	FR, HU	I2	Coniferous	Bozai (1970), Migeon (2003)
Eurytetranychus furcisetus Wainstein, 1956	A	Phytophagous	Asia-Temperate	1974, HU	HU	G	*Picea*	Bozai (1974)
Eutetranychus banksi (McGregor, 1914)	A	Phytophagous	C & S America	2001, ES	ES, PT	I	*Citrus*	Garcia et al. (2003)
Eutetranychus orientalis (Klein, 1936)	A	Phytophagous	Asia-Tropical	2001, ES	ES	I	*Citrus*	Garcia et al. (2003)
Oligonychus bicolor (Banks, 1894)	A	Phytophagous	North America?	1972, IT	IT-SAR, IT-SIC, IT, PT	I2	*Quercus robur, Castanea*	Rigamonti and Lozzia (1999)
Oligonychus ilicis (McGregor, 1917)	A	Phytophagous	Asia-Temperate	1985, IT	IT, NL	I2	*Azalea, Rhododendron, Camelia*	Rota and Biraghi (1987)
Oligonychus laricis Reeves, 1963	A	Phytophagous	North America	1964, PL	PL	I2	*Larix*	Boczek (1964), Doboz et al. (1995)
Oligonychus perditus Pritchard & Baker, 1955	A	Phytophagous	Asia-Temperate	1990, NL	NL	I2	*Juniperus chinensis*	Vierbergen (1990)

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Oligonychus perseae Tuttle, Baker & Abbatiello, 1976	A	Phytophagous	North America	2004, ES	ES	I1	*Persea americana*	Alcázar et al. (2005)
Oligonychus pritchardi (McGregor, 1950)	A	Phytophagous	North America	1984, PL	PL	G	*Quercus robur*	Kropczynska (1984), Doboz et al. (1995)
Oligonychus punicae (Hirst, 1926)	A	Phytophagous	C & S America	1988, FR-COR	FR-COR	I2	polyphagous: *Quercus, Juglans, Eucalyptus*	Bolland et al. (1998)
Panonychus citri (McGregor, 1916)	A	Phytophagous	Asia	1950, FR	AL, BG, ES, ES-CAN, FI, FR, GB, GR-CRE, GR, HR, HU, IT, IT-SAR, IT-SIC, MK, NL, NO, PL, PT, RO, SI, UA, YU	I1, I2	*Citrus*	Balevski (1967), Bernini et al. (1995), Bowman and Bartlett (1978), Bozai (1970), Ciampolini and Rota (1972), Ciglar and Barić (1998), Delrio et al. (1979), Emmanouel and Papadoulis (1987), Fauna Europaea (2009), Garcia Mari and de Rivero (1981), Jeppson et al. (1975), Mijušković (1953), Pande et al. (1989), Petanović (1980), Rambier (1958), Vacante (1983), Vappula (1965), Vierbergen (1989)
Petrobia (Tetranychina) lupini (McGregor, 1950)	A	Phytophagous	North America	1968, GR	GR	I	*Lupinus.*, *Fragaria*, Poaceae	Hatzinikolis (1970), Papaioannou-Souliotis et al. (1993)
Schizotetranychus bambusae Reck, 1941	A	Phytophagous	Asia-Temperate	2001, FR	FR	I2	Bambusaceae	Auger and Migeon (2007), Migeon et al. (2004)
Schizotetranychus parasemus Pritchard & Baker, 1955	A	Phytophagous	North America	1964, PL	PL	I	*Cynodon*, Poaceae	Boczek and Kropczynska (1964)

Family *Species*	Status	Regime	Native range	1st record in Europe	Invaded countries	Habitat	Hosts	References
Stigmaeopsis celarius Banks, 1917	A	Phytophagous	Asia-Temperate	1985, FR	BE, FR, GB, NL	I, X11, X22, X23, X24, X25	Bambusaceae	Auger and Migeon (2007), Bolland et al. (1998), Ostoja-Starzewski (2000), Witters et al. (2003)
Tetranychus canadensis (McGregor, 1950)	A	Phytophagous	North America	1954, HU	HU, PL	I2	Polyphagous: Rosaceae, *Carya, Corylus*	Boczek and Kropczynska (1964), Hetenyi (1954)
Tetranychus evansi Baker & Pritchard, 1960	A	Phytophagous	C & S America	1991, PT	ES, ES-BAL, ES-CAN, FR, IT, PT, PT-MAD, PT	I, J100, X	Solanaceae	Castagnoli et al. (2006), Ferragut and Escudero (1999), Ferragut et al. (1997), Ferreira and Carmona (1995), Migeon (2005), Migeon (2007)
Tetranychus kanzawai Kishida, 1927	A	Phytophagous	Asia-Tropical	1966, GR	BE, GR	J100	Saxifragaceae: *Hydrangea*	Hance et al. 1998, Hatzinikolis (1968), Hatzinikolis (1986)
Tetranychus macfarlanei Baker & Pritchard, 1960	A	Phytophagous	Asia-Tropical	1989, ES-CAN	ES, ES-CAN	I	*Musa, Ipomoea*, etc	Pande et al. (1989)
Tetranychus mcdanieli McGregor, 1931	A	Phytophagous	North America	1981, FR	FR	I	*Vitis, Acer, Lonicera, Fragaria, Ulmus*, etc.	Rambier (1982)
Tetranychus neocaledonicus André, 1933	A	Phytophagous	Tropical	1989, ES-CAN	ES-CAN	I	Polyphagous: *Citrus*, Fabaceae	Ferragut and Santonja (1989)
Tetranychus sinhai Baker, 1962	A	Phytophagous	North America	1964, PL	PL	I	*Helianthus, Agropyron, Prunus*	Boczek (1964)
Tetranychus tumidellus Pritchard & Baker, 1955	A	Phytophagous	North America	1986, GR	GR	I	*Sambucus, Passiflora, Solanum*	Hatzinikolis (1986)

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Tetranychus yusti McGregor, 1955	A	Phytophagous	C & S America	1981, GR	GR, GR-CRE	I2, X	*Plumeria*, *Lonicera*, exotic Fabaceae	Hatzinikolis (1986)
Varroidae								
Varroa destructor Anderson & Trueman, 2000	A	parasitic/predator	Asia	1964 RS	AL, BG, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, IT-SAR, IT-SIC, MT, PL, PT, RO, RS, RU, SI, SK	J	bee parasite	Colin (1982), De Rycke et al. (2002), Griffiths and Bowman (1981), Morse and Goncalves (1979), Ruttner (1983), Ruttner and Marx (1984)

Table 7.4.2. List and characteristics of the mite species alien *in* Europe. Country codes abbreviations refer to ISO 3166 (see Appendix I). Habitat abbreviations refer to EUNIS (see Appendix II).

Family Species	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat***	**Hosts**	**References**
Argasidae							
Argas reflexus (Fabricius, 1794)	parasitic/ predator	Europe	19th , DE	AT, BE, BG, CH, CZ, DE, DK, ES, FR, GB, GR, IT, PL, RO, RU, UA	J	Rat	Dautel and Kahl (1999)
Eriophyidae							
Aceria alpestris (Nalepa,1892)	Phytophagous	Alps	1952, CZ	AT, CZ, IT, RS	F2	*Rododendron ferrugineum*	Petanović and Stanković (1999)
Aceria loewi (Nalepa, 1890)	Phytophagous	Mediterranean East	1901, RO	AT, BG, CZ, CY, DE, FR, HU, IT, LT, LV, PL,GB	I2, X11	*Syringa*	Fauna Europaea (2009)
Aculus hippocastani (Fockeu, 1890)	Phytophagous	Mediterranean East	1907, CZ	BG, CZ, IT, RO, FR	G1,G4, X11	*Aesculus*	Fauna Italia
Eriophyes canestrinii (Nalepa, 1891)	Phytophagous	Mediterranean region	1998, RS	AT, BG, CZ, DE, HU, IS, PL	X 11, X24	*Buxus sempervirens*	Petanović (1998)
Glycyphagidae							
Glycyphagus domesticus (De Geer, 1778)	detrivorous	Europe	Unknown	DK, FÖ, IT, NO, PL, SE	J1, J2	Houes dust	Bigliocchi and Maroli (1995), Hughes (1976), Musken et al. (2000), Piotrowski (1990), Razowski (1997), Thind and Clarke (2001)
Ixodidae							
Hyalomma scupense Delpy 1946	parasitic/ predator	Europe	Unknown	AL, BG, ES, ES-CAN, FR, GR, HR, IT, IT-SAR, IT-SIC, MK, RU, RS, YU	J	Cattle	Morel et al. (1977)

Family Species	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat***	**Hosts**	**References**
Rhipicephalus sanguineus (Latreille 1806)	parasitic/ predator	Mediterranean region	Unknown	BE, CH, CZ, DE, DK, GB, IE, NL, NO, PL	J	Dogs	Černý (1985), Fauna Europaea (2009), Garben et al. (1980), Sibomana et al. (1986)
Phytoptidae							
Trisetacus laricis \(Tubeuf 1897)	Phytophagous	Alps	1912	BA,DE, GB, HR, SI	I2	*Larix*	Fauna Europaea (2009)
Phytoseiidae							
Amblyseius (Iphesius) degenerans (Berlese 1889)	parasitic/ predator	Mediterranean	1993, CZ	CZ, GB, GR, IT,PT	I	Predator of *Tetranychus*	Albajes et al. (1999), Bartlett (1992), EPPO (2002), Šefrová and Laštůvka (2005), Sengonca et al. (2004), van Houten and van Stratum (1993), van Houten and van Stratum (1995)

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Longhorn beetles (Coleoptera, Cerambycidae)
Chapter 8.1

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Abstract

A total of 19 alien longhorn beetle species have established in Europe where they presently account for ca. 2.8 % of the total cerambycid fauna. Most species belong to the subfamilies Cerambycinae and Laminae which are prevalent in the native fauna as well. The alien species mainly established during the period 1975–1999, arriving predominantly from Asia. France, Spain and Italy are by far the most invaded countries. All species have been introduced accidentally. Wood-derived products such as wood- packaging material and palettes, plants for planting, and bonsais constitute invasive pathways of increasing importance. However, only few species have yet colonized natural habitats outside parks and gardens. Present ecological and economical impacts, and future trends are discussed.

Keywords

Cerambycidae, Europe, Introductions, Establishments, Biogeographical origins, Pathways, Impacts

8.1.1 Introduction

The coleopteran family Cerambycidae (longhorn beetles) is currently classified in the superfamily Chrysomeloidea, along with the families Vesperidae and Distenidae (Hunt et al. 2007, Szeoke and Hegyi 2002). Cerambycidae is a large family comprising about

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40000 described species worldwide. Longhorn beetles are all phytophagous. Larvae may be found in conifer, deciduous and fruit trees, in bushes and herbaceous plants. They are mainly xylophagous borers of living, decaying or dead wood. Some species also bore small twigs, roots or fruit endocarps. They usually have a long period of larval development, some species being capable of developing in woody material a long time after the death of the tree. They are thus very susceptible to transport with wood products, facilitating their introduction and establishment.

The oldest known introduction of a longhorn beetle from one continent to another was probably that of the house borer, *Hylotrupes bajulus* (L., 1758), which was first described by Linnaeus from both Europe and 'America septentrionali' (von Linnaeus 1758). Since a study by Duffy in 1953 (Duffy 1953a) for Great Britain, there has been no further large synthesis of the alien cerambycid species introduced to Europe. Since 1999, the development of research interests in the Asian longhorn beetles, *Anoplophora* spp., in North America has raised awareness of the risks presented by cerambycid importation and provided a baseline for subsequent studies (Haack et al. 2000, Haack et al. 2010). There is an urgent need for a comprehensive literature review of the alien cerambycids that have successfully established in Europe.

The exponential growth in the volume of international trade in both horticulture and forestry has allowed an increasing number of wood products and ornamental plants potentially containing cerambycids to arrive in Europe. More than 250 species have been introduced to Europe or moved within Europe since the middle of the 18th century (Cocquempot 2007) but most of them never established. We have identified 19 species alien *to* Europe that have established in Europe but have not yet been eradicated.

8.1.2 Taxonomy of the Cerambycid species alien *to* Europe

Taxonomy in Cerambycidae *sensu lato* is not well established (e.g., Hunt et al. 2007, Lawrence and Newton 1995, Napp 1994, Özdikmen 2008, Sýkorová 2008) but a general consensus exists about the presence in Europe of 7 subfamilies, namely Cerambycinae, Lamiinae, Lepturinae, Necydalinae, Prioninae, Spondylidinae, and Vesperinae (the latter being sometimes considered as a valid family). A total of 677 native species are known to occur in Europe (Althoff and Danilevsky 1997, Fauna Europaea), being largely dominated by 3 subfamilies (Lamiinae- 343 spp.; Cerambycinae- 158 spp.; Lepturinae- 130 spp.) which account for 93.2% of the total.

The 19 alien species established in Europe belong to only 3 of these subfamilies, Cerambycinae, Laminae and Prioninae (Table 8.1.1). The alien species are mostly represented by the subfamily Cerambycinae, followed by Lamiinae but the relative proportion of aliens compared to the total cerambycid fauna is still limited (<6%) in these two subfamilies. By contrast, the proportion of aliens is much more important in Prioninae with 2 species adding to 10 native ones (Fig. 8.1.1.). In addition, Parandrinae, a subfamily which is not represented in the native European entomofauna, is represented by *Parandra brunnea,* a North American species introduced in Germany (Nüssler 1961).

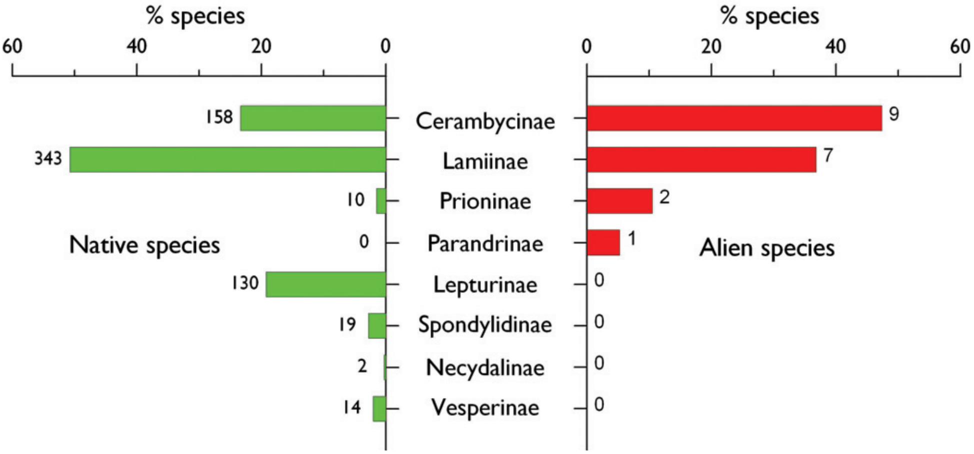

Figure 8.1.1. Relative importance of the subfamilies of Cerambycidae in the alien and native entomofauna in Europe. Subfamilies are presented in a decreasing order based on the number of alien species. Species alien *to* Europe include cryptogenic species. The number over each bar indicates the number of species observed per family.

Two more alien species have been introduced and established in Israel, *Batocera rufomaculata* (DeGeer, 1775) (Bytinski-Salz 1956, Chikatunov et al. 1999, Sama et al. 2010) and *Xystrocera globosa* (Olivier, 1795) (Chikatunov et al. 2006, Sama et al. 2010), but they have not yet spread to Europe and were not considered in Table 8.1.1.

Table 8.1.2 gives a list of species of European origin introduced through human activity in another part of Europe (aliens *in* Europe). These species are mostly of Mediterranean origin introduced in more northern areas and species from Continental Europe introduced to the Atlantic islands.

8.1.3 Major biological characteristics of the cerambycid species alien *to* Europe

Lepturinae but also Prioninae and Parandrinae share some biological characteristics that reduce their probability of introduction. Larvae in these subfamilies develop in decaying wood and are rarely imported with wood products or living plants. Interceptions have shown that they are mainly introduced through accidental importation in industrial packages or in stocks of perishable vegetables. Only a few species of Lepturinae (Tribe Rhagiini, and some Lepturinii) developing on recently felled trees are likely to be successfully introduced through the wood trade. The importation of living potted plants is also a potential new pathway for Prioninae.

Cerambycinae and Lamiinae seem more predisposed to introduction. Most species develope in living plants and several Cerambycinae undertake their entire life-cycle in dead wood, e.g. the cosmopolitan tribe Hesperophanini and the species *Hylotrupes bajulus* and *Gracilia minuta.* Thus, Cerambycinae and Lamiinae can easily survive throughout the importation process of living plants including bonsai (e.g. *Anoplophora chinensis* (Cocquempot 2007, EPPO 2006, van Rossem et al. 1981, Schmidt and Schmidt 1990)), recently felled logs and other non-aged wood products (e.g. *Anoplophora glabripennis* (Cocquempot et al. 2003, Haack et al. 2000), *Monochamus* spp. (Cocquempot 2007, Cocquempot (Unpubl.), Duffy 1953a), *Chlorophorus annularis* (Cocquempot 2007) and *Phoracantha* spp. (Cocquempot and Debreuil 2006)). Species in the genera *Hesperophanes*, *Trichoferus*, and *Stromatium* can emerge from wood products even several years after importation (Duffy 1953a).

Once a population is introduced, the capability for natural dispersal constitutes an important factor for establishment success. Although our knowledge about the dispersal behaviour of alien longhorn beetles is still rather limited and mostly concerns only a few species of recent invaders such as *Anoplophora glabripennis* (Smith et aol. 2001) and *A. chinensis* (Adachi 1990, Komazaki and Sakagami 1989), this variable is important when designing an eradication attempt (MacLeod et al. 2002).

8.1.4 Temporal trends of introduction in Europe of alien Cerambycids

Figure 8.1.2 presents the temporal changes in the records of Cerambycid species alien *to* Europe from 1492 to 2007. Cerambycids have tracked trade routes since the beginning of overseas communications. The first species to have moved are those which live in dry wood and undergo a long stage of larval development. These species have become cosmopolitan (e.g. *Hylotrupes bajulus*) or nearly so (e.g. *Stromatium* spp.). With the increased speed of international transport from 1850 to 1925, species with shorter life cycles were able to reach Europe alive and become established, e.g. *Neoclytus acuminatus* (Reineck 1919, Sama 2002, Tassi 1969). Later, only two species were introduced from North America to Europe via the US effort to supply extra furniture and increase military material after the 1st World War (i.e., *Parandra brunnea*, *Neoclytus acuminatus*). Subsequently, 50 years passed until a second wave of introduction arrived alongside with the rapid development of international exchange of goods and transportation after the 2nd World War. During the recent period, two further species have been detected in the wild - *Anoplophora chinensis* in 2000 in Italy (Colombo and Limonta 2001) and *A. glabripennis* in 2001 in Austria (Dauber and Mitter 2001).

The number of interceptions of Cerambycids is still increasing throughout Europe. However, more effective control at borders is like to have reduced establishments following interception or introductions. The importation of exotic plants also offers opportunities for introduction but also constraints the establishment of some alien species. For example, *Phoracantha* spp. could not have been introduced without the importation and mass cultivation of its host plants, *Eucalyptus* spp. in the Mediterranean basin. In south-eastern France, an Australian cerambycid, *Bardistus cibarius* (Newman, 1841) could survive only on its original host plant, an introduced grass tree (*Xanthorrhoea* sp., Xanthorrhoeaceae); the beetle population disappeared immediately after the infested host plants were removed (Cocquempot 2007). The case of *Batocera*

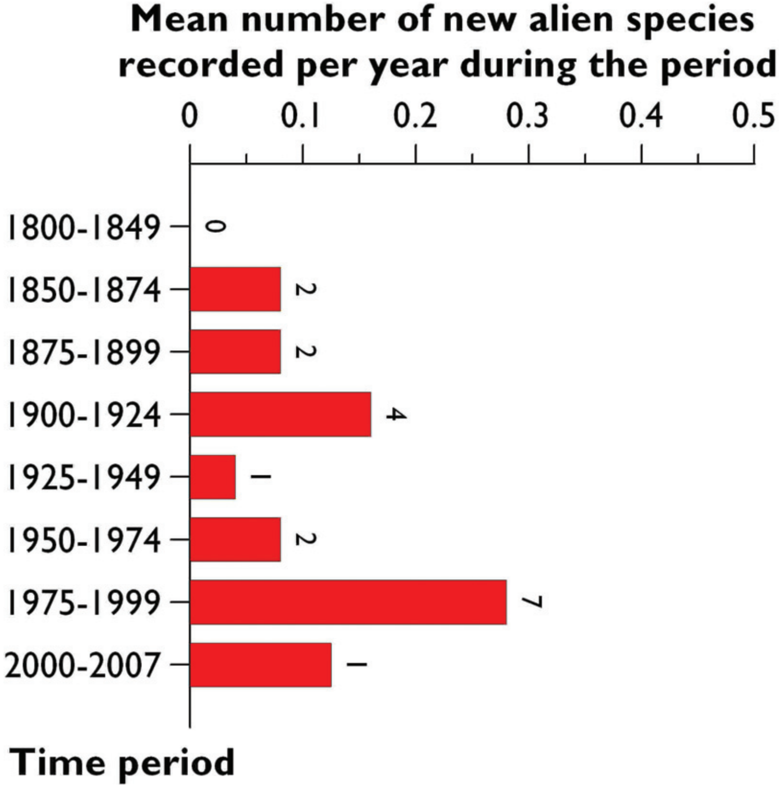

Figure 8.1.2. Temporal changes in the mean number of new records per year of Cerambycid species alien *to* Europe from 1492 to 2007. The number over each bar indicates the absolute number of species newly recorded per time period.

rufomaculata (DeGeer, 1775) found in Munster's Zoo (Germany) is similar (Cocquempot 2007) although this tropical species has established in Israel since at least 1948 (Bahillo de la Puebla and Iturrondobeitia-Bilbao 1995, Plavilstshtikov 1934, Sama et al. 2010). The combination of importation of longhorn beetle species with their specific host plant or groups of plants followed by establishment is rare. However the establishment of *A. chinensis* is an exception. Other species are frequent intercepted at border controls, e.g. *Mimectatina meridiana* (Matsushita, 1933) with *Cycas* fruits from Japan (Cocquempot 2007) or *Trichoferus campestris* (Faldermann 1835) with *Salix* timber from China (Cocquempot 2007).

The degree of polyphagy is also an important factor in the likelihood of establishment. Polyphagous species appear to have a higher potential to establish than oligophagous and monophagous species. The large number of hosts utilised by *Anoplophora* spp. (Cocquempot et al. 2003, Hérard and Roques 2009, Maspero et al. 2007a) is a main factor in the difficulty in eradicating this species for example. These difficulties appear much less important for oligophagous species such as *Callidiellum rufipenne* (Bahillo and Iturrondobeitia-Bilbao 1995, Campadelli and Sama 1988, Plavilstshtikov 1934) or Phoracanthine species. It is also the case for the North American wood borer *Saperda candida* (Fabricius, 1787), which was introduced in Germany in 2008 but apparently did not established yet (EPPO 2008, Nolte Krieger 2008). By contrast, *Monochamus* species have a regime close to polyphagy, including a large number of conifer species, and may spread throughout Europe. There is no example of establishment in Europe of a strictly monophagous exotic long-horned beetle. Species with a limited host range do not seem to be capable of going beyond the interception or introduction stage, e.g. *Bardistus cibarius* (Cocquempot 2007).

8.1.5 Biogeographic patterns of the cerambycid species alien *to* Europe

Alien species established in Europe mostly originated from Asia, followed by Africa (Figure 8.1.3). The region of origin appears to depend on the major trade routes developed by each country. Some North African species have colonized Mediterranean countries such as Spain, France, and Malta for example. Other African species have often been intercepted but only *Phryneta leprosa* has established in Malta where the climate is favourable for development (Mifsud and Dandria 2002). Long-established trade routes between Iberian countries and South American countries have resulted in some historic, isolated establishments in the Spanish and Portuguese Atlantic Islands but with a limited risk of further expansion (Lemos-Perreira 1978, Méquignon 1935). With the numerous interceptions in the U.K (Duffy 1953a) together with the colonial trade routes with African and Asiatic countries, it is surprising that only *Trinophylum cribratum* has established to date (Gilmour 1948); the incompatible climate may negate the development of tropical and subtropical species. Two species native to North America, *Parandra brunnea* and *Neoclytus acuminatus,* also colonized Europe at the beginning of the last century. The first species is well established but restricted to Dresden (Germany) (Nüssler 1961). The second is widely established in the Mediterranean area but its populations appear to be declining (Brustel et al. 2002). Beside these two species, there have been no further establishments originating from North America; the pathway of transported material is mainly in the reverse direction, from Europe to America.

Some Australian species have reached Europe but only those using *Eucalyptus* (*Phoracantha* spp.) have successfully established (Cocquempot and Sama 2004) and only in areas newly planted with these fast-growing tree species. The large differences in species composition between the floras of Australia and Europe probably accounts for the failure of Australasian longhorn beetles such as in *Bardistus cibarius* on *Xanthorrhoea* sp. (Cocquempot 2007) to establish.

Recent increases in commercial traffic from Asia (especially China) to Europe has accounted for the introduction of a number of new species of cerambycids. Striking examples are *Callidiellum rufipenne* which has recently established in Spain (Bahillo de la Puebla and Iturrondobeitia-Bilbao 1995) and Italy (Campadelli and Sama 1988), *Anoplophora glabripennis* and *A. chinensis* which can be considered as established or

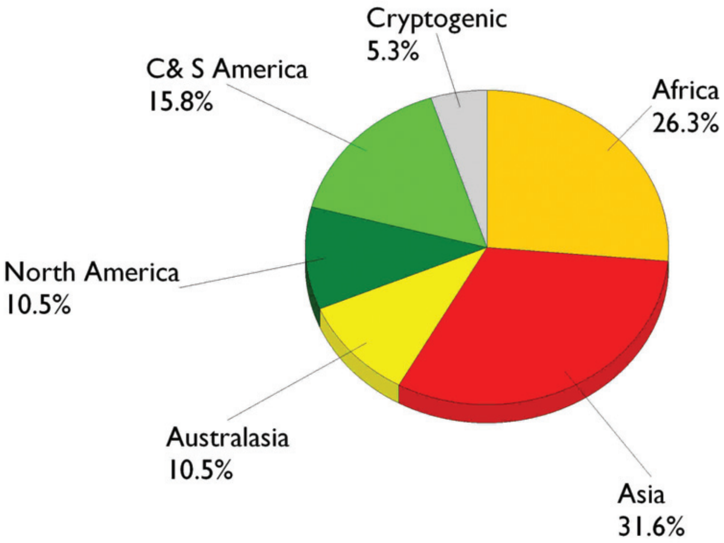

Figure 8.1.3. Origin of the Cerambycidae species alien *to* Europe

not eradicated in several countries (Hérard and Roques 2009, Maspero et al. 2007a), *Psacothea hilaris* (Pascoe, 1857) under eradication in Italy (Cocquempot 2007, Jucker et al. 2006), and *Monochamus alternatus* Hope, 1842 intercepted a number of times in Germany (Cocquempot 2007) and France (Cocquempot Unpubl.) but not yet established. A final case, *Xylotrechus stebbingi,* is less clear. It is believed that an initial introduction from its native area of central Asia to Asia Minor was followed by a step-wise expansion into southern Europe and North Africa (Cocquempot and Debreuil 2006, Sama 2002, Šefrová and Laštůvka 2005).

Alien cerambycid species are not evenly distributed throughout Europe. Large differences in the number of aliens are apparent between countries, France, Italy and Spain being by far the most invaded (Figure 8.1.4).

8.1.6 Main pathways of introduction to Europe of alien cerambycid species

All alien longhorn beetles established in Europe have been introduced accidentally; there are no examples of a successful, deliberate introduction. The principal pathways of arrival have been identified and presented by Frank 2002 and each relates to the import of immature stages that subsequently emerge as adults. There are relatively few records of living adults imported with vegetables or fruits although Eucalyptus beetles, *Phoracantha recurva,* were found in a cluster of bananas (Bosmans 2006).

The longest established pathway is timber importation for house construction (*Hylotrupes bajulus*) or building furniture (e.g. *Trichoferus* spp., *Stromatium* spp. and *Chlorophorus annularis* arriving with bamboo- made objects (Cocquempot 2007)). Species

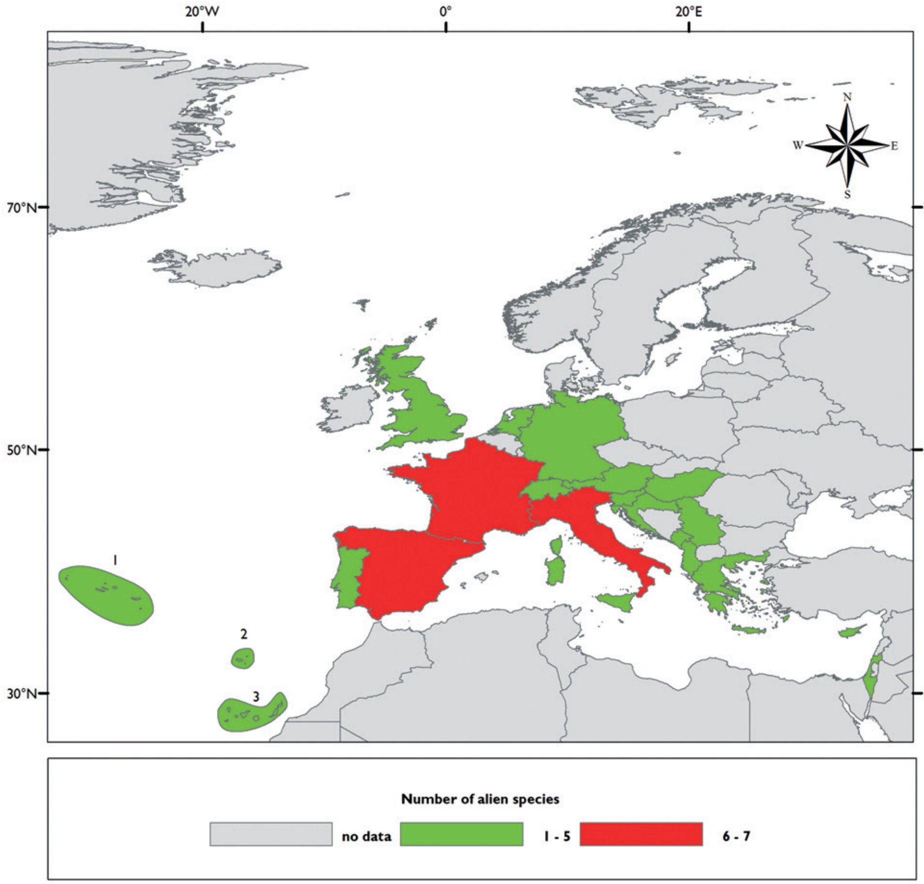

Figure 8.1.4. Comparative colonization of continental European countries and islands by Cerambycidae species alien *to* Europe. Archipelago: **1** Azores **2** Madeira **3** Canary islands.

introduced through this pathway have traditionally required a long life cycle but more rapid travel now enables the introduction of species with a one year life cycle. The second pathway is via the importation of timber for pulp (e.g., for *Phoracantha* spp.). A third, more recent, pathway concerns wood packages, palettes and other wood-derived products (e.g., for *Anoplophora glabripennis*) (Hérard and Roques 2009). The final pathway is the importation of plants for planting in nurseries, including the bonsai industry, which has resulted in the arrival of species such as *Anopolophra chinensis* (Cocquempot 2007, EPPO 2006, van Rossem et al. 1981, Schembri and Sama 1986), *Callidiellum rufipenne* and *Bardistus cibarius*.

All pathways are still prevalent but they vary in importance. Most recent interceptions (from the end of the 20th Century) have related to wood-manufactured products (e.g. *Chlorophorus annularis* and *Trichoferus campestris*). Importation of *Eucalyptus* wood for pulp has also resulted in the introduction of a second species of *Phoracantha, P. recurva* (Miquel 2008). If such importations continues a number of additional species of this genus, which are mainly related to *Eucalyptus* (Wang 1995), are expected to arrive.

Since their first usage, wood packaging and palettes have constituted an important introduction pathway. The source material spends sufficient time as logs without sanitary controls to be colonized by longhorn beetles. When the wood is turned into packages or palettes, infestation occurs mainly as unnoticed early stages (eggs or first-instar larva). Development continues in the woody material during importation and emergence of adults occurs often unnoticed in warehouses, weeks or months after arrival. This is the case for *A. glabripennis*, *P. hilaris* and *M. alternatus* which may already complete their entire lifecycle before the source wood is processed or destroyed. Wood package is often produced using low quality timber often colonized by longhorn beetle species, which is increasing its potential as a vector.

Other, less significant, introduction pathways have also been identified, yet they typically only transported one or a few individuals which fail to establish. The introduction route is unknown for other species such as *Acanthoderes jaspideus* (Méquignon 1935)*, Oxymerus aculeatus* (Alluaud 1935), *Deroplia albida*, and *Phryneta leprosa* (Mifsud and Dandria 2002) but they may be related to the uncontrolled importation of wild plants. Natural range expansion cannot be ruled out for a few species which have a nearby native range, e.g. *Lucasianus levaillantii* (Mayet 1905, Pellegrin and Cocquempot 2001) and *Xylotrechus stebbingi* (Šefrová and Laštůvka 2005) originating from North Africa and the Middle East, respectively.

8.1.7 Ecosystems and habitats invaded in Europe by alien cerambycid species

Although all natural or artificial terrestrial ecosystems and anthropogenic areas which contain trees, bushes or wood products are potentially occupied by alien longhorn beetles, establishment in Europe is concentrated in man-made habitats to date, especially in parks and gardens (Figure 8.1.5). To date, only the two clytine beetles, *Neoclytus acuminatus* and *Xylotrechus stebbingi*, have colonized natural habitats. *X. stebbingi* is very common on *Eucalyptus* cut wood in Crete (Sama 2002) for example and may be related to the polyphagous nature of these two species. Other polyphagous species such as *Anoplophora* spp. also have the potential to live in urban areas, in cultivated lanes (e.g. planted with poplars) as well as in natural forests where potential host plants occur. However, dispersal from man-made habitats to natural forests appears to be a slow process. For the first twenty-two years since its arrival in North America, *A. glabripennis* has been restricted to trees in urban areas until 2008 when it was found in natural forests dominated by *Acer* trees (Haack et al. 2010). Although such a process has not yet been observed in Europe, there is a strong risk that *Anoplophora* spp. will spread to naturally-forested landscapes, if the ongoing eradication attempts in Austria, Germany, France and Italy are unsuccessful.

The expansion of oligophagous species is inevitably more dependant on the presence of suitable host plants. Those using largely- planted trees can spread more easily.

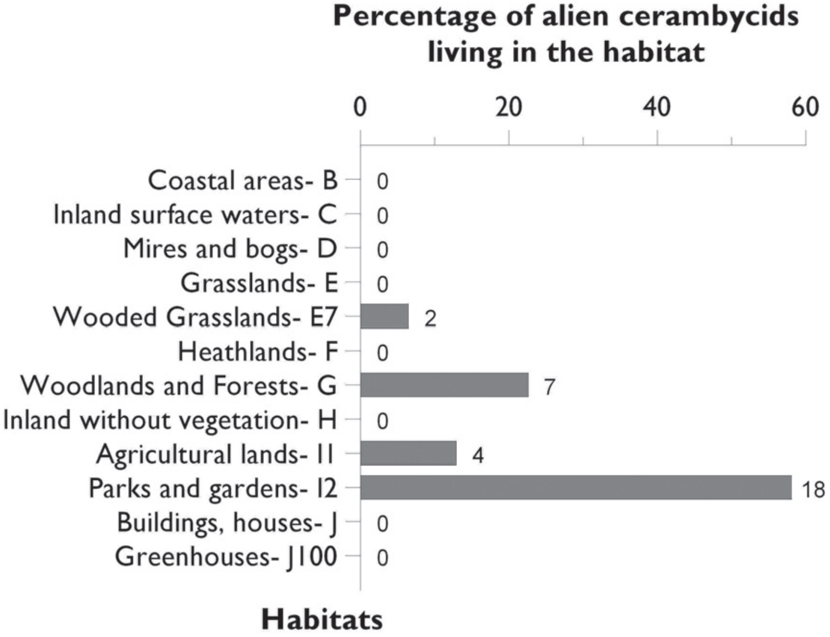

Figure 8.1.5. Main European habitats colonized by the established alien longhorn beetles. The number over each bar indicates the absolute number of alien longhorn beetles recorded per habitat. Note that a species may have colonized several habitats.

Thus, *Phoracantha* spp. that live only in eucalypt trees have colonized ornamental tree plantations in urban areas as well as old plantations such as those found on the Mediterranean islands and in neighbouring countries, and industrial plantations created for paper pulp. Other established species mostly have a distribution restricted to Mediterranean and Atlantic islands. In these areas, anthropogenic ecosystems are mainly colonized. A species of considerable concern with conifer forests is *Monochamus alternatus*, which could potentially become established in coniferous plantations and forests and subsequently transfer the pine wood nematode (Bursaphelenchus xylophilus Steiner & Buhrer, 1934).

8.1.8 Ecological and economic impact of alien cerambycid species

Although there is concern about the potential ecological impact of the invasive longhorn beetles *N. acuminatus* and *X. stebbingi*, there is no measure of their impact on trees or any estimation of possible competitive displacement of the native fauna. The ecological impact of *Anoplophora* species may also be important if they establish in European forests. *Anoplophora* could compete with other arthropods occupying the same niche, but they also create niches for other arthropods that live in tunnels in decaying wood or compete with other saproxylic beetles. The joint introduction and establishment of the Citrus longhorn beetle, *A. chinensis*, and its parasitoid, *Aprostocetus anoplophorae* Delvare, 2004, exemplifies the potential risk of adaptation of imported parasitoids which themselves might not specialise on the native fauna (Delvare et al. 2004).

Although the ecological niche occupied by an alien species may be vacant there remains a risk of secondary infection resulting from their damage. For example, secondary infestation by the pine wood nematode vectored by *Monochamus* spp. (Evans et al. 2008, Kawai Miho et al. 2006) may cause serious impacts to coniferous trees in all landscapes. *M. alternatus* has only been intercepted in Germany and France (Cocquempot 2007, Cocquempot (Unpubl.)); yet the pine wood nematode which it vectors was recorded from Portugal in 1999 (Mota et al. 1999). After having been contained for several years in a limited area, the nematode has spread throughout Portugal, as well as being eradicated following incursions into Spain in 2008 and Madeira in 2009. A novel association with the native species, *M. galloprovincialis* (Villiers 1967) has also been reported. The expansion as well as new introductions of the pine wood nematode could potentially have a substantial level of economic impact in all areas of coniferous cultivation in Europe.

Other economic impacts are mainly associated with ornamental trees in urban areas, cultivated trees such as poplars and eucalypts and nurseries, including these for bonsai production. Studies of *Anoplophora glabripennis* in North America and *A. chinensis* in China indicate the possible scale of economic damage following establishment of these species in a new country or in a plantation, especially of poplar or Citrus trees (Cocquempot et al. 2003, Haack et al. 2010, MacLeod et al. 2002). As a control measure, ornamental trees colonized by invasive longhorns must be eliminated without consideration of their aesthetic value. Eradication measures entail high costs to be borne by local communities or private owners. Special attention is paid to *A. chinensis* necessitating complete removal of trees, including the rootstock (Haack et al. 2010).

Poplars or eucalypt plantations can be highly affected as has already been the case in China (*A. glabripennis* on poplars) and in Spain (*Phoracantha* spp.), where infested trees become unsuitable for pulp and wood exploitation. The Citrus longhorn beetle is also considered as an important risk for all Citrus fruit production in the Mediterranean area and its islands.

The nursery industry is already concerned. There are several examples of introductions or establishments of potentially invasive species such as *Callidiellum rufipenne* and *Anoplophora chinensis*, with the imports of nursery plants. Nurseries can themselves be vectors of aliens when they dispatch their products.

The eradication process established for quarantine species aims to limit introductions although only a few eradications have been officially reported in Europe, e.g. as for *Anoplophora chinensis* in France (Hérard et al. 2006, Hérard and Roques 2009). Phytosanitary interceptions at borders are likely to have prevented a number of introductions and further establishments (e.g., *Monochamus alternatus*, *Trichoferus campestris* in France, *Anoplophora glabripennis* and *A. chinenis* in several countries) (Cocquem-

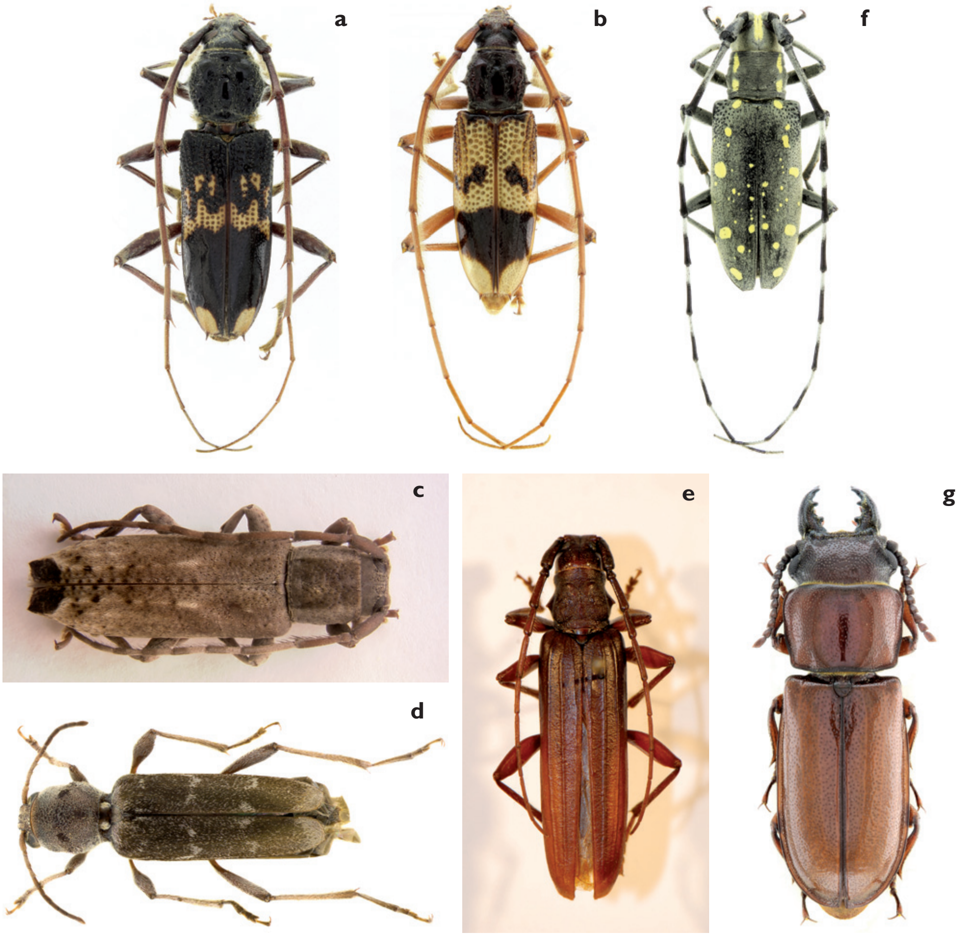

Figure 8.1.6. Adults of some alien longhorn beetle species. **a** *Phoracantha semipunctata* **b** *Phoracantha recurva* **c** *Mimectatina meridiana* (Credit: Christian Cocquempot) **d** *Xylotrechus stebbingi* (Credit: Vítěslav Maňák) **e** *Bardistes cibarius* (Credit: Christian Cocquempot) **f** *Psacothea hilaris* **g** *Parandra brunnea* (a, b, e, f, g: Credit: Henri-Pierre Aberlenc).

pot 2007) whilst at the same time, several non-quarantine species not submitted to importation controls have become established (e.g., *Xylotrechus stebbingi*, *Phoracantha semipunctata*, *Neoclytus acuminatus*). This illustrates the importance of quarantine species lists, which should be preventive and not only curative to be most effective.

Human-mediated dispersal should also be tightly controlled during the eradication process. Without due respect for control obligations, eradication can fail. For example, the long delay by Italian authorities in applying control measures and strong management measures against *Anoplophora chinensis* (EPPO 2009, Jucker et al. 2007) or inadvertent movement of untreated wood material for *A. glabripennis* in New-York (Haack et al. 1997) are examples of ineffective eradication efficacy.

8.1.9 Expected trends

The combination of increasing volumes of trade, the increased speed of import of potential vectors, the diversity of sources and sites for introduction is likely to result in increasing invasion risk (Cocquempot 2007). All recently established species alien *to* Europe have been intercepted too late after their introduction and have been outside official institutional controls. These factors make it increasingly difficult for rapid eradication after initial arrival. Effective monitoring of each point of possible entry is unfeasible when the key pathways identified here have different vectors and locations of arrival (e.g. airports, harbours, stations, lorry parks), and there are major difference in the quality of phytosanitary controls between European countries, particularly following the enlargement of the EU. The risk depends on volume and diversity of vector material imported, and subsequently there is greatest risk in countries such as the UK, France, Spain, Italy, Netherlands, Belgium and Germany. The case of *Anoplophora glabripennis* in North America and Europe clearly demonstrates the possibility of spread in our continent; such detailed assessment is required for all potentially invasive longhorn beetles (MacLeod et al. 2002).

According to Worner (2002), progress in the knowledge of invasion processes and associated preventive measures have not been followed by actions since the late 1980's. Preventive methods are still routinely applied, e.g. the application of ISPM 15 (International Standard for Phytosanitary Measures No.15), which set standards for heat treatment and fumigation of wood product materials used in international trade is likely to limit the arrival of longhorn beetles related to these materials although a few have been found to survive (Haack et al. 2010). However, this method is not uniformly applied to all imported living trees, shrubs plants for planting or bonsais. Thus, a high number of imported bonsais or other nursery trees infested with *Anoplophora chinensis* are still discovered (Hérard and Roques 2009). Although importation controls could be improved, they will never offer full protection. Further, controls which reduce the risk of introduction are mainly restricted to quarantine species. Post-interception or controls at importation points should be extended to all the potential pests posing risk and not be restricted to quarantine species already intercepted, introduced or established.

References

Adachi I (1990) Population studies of *Anoplophora malasiaca* adults (Coleoptera: Cerambycidae) in a Citrus grove. *Research Population Ecology* 32: 15–32.

Adlbauer K (2006) personnal communication.

Allenspach V (1973) *Insecta Helvetica 3 – Coleoptera Cerambycidae*. Züric, Switzerland: Fotorotar AG. 216 pp.

Alluaud C (1935) Les Coléoptères des îles Salvages. *Revue française d'Entomologie* 2: 35–44.

Althoff J, Danilevsky ML (1997) *A Check-List of Longicorn Beetles* (*Coleoptera, Cerambycoidea*) *of Europe*. Ljubljana, Slovenia: Slovensko Entomološko Društvo štefana Michielija, 1–64.

Bahillo P, Iturrondobeitia-Bilbao JC (1995) Primera cita de *Callidiellum rufipenne* (Motschulsky, 1860) para la Península Ibérica (Coleoptera: Cerambycidae). *Boletín de la Asociación española de Entomología* 19: 204.

Bercedo P, Bahillo P (1998) *Phoracantha recurva* (Coleoptera: Cerambycidae): Una nueva plaga en los eucaliptales españoles. *Boletín de la Sociedad Entomológica Aragonesa* 23: 52.

Bercedo P, Bahillo P (1999) Primera cita para Europa de *Phoracantha recurva* Newman, 1840 (Coleoptera, Cerambycidae). *Estudios del Museo de Ciencias Naturales de Alava* 14: 169–174.

Berger P (1992) Présence de *Phoracantha semipunctata* F. dans le sud de la France : une menace pour les eucalyptus (Coleoptera Cerambycidae). *Bulletin mensuel de la Société Linnéenne de Lyon* 61: 301–304.

Bertolini S (1872) *Catalogo sinonimico e topografico dei Coleotteri d'Italia*. Firenze : Tipografia Cenniniana, 263 pp.

Bijaoui R (1980) Notes de chasses et observations diverses : *Neoclytus acuminatus* (Col. Cerambycidae) dans le Tarn. *L'Entomologiste* 36: 268.

Borges PAV, Cunha R, Gabriel R, Frias Martins A, Silva L and Vieira V (eds) *A list of the terrestrial fauna* (*Mollusca and Arthropoda*) *and flora* (*bryophyta, Pteridophyta and Spermatophyta*) *from the Azores*. Direccao Regional do Ambiente and Universidade das Açores, 317 pp.

Bosmans B (2006) *Phoracantha recurva* (Coleoptera: Cerambycidae) found in a cluster of bananas *Phegea* 34: 105.

Brustel H, Berger P, Cocquempot C (2002) Catalogue des Vesperidae et des Cerambycidae de la faune de France (Coleoptera). *Annales de la Société entomologique de France* 38: 443–461.

Bytinski-Salz H (1956) The Cerambycidae of Israel. *Bulletin of the Research Council of Israel* 5B: 207–226.

Cadahia D (1980) Proximidad de dos nuevos enemigos de los Eucalyptus en España. *Boletín del Servicio de Plagas forestales* 6: 165–192.

Campadelli G, Sama G (1988) Prima segnalazione per l'Italia di cerambicide giapponese: *Callidiellum rufipenne* Motchulsky. *Bollettino dell'Istituto di Entomologia "Guido Grandi" della Universita degli Studi di Bologna* 43: 69–73.

Carter M, Smith M, Harrison R (2009) Genetic analyses of the Asian longhorned beetle (Coleoptera, Cerambycidae, *Anoplophora glabripennis*), in North America, Europe and Asia. *Biological Invasions*. doi 10.1007/s10530-009-9538-9

Cavalcaselle B (1983) Osservazioni sulla diffusione di *Phoracantha semipunctata* F. in Sardegna, Sicilia e nell'Italia centro-meridionale. *Atti XIII Congresso Nazionale Italiano di Entomologia, Sestriere-Torino*, 455–464.

Černý Z (2002) A contribution to the understanding of Beetles of the family Coleoptera: Cerambycidae in Greece. *Studie a Zprávy Okresniho Muzea Praha-Vychod* 14: 3–26.

Chikatunov V, Kravchenko, Dorchin Y, Müller G (2006) The xylophagous beetles (Buprestidae, Lyctidae, Bostrichidae, Anobiidae, Cerambycidae, Scolytidae, Platypodidae) collected in the Israeli light trap survey and their association with the major phyto-geographical zones of Israel. Esperiana. *Buchreiche zur Entomologie* 12: 313–320.

Chikatunov V, Pavlicek T, Nevo E (1999) Coleptera of "Evolution Canyon". Lower Nahal Oren, Mount Carmel, Israel. *Pensoft Series faunistica* 14: 1–174.

Cocquempot C (1993) Notes de chasse et Observations diverses – Nouvelle extension pour *Phoracantha semipunctata* (F.) (Col. Cerambycidae). *L'Entomologiste* 49: 37.

Cocquempot C (2007) Alien longhorned beetles (Coleoptera Cerambycidae): Original interceptions and introductions in Europe, mainly in France, and notes about recently imported species. *Redia* 89: 35–50.

Cocquempot C, Debreuil M (2006) *Xylotrechus stebbingi* Gahan 1906 et *Phoracantha semipunctata* (Fabricius, 1775): historique de l'expansion française de deux envahisseurs (Coleoptera Cerambycidae). *Rutilans* 9: 85–89.

Cocquempot C, Grousset C, Pellegrin D (2007) *Distribution française de Lucasianus levaillantii* (*Lucas, 1846*) *et des sous-espèces d'Icosium tomentosum* (*Lucas, 1854*) (*Coleoptera Cerambycidae*). Rutilans 10: 35–39.

Cocquempot C, Hérard F, Reynaud P (2003) Les longicornes asiatiques *Anoplophora glabripennis* et *Anoplophora chinensis*, une menace sérieuse pour l'arboriculture fruitière, les plantes d'ornement et les forêts françaises. *Phytoma – La Défense des Végétaux* 561: 24–28.

Cocquempot C, Sama G (2004) L'expansion circumméditerranéenne de *Phoracantha recurva* (Newman, 1840) (Coleoptera, Cerambycidae). *L' Entomologiste* 59: 209–214.

Colombo M, Limonta L (2001) *Anoplophora malasiaca* Thomson (Coleoptera Cerambycidae Lamiinae Lamiini) in Europe. *Bollettino di Zoologia agraria e di Bachicoltura II Ser* 33: 65–68.

Dauber D, Mitter H (2001) Das erstmalige Auftreten von *Anoplophora glabripennis* Motschulsky 1853 auf dem europaïschen Festland (Coleoptera: Cerambycidae: Lamiinae). *Beiträge zur Naturkunde Oberösterreichs* 10: 503–508.

De Fluiter HJ (1950) *Monochamus* (*Monohammus*) *galloprovincialis* Oliv. (Col.Cerambicidae). *Entomologische Berichten* 13: 135–136.

Delvare G, Bon M-C, Hérard F, Cocquempot C, Maspero M, Colombo M (2004) Description of *Aprostocetus anoplophorae* n. sp. (Hymenoptera: Eulophidae), a new egg parasitoid of the invasive pest *Anoplophora chinensis* (Förster) (Coleoptera: Cerambycidae). *Annales de la Société entomologique de France* 40: 227–233.

Demelt C (1974) Zusammenfassung und revision der cerambycidenfauna der Canarischen Inseln. *Nouvelle Revue d'Entomologie* 4: 227–236.

Dioli P, Vigano C (1990) Presenza in Valtellina di un cerambice nuovo per la Fauna italiana: *Xylotrechus stebbingi* Gahan, 1906 (Insecta, Coleoptera, Cerambycidae). *Il Naturalista Valtellinese* 1: 7–10.

Duffy EAJ (1953a) *A Monograph of the immature stages of British and imported Timber Beetles* (*Cerambycidae*). London: British Museum (Natural History). 350 pp.

Duffy EAJ (1953b) *Trinophylum cribratum* Bates (Col., Cerambycidae). A new Indian pest of British timber yards. *Entomologist's Gazette* 4: 254–264.

EPPO (2004). First report of *Anoplophora glabripennis* in Germany. *EPPO Reporting Services* 5: 2004/072.

EPPO (2006). Recent interceptions of *Anoplophora* species in United Kingdom. *EPPO Reporting Services* 5: 2006/098.

EPPO (2008) Premier signalement de *Saperda candida* en Allemagne: addition à la Liste d'Alerte de l'OEPP. *EPPO Reporting services 7*: 2008/139.

EPPO (2009a) De plus amples détails sur le foyer d'*Anoplophora chinensis* à Roma (IT). *EPPO Reporting Services* 3: 2009/048.

EPPO (2009b) *Anoplophora chinensis* found on *Cornus* and *Crataegus* in the Netherlands. *EPPO Reporting Services* 9: 2009/173

Evans S, Evans HF, Ikegami M (2008) Modeling PWN-Induced Wilt Expression: A Mechanistic Approach. In: Mota M, Vieira P (Eds) *Pine Wilt Disease: A Worldwide Threat to Forest Ecosystems*. The Netherlands: Springer Science+Business Media B.V., 259–278.

EPPO (2010) *Anoplophora chinensis* found again in the Netherlands. *EPPO Reporting Services* 2 : 2010/025

Fauna Europaea. http://www.faunaeur.org.

Fauvel (1884) Les Longicornes Gallo-Rhénans (suite) - Catalogue. *Revue d'Entomologie* 3: 317–390.

Frank H (2002) Pathways of arrival. In: Hallman GJ, Schwalbe CP *Invasive Arthropods in Agriculture: Problems and Solutions.* Enfield, UK: Sciences Publishers Inc., 71–86.

Friedman ALL, Rittner O, Chikatunov VI (2008) Five new invasive species of longhorn beetles (Coleoptera: Cerambycidae) in Israel. *Phytoparasitica* 36: 242–246

Gilmour EF (1948) *Trinophylum cribratum* Bates (Col., Cerambycidae) new to Britain.*The Entomologist's monthly Magazine*, 84: 12–16.

Haack RA, Poland TM, Gao RT (2000) The United States experience with the exotic Cerambycid *Anoplophora glabripennis*: Detection, Quarantine, and Control. In: *Quarantine pests, risks for the forestry sector and their effects on foreign trade. Proceedings on CD-Room of Silvotecna Conference 14, 27–28 June 2000*. Concepcion, Chile: CORMA. 12 pp.

Haack RA, Law KR, Mastro VC, Ossenbruggen SH, Raimo BJ (1997) New York's battle with the Asian Long-Horned Beetle. *Journal of Forestry* 95: 11–15.

Haack RA, Hérard F, Sun JH, Turgeon JJ (2010) Managing invasive populations of Asian longhorned beetle and Citrus longhorn beetle: A worldwide perspective. *Annual Review of Entomology* 55: 521–546.

Hérard F, Ciampitti M, Maspero M, Krehan H, Benker U, Boegel C, Schrage R, Bouhot-Delduc L, Bialooki P (2006) *Anoplophora* species in Europe: infestations and management processes. *Bulletin OEPP/EPPO Bulletin* 36: 470–474.

Hérard F, Maspero M, Ramualde N, Jucker C, Colombo M, Ciampitti M, Cavagna B (2009) *Anoplophora glabripennis* - Eradication programme in Italy (April 2009). http://www.eppo.org/QUARANTINE/anoplophora_glabripennis/ANOLGL_IT.htm.

Hérard F, Roques A (2009) Current status of *Anoplophora* spp. in Europe and an update on suppression efforts. In: Gottschalk KW (Ed) Proceedings of the 20th U.S. 20th USDA Interagency Research Forum on Invasive Species Annapolis, Maryland, 13- 16 January 2009. Gen. Tech. Rep. NE-337. Morgantown, USA: USDA Forest Service, Northeastern Research Station.

Heyrovský L (1930) Entomologické Prírucky XV. Catalogus Coleopterum Cechosloveniae – 1. Cerambycidae. *Casopis Ceskoslovenské spolecnosti Entomologické* 26–27: 1–61.

Heyrovský L (1951) Catalogus Coleopterum Cechosloveniae. Supplementum. Cerambycidae (Tesaríci). *Casopis Cekqslovenské spolecnosti Entomologické*, 48: 43–53.

Heyrovský L, Sláma G (1992) Tesaríkovití – Coleoptera, Cerambycidae. Zlín, Czech Republic: Kabourek. 367pp.

Horion A (1974) *Faunistik der mitteleuropäischen Käfer 12: Cerambycidae – Bockkäfer*. Überlingen-Bodensee. 228 pp.

Hunt T, Bergsten J, Levkanicova Z, Papadopoulou A, Saint-John O, Wild R, Hammond P M, Ahrens D, Balke M, Caterino M S, Gómez-Zurita J, Ribera I, Barraclough TG, Bocakova M, Bocak L, Vogler AP (2007) A Comprehensive Phylogeny of Beetles Reveals the Evolutionary Origins of a Super-radiation. *Science*, 318: 1913–1916.

Ilić N (2005) [*Longhorn beetles* (*Coleoptera, Cerambycidae*) *from Serbia.* Faunistic review] (in Serbian) Belgrade: SZGR "Joksimović".180pp.

Jucker C, Tantardini A, Colombo M (2006) First record of *Psacothea hilaris* (Pascoe) in Europe (Coleoptera Cerambycidae lamiinae Lamiini). *Bollettino di Zoologia agraria e di Bachicoltura* 38: 187–191.

Jucker C, Maspero M, Colombo M (2007) Principali fitofagi in ambiente urbano e loro contenimento. *Informatore fitopatologico*: 22–25.

Kawai Miho, Etsuko Shoda-Kagaya, Tadashi Maehara T, Zhou ZH, Lian CL, Iwata RT, Yamane A, Hogetsu T (2006). Genetic structure of pine sawyer *Monochamus alternatus* (Coleoptera: Cerambycidae) populations in Northeast Asia: consequences of the spread of Pine Wilt Disease. *Environmental Entomology* 35, 569–579.

Köhler F (2000) Erster Nachtrag zum „Verzeichnis der Käfer Deutschlands“. *Entomologische Nachrichten und Berichte* 44: 60–84.

Komazaki S, Sakagami Y (1989) Capture-Recapture Study on the Adult Population of the White Spotted Longicorn Beetle, *Anoplophora malasiaca* (Thomson) (Coleoptera: Cerambycidae) in a Citrus Orchard. *Applied Entomology and Zoology,* 24: 78–84.

Korcynski I (1985) The Biology of *Nathrius brevipennis* (Muls.) (Coleoptera, Cerambycidae) in Poland. *Polskie Pismo Entomologiczne* 55: 73–78.

Lawrence JF, Newton AF (1995) Families and subfamilies of Coleoptera (with selected genera, notes, references and data of family-group names. In: Pakaluk J, Ślipiński SA (Eds) *Biology, Phylogeny, and Classification of Coleoptera*. Papers celebrating the 80th Birthday of Roy Crowson. Warzawa: Muzeum i Instytut Zoologii PAN, 779–1006.

Lemos-Perreira AB (1978) Sobre o aparecimento em Portugal de um Coleóptero Longicórnio exótico, do género *Acrocinus*. *Publicações do Instituto de Zoologia «Dr. Augusto Nobre», Faculdade de Ciências do Porto* 138: 1–13.

Linnaeus C von (1758) *Systema naturae per regna tria naturae, secundum classes, ordines, genera, species, cum characteribus, differentiis, synonymis, locis*. 10th Edition. Holmiæ, Impensis direct. Laurentii Salvii (Salvius)

Lucht WH (1987) *Die Käfer Mitteleuropas. Katalog*. Krefeld, Germany: Goecke & Evers Verlag. 342pp.

MacLeod A, Evans HF, Baker RHA (2002) An analysis of pest risk from an Asian longhorn beetle (*Anoplophora glabripennis*) to hard wood trees in the European community. *Crop Protection*, 21: 635–645.

Maspero M, Cavalieri G, D'Angelo G, Jucker C, Valentini M, Colombo M, Hérard F, Lopez J, Ramualde N, Ciampitti M, Caremi G, Cavagna B (2007a) *Anoplophora chinensis* - Eradication programme in Lombardia (Italy) http://www.eppo.org/QUARANTINE/anoplophora_chinensis/chinensis_IT_2007.htm.

Maspero M, Jucker C, Colombo M (2007b) First record of *Anoplophora glabripennis* (Motschulsky) (Coleoptera Cerambycidae Lamiinae Lamiini) in Italy. *Bollettino di Zoologia agraria e di Bachicoltura*, Serie II 39: 161–164.

Mayet V (1905) Le *Lucasianus levaillanti* Lucas (Col.), sa découverte en France et ses mœurs. *Bulletin de la Société entomologique de France*: 277–279.

Mazzeo G, Siscaro G (2007) Presenza di *Phoracantha recurva* su eucalipto in Sicilia. *Informatore fitopatologico*: 35–37.

Mendizábal M (1944) Cerambícidos de interés agricola. Boletín de Patología vegetal y Entomología agrícola 11: 463–476.

Méquignon A (1935) Voyage de MM. L. Chopard et A. Méquignon aux Açores (aoùt- septembre 1930) – VIII. Coléoptères américains acclimatés aux Açores. *Bulletin de la Société entomologique de France* 13: 203–204.

Mifsud D (2002) Longhorns beetles of the Maltese Islands (Coleoptera, Cerambycidae). *The Central Mediterranean Naturalist* 3: 161–168.

Mifsud D, Booth R (1997) Further contributions to the knowledge of the Longhorn Beetles (Coleoptera: Cerambycidae) of the Maltese Islands. *The Central Mediterranean Naturalist* 2: 35–36.

Mifsud D, Dandria D (2002) Introduction and establishment of *Phryneta leprosa* (Fabricius) (Coleoptera, Cerambycidae) in Malta.*The Central Mediterranean Naturalist* 3: 207–210.

Miquel ME (2008) The presence of *Phoracantha recurva* (Newman) (Coleoptera: Cerambycidae) in France and how to differentiate if from *P. semipunctata*. *British Journal of Natural History* 21: 193–194.

Mota MM, Braasch H, Bravo MA, Penas AC, Burgermeister W, Metge K and Sousa E (1999) First report of *Bursaphelenchus xylophilus* in Portugal and in Europe. *Nematology* 1: 727–734.

Napp DS (1994) Phylogenetic relationships among the subfamilies of Cerambycidae (Coleoptera – Chrysomeloidea). *Revista Brasileira de Entomologia* 38: 265–419.

Nolte O, Krieger D (2008) Nachweis von *Saperda candida* Fabricius 1787 auf Fehmarn – eine weitere, bereits in Ansiedlung befindliche, eingeschleppte Käferart in Mitteleuropa. *DgaaE-Nachrichten* 22: 133–136.

Nüssler H (1961) Ein beständiges Vorkommen des nearktischen Bockkäfers *Parandra brunnea* Fabr. (Col. Cerambycidae) in Deutschland. *Abhandlungen und Berichte aus dem Staatliches Museum für Tierkunde in Dresden* 26: 125–130.

Orousset J (1984) *Phoracantha semipunctata* Fabr., un ravageur des eucalyptus présent en Corse (Col. Cerambycidae). *Nouvelle Revue d'Entomologie* 1: 322.

Orousset J (1991) Présence aux Îles Canaries du ravageur des Eucalyptus *Phoracantha semipunctata* (Col. Cerambycidae). *Nouvelle Revue d'Entomologie* 8: 76.

Orousset J (2000) *Phoracantha recurva* Newman sera-t-il à ajouter à la faune de France ? (Coleoptera, Cerambycidae). *Le Coléoptériste* 39: 129–131.

Özdikmen H (2008) A nomenclatural act: some nomenclatural changes on palaearctic longhorned beetles (Coleoptera: Cerambycidae). *Munis Entomology and Zoology* 3: 707–715.

Palmeri V, Campolo O (2006) Sulla presenza di *Phoracantha recurva* e *Phoracantha semipunctata* F. (Coleoptera Cerambycidae) in Calabria. *Bollettino di Zoologia agraria e di Bachicoltura* 38: 251–254.

Pellegrin D (1990) *Icosium tomentosum* Lucas, espèce nouvelle pour la France continentale (Col. Cerambycidae Cerambycinae). *L'Entomologiste*, t. 46 (4): 167–169.

Pellegrin D, Cocquempot C (2001) Réhabilitation de la présence en France de *Lucasianus levaillanti* (Lucas, 1849) et nouvelles données géographiques. *Biocosme mésogéen* 18: 27–31.

Pérez Moreno I (2001) *Plagas introducidas em España peninsular em la segunda mitad del siglo XX*. ARACNET 4 http://entomologia.rediris.es/aracnet/num4/entomap/index.htm.

Picard F (1937) Sur les Cérambycides de Madère et des îles voisines. *Compte rendu sommaire des Séances de la Société de Biogéographie* 13: 70–72.

Pil N, Stojanović D (2005) Some rare longhorn beetles (Coleoptera: Cerambycidae) without Protection on the national level found on Mt. Fruška Gora, Serbia. *Archives of Biological Science Belgrade* 57: 137–142.

Plavilstshtikov NN (1934) *Bestimmungs-Tabellen der europaïschen Coleopteren. 112 Heft. Cerambycidae III. Teil. Cerambycinae: Cerambycini II1* (*Callichromina, Rosaliina, Callidiina*), Troppau, Germany: Verlag Edmund Reitter. 230pp.

Plaza Lama J (1990) Primera cita para la fauna ibérica de *Lucasianus levaillanti* (Lucas, 1849) (Col. Cer.). *Boletín del Grupo Entomológico de Madrid* 5: 73–75.

Reineck G (1919) Die Insekten der Mark Brandenburg. 2. Coleoptera. Cerambycidae. *Beiheft der Deutsche Entomologische Zeitschrift* 63: 1–92.

Rossem G. van, van de Bund CF, Burger HC, de Goffau LJW (1981) Bijzondere aantastingen door insekten in 1980. *Entomologische Berichten* 41: 84–87.

Ruiz JL, Barranco P (1998) *Phoracantha recurva* Newman, 1840, nueva especie plaga para la Región Mediterránea (Coleoptera: Cerambycidae). *Boletín de la Asociación Española de Entomología* 22: 227–228.

Sama G (1984) *Fauna d'Italia Vol. XXV. Coleoptera Cerambycidae, Catalogo topographico e sinonimico*. Bologna, Italia: Edizioni Calderini. 216 pp.

Sama G (2002) *Atlas of the Cerambycidae of Europe and Mediterranean area. Vol 1: Northern, Western, Central and Eastern Europe.* Zlín, Czech Republic : Kabourek. 173 pp.

Sama G (2006a) Notes on *Taeniotes scalaris* (Fabricius, 1781) and *T. cayennensis* (Thomson, 1859) (Coleoptera: Cerambycidae) in the Azorean Archipelago. *Boletín de la Sociedad Entomológica Aragonesa* 39: 231–234.

Sama G (2006b) Taxonomical remarks on *Xylotrechus smei* (Castelnau & Gory, 1841) and *X. stebbingi* Gahan, 1906 and their distribution in Western Palaearctic region. *Doriana* 7: 1–6.

Sama G, Bocchini R (2003) *Phoracantha recurva* (Newman, 1840) (Insecta Coleoptera Cerambycidae), prima segnalazione per la fauna italiana.*Quaderno di Studi e Notizie di Storia naturale della Romagna* 18: 168.

Sama G, Buse J, Orbach E, Friedman ALL, Rittner O, Chikatunov V (2010) A new catalogue of the Cerambycidae (Coleoptera) of Israel with notes on their distribution and host plants. *Munis Entomology and Zoology* 5: 1–51.

Šefrová H, Laštůvka Z (2005) Catalogue of alien animal species in the Czech Republic. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis* 53: 151–170.

Sama G, Cocquempot C (1995) Note sur l'extension européenne de *Xylotrechus stebbingi* Gahan, 1906 (Coleoptera, Cerambycidae, Clytini). *L'Entomologiste* 51: 71–75.

Schembri S, Sama G (1986) The Cerambycidae of the Maltese Islands (Coleoptera). *Bollettino della Società entomologica italiana* 118: 93–100.

Schmidt G, Schmidt HU (1990) Ein ungewöhnlicher "Gast" aus einem Bonsai- Bäumchen: *Anoplophora malasiaca* Thoms. (Coleoptera: Cerambycidae). *Mitteilungen des Internationalen Entomologischen Vereins* 15: 69–75.

Serrano ARM (1982) Contribuciao para o conhecimato do poro amerto, distribuciao e oviger dos Coleopteros do Archipelago dos Açores. *Boletim do Museu Municipal do Funchal* 34: 67–104.

Sliwinski Z (1958) *Nathrius brevipennis* (Muls.) Bosq. a new species of beetle (Coleoptera, Cerambycidae) for fauna Polands. *Polskie Pismo Entomologiczne* 28: 129–131.

Smith MT, Bancroft J, Li G, Gao R, Teale S (2001) Dispersal of *Anoplophora glabripennis* (Cerambycidae). *Environmental Entomology* 30: 1036–1040

Speight MCD (1988) The Irish Cerambycid fauna (Coleoptera : Cerambycidae). *Bulletin of the Irish biogeographical Society* 11: 41–76.

Sýkorová M (2008) *Molecular phylogeny of subfamilies Spondylidinae and Lepturinae based on mitochondrial 16S rDNA, BCc.* PhD Thesis. České Budějovice, Czech Republic: Faculty of Science, University of South Bohemia. 34pp.

Szeoke K, Hegyi T (2002) A szolo uj kartevoje az amerikai darazscincer (*Neoclytus acuminatus* Olivier). [A new grapevine pest: redheaded ash borer (*Neoclytus acuminatus* Olivier)]. *Novenyvedelem Majus* 38: 268–269.

Tassi F (1969) Un longicorne australiano per la prima volta in Italia (Col. Cerambycidae). *Bolletino dell' Associazione Romana di Entomologia* 24: 69–71.

Teunissen (2002) Waarnemingen van *Xylotrechus stebbingi* in Griekenland. Een Aziatische wespenboktor die zich in korte tijd heeft verbreid in het Middellandsee-Zeegebied. *Entomologische Berichten* (*Amsterdam*) 62: 57–58.

Tomiczek C, Hoyer-Tomiczek U (2008). Biology Studies Relevant to the Vector Role of *Monochamus* Species for PineWood Nematode. In: Mota M, Vieira P (2008) *Pine Wilt Disease: A Worldwide Threat to Forest Ecosystems*. Dordrecht, The Netherlands: Springer, 215–221.

Verdugo Páez AV (2004) Los cerambícidos de Andalucía (Coleoptera: Cerambycidae). Córdoba, Spain: Sociedad Andaluza de Entomología. Monográfico 1. 148 pp.

Villiers A (1967) Coléoptères Cérambycides de l'île de Chypre. *L'Entomologiste* 23: 63–64.

Villiers A (1979) Un nouveau Clytini en France ? *L'Entomologiste* 35: 144.

Vincent R (2007) *Catalogue des Coléoptères du département de la Saône-et-Loire* (*F-71*). *Volume I: Cerambycidae.* Terre Vive, Supplément Hors-Série: 183 pp.

Vives E (1995) Notas sobre longicornios ibéricos (V). Cerambícidos importados o aclimatados en la Península Ibérica (Coleoptera, Cerambycidae). Zapateri, *Revista aragonese de Entomologia* 5: 165–174.

Wang Q (1995) A Taxonomic Revision of the Australian Genus *Phoracantha* Newman (Coleoptera: Cerambycidae). *Invertebrate Taxonomy,* 9: 865–958.

Weidner H (1973) Insekten als Schädlinge an Drogen in Apotheken un Drogerien. *Anzeiger für Schädlingskunde und Pflanzen- und Umweltschutz vereinigt mit Schädlingsbekämpfung* 46: 177–180.

Weyers M (1875) Communication sur *Leptidea brevipennis* à Bruxelles. *Annales de la Société entomologique de Belgique, Comptes rendus des Séances* 18: 86–87.

Weyers M (1876) Communication à propos de Longicornes nouveaux pour la faune belge. *Annales de la Société entomologique de Belgique, Comptes rendus des Séances* 19: 65.

Wiel P van der (1956) Bijdrage tot de kennis der Nederlandse kevers, IV. Tijdschrift voor Entomologie, t. 99 (1–2): 1–21.

Winkler A (1932) *Catalogus Coleopterum regionis palaearcticae*. Wien: Albert Winkler Verlag: 1135–1226.

Wittenberg R (Ed) (2005) An inventory of alien species and their threat to biodiversity and economy in Switzerland. Délemont, Switzerland: CABI Bioscience Switzerland Centre, Report to Swiss Agency for Environment, Forest and Landscape. 417 pp.

Wollaston TV (1863) On the Canarian Longicorns. *Journal of Entomology* 8: 99–110.

Worner SP (2002) Predicting the invasive potential of exotic insects. In: Hallman GJ, Schwalbe CP *Invasive Arthropods in Agriculture: Problems and Solutions.* Enfield, UK: Sciences Publishers Inc., 119–137.

Table 8.1.1. List and characteristics of the Cerambycidae species alien to Europe. Status: A: Alien to Europe; C: cryptogenic species. Country codes abbreviations refer to ISO 3166 (see appendix I). Habitat abbreviations refer to EUNIS (see appendix II).

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Acanthoderes jaspidea Germar, 1824	A	phyto-phagous	Brazil	1880, PT-AZO	PT-AZO	I2	*Acacia, Albizzia*	Borges et al. 2005, Méquignon 1935, Serrano 1982
Acrocinus longimanus (Linnaeus, 1758)	A	phyto-phagous	Brazil	1977, PT	PT, PT-MAD	I2	Moraceae, Apocynaceae	Lemos-Perreira 1978 , Vives 1995
Anoplophora chinensis (Förster, 1848) (=*A. malasiaca* Thompson, 1865)	A	phyto-phagous	China South-Central	2000, IT	IT, NL	FB, FA, I2, G	*Acer, Betula, Carpinus Citrus, Corylus, Rosa* and deciduous shrubs (polyphagous)	Cocquempot 2007, Colombo and Limonta 2001, 2009a, EPPO 2009b, Evans et al. 2008, Hérard et al. 2006
Anoplophora glabripennis (Motschulsky, 1853)	A	phyto-phagous	China South-Central	2001, AT	AT, DE, FR, IT	FB, FA, I	*Acer, Aesculus, Betula, Carpinus, Fagus, Populus, Salix*	Carter et al. 2009, Cocquempot 2007, Cocquempot et al. 2003, Dauber and Mitter 2001, EPPO 2004, Hérard et al. 2006, 2009
Callidiellum rufipenne (Motschulsky, 1860)	A	phyto-phagous	Eastern Asia, Japan	1906, FR	ES, FR, IT	FA, FB, G1, G5, J4	Cupressaceae (*Cupressus macrocarpa*)	Bahillo and Iturrondobeitia 1995, Campadelli and Sama 1988, Cocquempot 2007
Chlorophorus annularis (Fabricius, 1787)	A	phyto-phagous	Asia-Temperate	1991, ES	ES	G	Bamboo	Vives 1995
Cyrthognathus forficatus (Fabricius, 1792)	A	phyto-phagous	Africa	1872, MT	MT	U	Unknown	Bertolini 1872
Derolus mauritanicus Buquet, 1840	A	phyto-phagous	Northern Africa	1884, FR	ES ?, FR ?	E7, F5, F8, FB, I2, X11	*Nerium oleander*	Brustel et al. 2002, Fauvel 1884, Mendizábal 1944, Verdugo 2004

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Deroplia albida (Brullé, 1838)	A	phyto-phagous	Canary Islands	1988, ES	ES	E7, F6, FB, G5	*Pelargonium*	Vives 1995
Lucasianus levaillantii (Lucas, 1846)	A	phyto-phagous	Northern Africa	1905, FR	ES, FR, PT	FA, G, FB	*Cupressus*	Brustel et al. 2002, Cocquempot et al. 2007, Mayet 1905, Pellegrin and Cocquempot 2001, Plaza Lama 1990, Vives 1995
Neoclytus acuminatus (Fabricius, 1775)	A	phyto-phagous	South-Central U.S.A.	1908, IT	CH, CZ, DE, FR, HR, HU, IT, ME, PT-MAD, RS, SI	FB, G, G1, G5, I2, X11	*Ulmus, Fraxinus, Juglans*	Bijaoui 1980, Brustel et al. 2002, Cocquempot 2007, Heyrovský 1951, Ilić 2005, Picard 1937, Pil and Stojanović 2005, Reineck 1919, Sama 1984, Tassi 1969, Villiers 1979, Winkler 1932, Wittenberg 2005
Oxymerus aculeatus lebasi Dupont, 1838	C	phyto-phagous	Unknown	Unknown	ES-CAN	U	*Calophyllum*	Alluaud 1935
Parandra brunnea (Fabricius, 1789)	A	phyto-phagous	North America	1916, DE	DE	G, J1	*Tilia, Populus,* deciduous trees	Grämer 1961, Nüssler 1961
Phoracantha recurva Newman, 1840	A	phyto-phagous	Australia	1992, IT	ES, GR, IL, IT, IT-SAR, IT-SIC, MT, PT	G1	*Eucalyptus*	Bercedo and Bahillo 1998, Bercedo and Bahillo 1999, Černý 2002, Cocquempot 2007, Cocquempot and Sama 2004, Friedman et al. 2008, Mazzeo and Siscaro 2007, Mifsud 2002, Miquel 2008, Orousset 2000, Palmeri and Campolo 2006, Pérez Moreno 2001, Ruiz and Barranco 1998, Sama and Bocchini 2003, Sama et al. 2010, Wang 1995

Family *Species*	Status	Regime	Native range	1st record in Europe	Invaded countries	Habitat	Hosts	References
Phoracantha semipunctata (Fabricius, 1775)	A	phyto-phagous	Australia	1948, IL	CY, FR, FR-COR, ES, ES-CAN, GR, IL, IT, IT-SAR, IT-SIC, MT, PT, PT-MAD	FB, G, G1, G5, I2, X11	*Eucalyptus*	Berger 1992, Brustel et al. 2002, Cadahia 1980, Cavalcaselle 1983, Černý 2002, Cocquempot 1993, Cocquempot 2007, Cocquempot and Sama 2004, Mifsud and Booth 1997, Orousset 1984, Orousset 1991, Sama et al. 2010, Teunissen 2002, Vives 1995, Wang 1995
Phryneta leprosa (Fabricius, 1775)	A	phyto-phagous	South Tropical Africa	1997, FR	FR, MT	G	*Morus nigra*	Mifsud and Dandria 2002, Vincent 2007
Taeniotes cayennensis Thomson, 1859	A	phyto-phagous	Central America	1858, PT	PT-AZO	U	Tropical trees	Sama 2006a
Trinophylum cribratum (Bates, 1878)	A	phyto-phagous	India	Unknown	GB	I2	Deciduous trees, *Larix*, *Pinus* (polyphagous)	Duffy 1953b, Gilmour 1948
Xylotrechus stebbingi Gahan, 1906	A	phyto-phagous	Central Asia	1990, IT	CH, CY, DE, FR, GR, GR-CRE, GR-NEG, GR-SEG, IL, IT, IT-SAR	FB, G, G1, G5, I2, X11	*Alnus*, *Ficus*, *Morus*, *Populus*	Cocquempot 2007, Cocquempot and Debreuil 2006, Dioli and Vigano 1990, Köhler 2000, Sama 2006b, Sama et al. 2010, Šefrová and Laštůvka 2005, Tomiczek and Hoyer-Tomiczek 2008, Wittenberg 2005

Table 8.1.2. List and characteristics of the Cerambycidae species alien *in* Europe. Country codes abbreviations refer to ISO 3166 (see appendix I). Habitat abbreviations refer to EUNIS (see appendix II).

Family species	**Regime**	**Native range**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Arhopalus rusticus (Linnaeus, 1758)	phytophagous	Continental Europe	PT-AZO, PT-MAD	G3	*Pinus, Picea, Abies, Larix*	Fauvel 1897, Picard 1937, Serrano 1982
Aromia moschata (Linné, 1758)	phytophagous	Continental Europe	PT-AZO	I2	*Salix, Populus, Alnus*	Borges et al. 2005
Cerambyx carinatus Küster, 1846	phytophagous	Balkans	MT	G	*Prunus*	Sama and Cocquempot 1986
Cerambyx nodulosus Germar, 1817	phytophagous	Balkans	MT	G	*Pyrus, Malus*	Fauvel 1897, Schembri and Sama 1986
Clytus arietis (Linné, 1758)	phytophagous	Continental Europe	PT-MAD	E5, G, G1, G5	Deciduous trees (polyphagous)	Picard 1937, Wollaston 1854
Gracilia minuta (Fabricius, 1781)	phytophagous	Southern Europe	AT, CH, , ES-CAN, IE, LV, LT, PT-AZO, PT-MAD	F3, G, G5	Deciduous trees (polyphagous	Borges et al. 2005, Bytinski-Salz 1956, Lucht 1987, Speight 1988, Wollaston 1863
Icosium tomentosum atticum Ganglbauer, 1881	phytophagous	Southeastern Europe	FR	G3	Cupressaceae	Cocquempot et al. 2007, Pellegrin 1990
Monochamus galloprovincialis (Olivier, 1795)	phytophagous	Southwestern Europe	NL	G3	*Pinus*	De Fluiter 1950
Monochamus sartor (Fabricius, 1787)	phytophagous	Northern Europe, Alps	BE, , NL	G3	*Picea*	Fauvel 1884, Wiel 1956, Lucht 1987
Monochamus sutor (Linnaeus, 1758)	phytophagous	Central and Northern Europe	BE, PT	G3	*Picea, Pinus*	Speight 1988, Weyers 1876
Morimus asper funereus Mulsant, 1863	phytophagous	Southeastern Europe	CZ, MT	G	Deciduous trees (polyphagous	Schembri and Sama 1986, Šefrová and Laštůvka 2005

Family species	**Regime**	**Native range**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Nathrius brevipennis (Mulsant, 1839)	phytophagous	Southwestern Europe	AT, BE, CH, CZ, DE, GB, IE, LU, LV, PL, PT-AZO	F3	Deciduous and conifer trees (polyphagous)	Adlbauer 2006, Borges et al. 2005, Duffy 1953a, Heyrovský 1930, Korcynski 1985, Lucht 1987, Sliwinski 1958, Speight 1988, Weidner 1973, Weyers 1875
Phymatodes testaceus (Linné, 1758)	phytophagous	Continental Europe	PT-AZO	G	Deciduous and fruit trees, preferably on *Quercus*	Fauvel 1897, Picard 1937, Wollaston 1854
Poecilium lividum (Rossi, 1794)	phytophagous	Southeastern Europe	BE, CH, CZ, DE, LU, NL	G,J1	*Quercus, Castanea*	Lucht 1987, Heyrovský and Sláma 1992, Horion 1974, Šefrová and Laštůvka 2005, Wittenberg 2005
Rhagium inquisitor (Linné, 1758)	phytophagous	Continental Europe	IE	G3	Conifers *(Pinus, Picea, Abies, Larix);* deciduous trees (*Betula, Fagus, Quercus*)	Speight 1988
Rosalia alpina (Linné, 1758)	phytophagous	Central Europe, Alps	MT	G, I2, J1	*Fagus*, and other deciduous trees	Horion 1974, Schembri and Sama 1986
Stictoleptura rubra (Linné, 1758)	phytophagous	Central Europe	PT-AZO	G3	Conifers (*Pinus, Picea, Abies, Larix*)	Borges et al. 2005
Stromatium unicolor (Olivier, 1795)	phytophagous	Southeastern Europe	PT-MAD	G	Deciduous trees (mostly) and conifers (polyphagous)	Fauvel 1897, Picard 1937
Trichoferus fasciculatus (Faldermann, 1837)	phytophagous	Southeastern Europe	CH, PT-MAD	G	Deciduous trees (polyphagous)	Allenspach 1973, Picard 1937
Trichoferus griseus (Fabricius, 1792)	phytophagous	Southeastern Europe	CZ	G	*Ficus, Pistacia, Rosa*	Šefrová and Laštůvka 2005
Xylotrechus arvicola (Olivier, 1795)	phytophagous	Southeastern Europe	SP-CAN	G	Deciduous trees (polyphagous)	Demelt 1974

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Weevils and Bark Beetles (Coleoptera, Curculionoidea)
Chapter 8.2

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Abstract

We record 201 alien curculionoids established in Europe, of which 72 originate from outside Europe. Aliens *to* Europe belong to five families, but four-fifths of them are from the Curculionidae. Many families and subfamilies, including some species-rich ones, have few representatives among alien curculionoids, whereas some others are over-represented; these latter, Dryophthoridae, Cossoninae and specially Scolytinae, all contain many xylophagous species. The number of new records of alien species increases continuously, with an acceleration during the last decades. Aliens *to* Europe originate from all parts of the world, but mainly Asia; few alien curculionoids originate from Africa. Italy and France host the largest number of alien *to* Europe. The number of aliens per country decreases eastwards, but is mainly correlated with importations frequency and, secondarily, with climate. All alien curculionoids have been introduced accidentally via international shipping. Wood and seed borers are specially liable to human-mediated dispersal due to their protected habitat. Alien curculionoids mainly attack stems, and half of them are xylophagous. The majority of alien curculionoids live in human-modified habitats, but many species live in forests and other natural or semi-natural habitats. Several species are pests, among which grain feeders as *Sitophilus* spp. are the most damaging.

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Keywords
Europe, Coleoptera, Curculionoidea, Curculionidae, alien species, invasive species, xylophagy, seed feeder

8.2.1. Introduction

The superfamily Curculionoidea encompasses the weevils and the bark and ambrosia beetles; here we will use „weevils" to refer to the entire superfamily. It is the most species-rich beetle clade, with more than 60,000 described species (Oberprieler et al. 2007). Four fifths of all weevils are in the family Curculionidae. Curculionoids are distributed worldwide, everywhere vegetation is found.

This is a rather homogeneous group, its members being generally easily recognizable despite various aspects. Adults are primarily characterized by the head being produced into a rostrum (snout) to which the antennae and mouthparts are attached. The rostrum is highly variable in size and shape, varying from as long as the body to very short or absent. Larvae, generally white and C-shaped, are catepillar-like (eruciform), soft-bodied, with legs being either vestigial or (usually) absent, except in some species of the primitive family Nemonychidae.

Except for a few rare species, adults and larvae of Curculionoidea are phytophagous. Larvae are mainly endophytic or subterranean. Weevils feed on a large variety of plants, attacking all parts. Many species are important pests for agriculture or forestry.

The Macaronesian islands[1] pose a special problem. While many of their weevils are only found on single islands or groups of islands and are thus clearly endemic, other species are shared between island groups, or between Macaronesian islands and the continental Europe or North Africa. For example, a number of scolytines specialized to *Euphorbia* are shared between the Canary Islands and Madeira, or between the Canary Islands and the Mediterranean and North Africa (Table 8.2.1). Given the difficulties involved with dispersal by these tiny insects over vast expanses of salt water, we have chosen to interpret the distributions of non-endemic species as resulting from recent human transport. We are well aware that rare instances of natural dispersal do occur, at least on evolutionary time scales: after all, such natural dispersal has resulted in many instances of well documented species radiations (Emerson 2008, Juan et al. 2000). Because of the inherent uncertainty in distinguishing between recent anthropogenic spread and older natural dispersal, we classify nonendemic species of these archipelagos as *presumed* aliens (they are indicated in tables 8.2.1 & 8.2.2). Without contradictory data, we consider: 1) species known from Europe and found on a Macaronesian island as *presumed* alien *in* Europe; 2) species known from Africa (and not from Europe) and found in Macaronesia as *presumed* alien *to* Europe; 3) species from the Canary Islands which also occur further north on Madeira or the Azores as *presumed* alien

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[1] We include in our coverage the Macaronesian islands associated with European countries (Madeira, the Azores, the Canary Islands); we exclude the Cape Verde Islands.

from the Canary Islands and *presumed* alien *to* Europe. *Presumed* alien are often considered below separately than others, due to the uncertainty attached to their status and the geographical and biogeographical differences between Macaronesia and Europe.

We consider that 201 alien curculionoids currently live in Europe, of which 72 species originate outside of Europe (aliens *to* Europe, Table 8.2.1; 20 *presumed* alien are included) and 129 species originate from other parts of Europe (aliens *in* Europe, Table 8.2.2; 60 *presumed* alien are included)[2]. Except where otherwise noted, our discussion of exotic curculionoids only pertains to alien *to* Europe.

8.2.2. Taxonomy and biology

The systematics of the superfamily Curculionoidea have long been controversial, in part due to the enormous number of taxa involved, in part due to extensive parallel evolution arising from the similar ecologies of unrelated clades (Alonso-Zarazaga and Lyal 1999, Oberprieler et al. 2007). We follow here the current classification of Fauna Europaea (Alonso-Zarazaga 2004), which notably considers the traditional Platypodidae and Scolytidae families as subfamilies of Curculionidae.

About 5,000 native curculionoids live in Europe, distributed among 13 families. Comparatively, the alien entomofauna is very limited with only 72 established species recorded at this time (Fig. 8.2.1). These alien species belongs to five families, all of which have native representatives.

Anthribidae. Principally present in tropical areas, these largely fungus-feeding curculionoids generally live primarily in fungus-infested wood. There is only one alien species in Europe, *Araecerus coffeae*, which is a seed feeder, an exceptional biology in this family.

Apionidae. Characterized in part by their non-geniculate antennae and endophytous larvae, these tiny curculionoids are represented in Europe by three alien species, all living on alien ornamental *Alcea* (Malvaceae).

Dryophthoridae. This family contains large weevils mainly living on woody monocotyledons. Alien dryophthorids consist of woody monocotyledons borers and seed feeders. They are particularly numerous compared with the world fauna (Fig. 8.2.1) and especially with respect to the few native species in Europe (8 aliens vs 6 natives, according to Fauna Europaea (Alonso-Zarazaga 2004)). This situation could be explained first by the few woody monocotyledons in Europe-native flora in contrast with the several woody monocotyledons introduced in Europe for ornamental or agricultural purpose. The human-mediated transport of seeds, and consequently seed feeders, is probably a further explanation.

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[2] Other aliens have been recorded, but have not been taken into account here because their establishment have not been confirmed. We have also excluded some possible *presumed* aliens due to the uncertainty about their distribution.

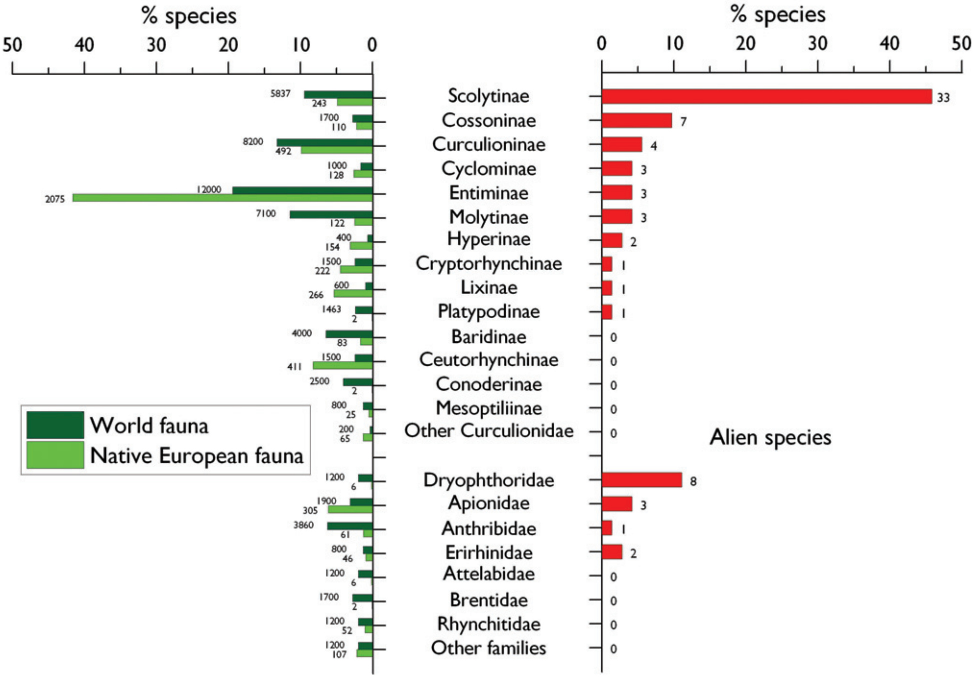

Figure 8.2.1. Taxonomic overview of Curculionoidea species alien to Europe compared to the native European fauna and to the world fauna. **Right**- Relative importance of the Curculionoidae families and subfamilies in the alien entomofauna is expressed as percentage of species in the family/ subfamily compared to the total number of alien Curculionidea in Europe. Subfamilies of Curculionidae and other families of Curculionidea are presented in a decreasing order based on the number of alien species. The number over each bar indicates the total number of alien species observed per family/ subfamily. **Left**- Relative importance of each family/ subfamily in the native European fauna of Curculionidea and in the world fauna expressed as percentage of species in the family/ subfamily compared to the total number of Curculionidea in the corresponding area. The number over each bar indicates the total number of species observed per family/ subfamily in Europe and in the world, respectively

Erirhinidae. Curculionoids of this small family mainly live on herbaceous monocotyledons, often aquatic ones. With two alien species, they are relatively well represented in Europe.

Curculionidae. This huge family encompasses more than 80% of weevils and notably includes the bark beetles and pinhole borers (Scolytinae and Platypodinae). Curculionids have a large variety of habits, but are all phytophagous. The European species are distributed in 16 subfamilies. The alien species belong to 10 subfamilies, all having native representatives. Many subfamilies, including the world's largest (Entiminae, Curculioninae and Molytinae), are under-represented among alien curculionoids compared with their world importance in the superfamily (Fig. 8.2.1). On the other hand, the subfamily Cossoninae, which mainly contains wood-boring weevils, are over-represented, but the most remarkable result is the over-representation of Scolytinae.

Scolytinae are small, cylindrical wood borers, without a rostrum or with only a very reduced one; they include some of the most important forest pests in the world. The majority are phloeophagous, breeding in the inner bark. Most others are xylomycetophagous, feeding on symbiotic fungi which they cultivate in tunnels in the wood (ambrosia beetles). The scolytines represent about 10% of world curculionoids but almost half of curculionoids alien *to* Europe. Alien bark beetles represent more than 12% of all bark beetle species in Europe. The over-representation of Scolytinae is related to the frequency with which they are transported in wooden packing material, pallets, and timber (Haack 2001, 2006, Brockerhoff et al. 2006). All stages of these beetles can survive long voyages well, since both adults and larvae are in tunnels under bark or in wood and not directly exposed to temperature extremes or dessication. The importance of a stable, protected microenvironment is illustrated by the high prevalence of ambrosia beetles in the Scolytinae plus Platypodinae (35%) among successful aliens *to* Europe (Table 8.2.1), compared with the prevalence of ambrosia beetles in these groups in temperate climates generally (below 20%: Kirkendall 1993). The establishment of ambrosia beetles in Europe is further facilitated by polyphagy (11/12 spp.) and inbreeding (10/12 spp.), as is generally believed to be the case for ambrosia beetles globally (Kirkendall 1993, Haack 2001).

The curculionoids alien *in* Europe are more representatives of Europe-native fauna. Scolytines (25% of aliens *in* Europe) are also over-represented compared with their importance among European curculionoids (5%), but not cossonines (3% of aliens *in* Europe). On the other hand, Entiminae (26% of alien *in* Europe, mostly *Otiorhynchus* and *Sitona*) are under-represented compared with the European fauna, but less so than among aliens *to* Europe.

8.2.3. Temporal trends

Of the five families considered in this chapter, the first information concerning an alien species in Europe was probably the description by Ratzeburg in 1837 of *Xyleborus pfeilii* based on specimens from southern Germany[8]. The curculionid *Pentarthrum huttoni* was introduced to Great Britain from New Zealand in 1854, and has subsequently become naturalized in many European countries (Table 8.2.1). Only three other introduced species were recorded in the second half of 19th century.

With the beginning of the 20th century, alien species began to be discovered more frequently, though this was limited to sporadic introductions (about 2 species per decade) confined to southern Europe – which perhaps provided more favourable climatic conditions – and along the main routes of international trade. Since the 1920s the rate of new introductions has slightly increased (Fig. 8.2.2), with a mean of nearly three species every decade, but remaining stable until middle of 1970s.

Despite the European laws regulating the trade of plant material, the number of records of new exotic species introduced to Europe has increased rapidly since 1975 and especially since 2000, reaching worrying levels with an average of more than one

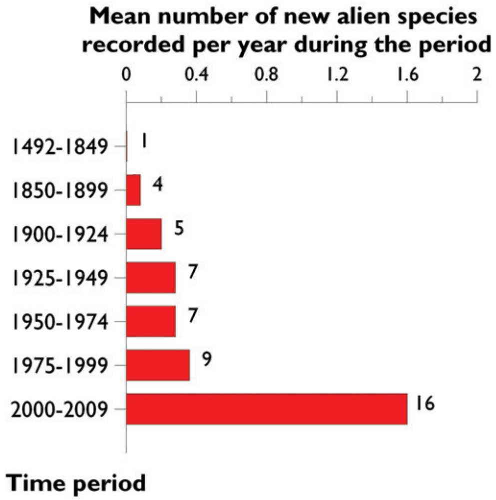

Figure 8.2.2. Temporal trend in establishment of Curculionoidea species alien *to* Europe from 1492 to 2010. *Presumed* alien species are excluded. The number besides each bar indicates the absolute number of new records during the time period. For the introduction year of each species see Table 8.2.1.

species per year (16 new species from 2000 to 2009: Table 8.2.1), and a peak of five new species per year in 2004 (8 species in 2003–2004). It is too early to say if the relatively low number of establishments observed since 2005 will be confirmed or is only due to stochastic variations. However, if the trend towards increasing rates of introduction continues unabated, in a few decades the mean number of alien species becoming established in Europe could reach several per year.

The temporal trend of alien curculionoids establishment is very similar to that observed in Europe for all alien terrestrial invertebrates (Roques et al. 2009, but see also Smith et al. 2007 for contradictory (more limited) data). On the other hand, this trend varies among weevils. Aliens from Asia follow the general trend (half of them have been recorded after 1975, a third after 2000), but the increasing of establishment rate is faster for those from North and South America (two-thirds of them have been recorded after 2000) while it is slower for those from others continents (half of them have been recorded before 1950, and none after 2000). Regarding feeding habits, all aliens follow the general trend except those with spermatophagous larvae, which show no trend. This particularity of the formers seems related to the oldness and intensity of human-mediated seed transport.

Unfortunately, for many alien species spread over large parts of Europe, data on the place and time of introduction are lacking, and generally the data on time of arrival of exotic species are very weak. Often, introduced species – especially those which are not pests – are first noticed only many years after arrival, or following subsequent and repeated introductions. As prompt communication of new findings is extremely important for the application of specific monitoring and eradication programs, the poor quality of these data is a major obstacle to aliens management.

8.2.4. Biogeographic patterns

Origin of alien species

All *presumed* aliens probably come from Africa (among which 35% from the subregion Macaronesia). These species are not included in further discussion due to uncertainty of their status and specially because their arrival modes have probably been different from other aliens due to proximity of the source region.

A probable region of origin could be specified for 51 of the 52 curculionoid species alien *to* Europe. There is one species, *Sitophilus zeamais* (Dryophthoridae), whose region of origin is uncertain (*cryptogenic*). *Cryptogenic* species are thus rare in this group compared to all alien terrestrial invertebrates (14%: Roques et al. 2009). *Sitophilus zeamais* is associated with maize crops, *Zea mays*, and feeds on maize grain stores, and it is likely that this species is American.

More than one-third (40%) of the exotic curculionoid species originate from Asia. Central and South America represents the second most important region of origin, with 19% of the species coming from this area. North America and Australasia both represent 14% of the contributing regions. Africa is a minor region of origin (6%), and the remaining species (6%) arrived from tropical or subtropical areas but the region of origin could not be precisely identified (Figure 8.2.3). This distribution is rather similar to that for all alien terrestrial invertebrates (Roques et al. 2009). The main differences are the under-representation of African aliens (6% vs. 12%) and the over-representation of South American (19% vs. 11%) and Australasian (14% vs. 7%) ones. A rather surprising result is that species originated from areas with tropical or subtropical climates all around the world represent about half of alien curculionoids.

Thirteen out of the twenty-one alien species originating from Asia are from the family Curculionidae, twelve species belonging to the subfamily Scolytinae and one species to the subfamily Cyclominae. Other families consist of Dryophthoridae (4 spp.), Apionidae (3 spp.) and Anthribidae (1 sp.). Scolytines originate from very different parts of this large continent. For example *Cyclorhipidion bodoanus* is native to Siberia and temperate northeast Asia, *Phloeosinus rudis* to Japan, and the three species of the genus *Xylosandrus* to Southeast Asia. In contrast, all the weevils of the Dryophthoridae family originate from tropical Asia. This group includes the banana root weevil *Cosmopolites sordidus*, the coconut weevil *Diocalandra frumenti*, the palm weevil *Rhynchophorus ferrugineus* and the rice weevil *Sitophilus oryzae*. The introduced apionids, *Alocentron curvirostre*, *Aspidapion validum* and *Rhopalapion longirostre*, all feed on flowers and seeds of *Alcea rosea* and other Malvaceae species (Bolu and Legalov 2008); these all originate from central Asia. Finally, the anthribid *Araecerus coffeae* originates from India.

The ten curculionoid species coming from Central and South America consist of curculionids (8 spp.) and dryophthorids (2 spp.). Curculionids originating from this region are as highly diverse taxonomically (they are distributed in six subfamilies) as in feeding habits. The native ranges of many species largely extend through the continent

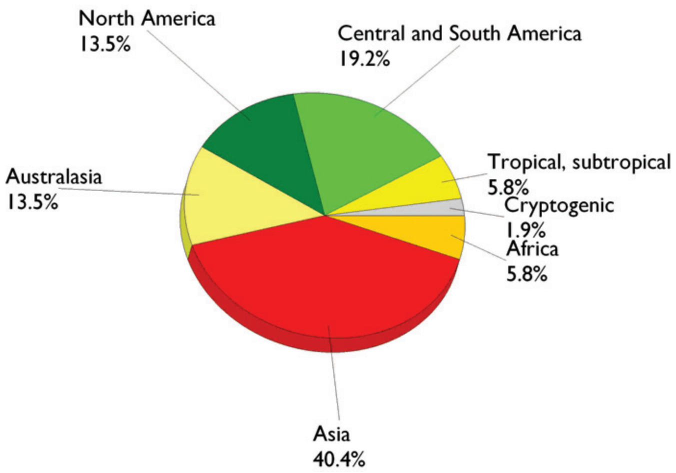

Figure 8.2.3. Origin of Curculionoidea species alien *to* Europe. *Presumed* alien species are excluded.

(including sometimes part of North America), though those of others are more narrow as for *Rhyephenes humeralis* (central Chile and neighboughring area of Argentina) and *Paradiaphorus crenatus* (Brazil).

Seven alien curculionoids are known to originate from North America. They include five species of the family Curculionidae and two of Erirhinidae. Many curculionids introduced from North America are xylophagous *sensu lato*[7], feeding on several broadleaved or coniferous hosts. The exceptions are the ash seed weevil *Lignyodes bischoffi* and *Caulophilus oryzae*, originally from the southeastern USA, which feeds on seeds. In contrast, the two Erirhinidae species feed externally on weed roots and ferns, respectively.

Seven curculionoid species come from Australasia, all curculionids: four cossonines, two molytines and one cyclomine. Three woodboring weevils (*Pentarthrum huttoni*, *Euophryum confine* and *E. rufum*, all from Cossoninae), feeding on decaying wood, originate from New Zealand. The four other species were unintentionally introduced from Australia. All feed inside plant material (*xylophagous* or *herbiphagous*), except the Eucalyptus snout beetle, *Gonipterus scutellatus*, a defoliator of *Eucalyptus* trees originated from Southern Australia.

Only three curculionoid species are known to originate from Africa, a curculionine and two scolytines. The palm flower weevil, *Neoderelomus piriformis*, probably originates from North Africa; it feeds on but also pollinates flowers of palms like *Phoenix canariensis*. The scolytines both originate from Canary Islands; *Dactylotrypes longicollis* breeds in *Phoenix canariensis* seeds, while *Liparthrum mandibulare* is a highly polyphagous phloeophage.

Three cosmopolitan curculionoid species originate from undetermined areas of the tropical and subtropical parts of the world: the tamarind seed borer, *Sitophilus linearis* (Dryophthoridae), and the palm seed borers *Coccotrypes carpophagus* and *C. dactyliperda* (Scolytinae). As seed-feeders, they are readily distributed through commerce, which probably explain the uncertainty about their origin.

Concerning the curculionoids alien *in* Europe, nine-tens of these (114 spp. among 129, Table 8.2.2) are introduced from mainland Europe to islands (mainly the Canary Islands, the Azores, the British Isles and Madeira). They are often widespread continental species which have been introduced to islands by human transport. Other cases are mainly species of southern and western regions which were introduced into northern Europe (as *Otiorhynchus corruptor*), especially to Denmark and Sweden. However, some species have moved westwards (as *Otiorhynchus pinastri* and *Phloeotribus caucasicus*) and even southwards (*Ips duplicatus*).

Distribution of alien species in Europe

As for the other arthropod groups, alien curculionoid species are unevenly distributed throughout Europe, which may partly reflect differences in sampling intensity (Fig. 8.2.4, Table 8.2.1). In continental Europe, mainland Italy and France host the largest number of species alien *to* Europe, with 28 and 26 introduced curculionoid species, respectively. These countries are followed by continental Spain (17 spp.), Austria (15 spp.), and Germany, Switzerland and United Kingdom[3] (13 spp.). This distribution is similar as that of all alien terrestrial invertebrates (Roques et al. 2009). The number of aliens per country significantly decreases eastwards ($y=12 - 0.29*\text{longitude}$, $R^2=0.21$, $F_{1,31}=8.08$, $p=0.008$), but it is mainly correlated with human variables, country population ($y=-1.5 + 3.7\ln(\text{population})$, population in million inhabitants, $R^2=0.39$, $F_{1,31}=19.6$, $p=1*10^{-4}$) and country importation values ($y=-32 + 3.5\ln(\text{value})$, value 2003–2007 in million USD: The World Factbook 2009, $R^2=0.53$, $F_{1,29}=32.4$, $p=4*10^{-6}$)[4]. The best model integrates importations and latitude ($y=-19 + 3.6\ln(\text{value}) - 0.28*\text{latitude}$, value in million USD, $R^2=0.60$, $F_{2,28}=20.6$, $p=3*10^{-6}$), indicating that alien establishment is favored by human trade and warm climate. The abundance of aliens in mainland Italy and France is not fully explained by the model (predicted values 17 and 16 alien species, respectively); it is likely related to a combination of the diversity of habitats and plants present with the favorable climate and the importance in international shipping.

Islands have a rather rich alien curculionoid fauna, especially Macaronesia: 29 (of which 14 *presumed*), 18 (8 *presumed*) and 10 (2 *presumed*) species in the Canary Islands, Madeira and the Azores, respectively. These islands are followed by Sicily (10 spp.), Corsica (8 spp.) and Malta (6 spp.). As it has been found for other alien terrestrial invertebrates (Roques et al. 2009), the number of alien curculionoids per km^2 in European islands is higher than in continental countries (on average 2.8 vs 0.17

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[3] Concerning species alien *to* Europe, United Kingdom characteristics are closer to those of continental countries than to those of other islands, so we consider it as part of continental Europe. This is likely related to its large size and population.

[4] Computations were performed without small countries where no alien curculionoid is recorded, because this absence is probably due to lack of data. Israel was also excluded due to its special location.

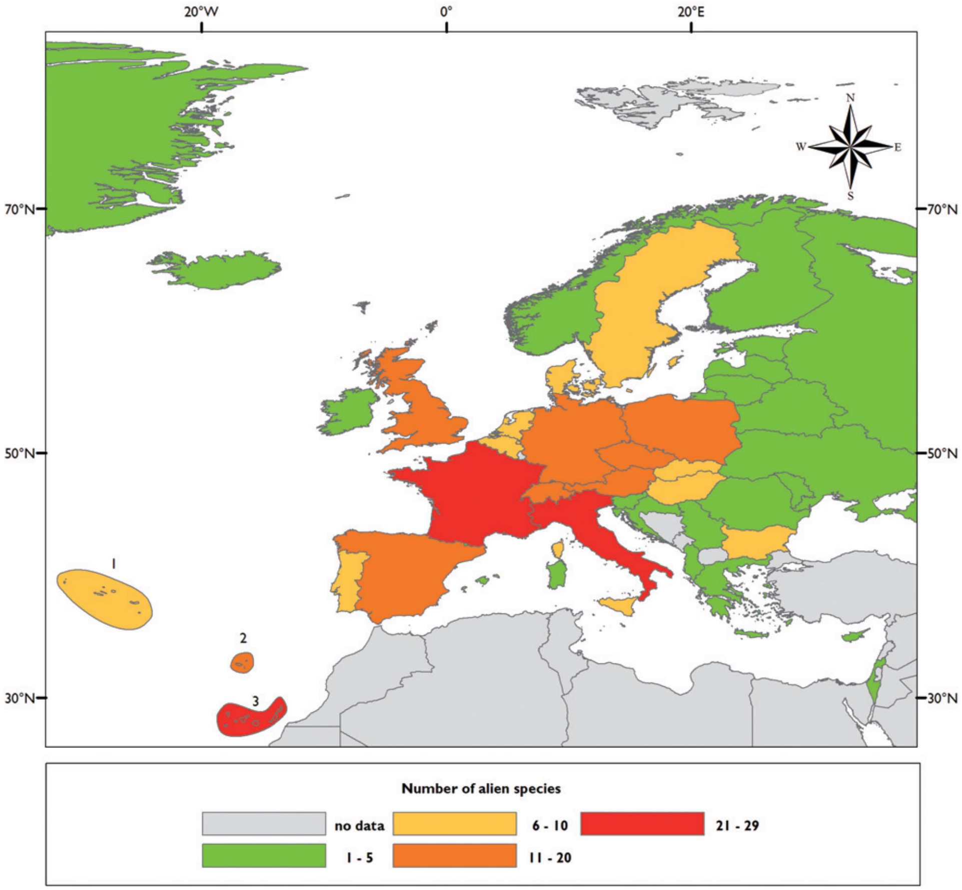

Figure 8.2.4. Comparative colonization of continental European countries and islands by Curculionoidea species alien *to* Europe. Archipelagos: **1** the Azores **2** Madeira **3** the Canary Islands.

alien/1000km^2, R^2=0.10, $F_{1,58}$=6.56, p=0.013). Aliens density is specially high in Madeira and Malta (23 and 19 alien/1000km^2, respectively), perhaps because these tiny islands are stopping places on trade routes. Islands show no global trend of alien distribution. However, cold nordic islands (Greenland, Iceland, Svalbard) host few aliens, and in Macaronesia alien number (specially *presumed* alien number) decreases when distance to continent increases.

Near half of alien curculionoid species (33 spp.) have been observed in only one country, most of them (31 spp.) in a peninsular region or on islands: Italy, Iberia, Macaronesian islands, Malta or the British Isles. Aliens introduced to such areas are less likely to move to nearby countries in comparison with aliens in other mainland regions, but Austria and Russia also host each an own alien species. As examples, *Syagrius intrudens* from Australia is encountered only in Great Britain, *Naupactus leucoloma*, from South America, is found only in the Azores, and *Paradiaphorus crenatus*, from Brazil, is known only from the Canary Islands. After the Canary Islands, Italy hosts the highest number of alien species unique to one country, eight in total, of which six are from subfamilies Scolytinae and Platypodinae. Also, the recent arrival of these species, most of them having first been discovered later than 2000, may in part explain their currently restricted distribution.

Ten alien species (14%) are limited to two countries. In almost all cases, the species are found in neighbour countries, as with the scolytine *Dryocoetes himalayensis* in France and Switzerland, and *Macrorhyncolus littoralis* in Great Britain and Ireland. One alien species, *Scyphophorus acupunctatus*, occurs in two distinct regions, Sicily and France, suggesting the possiblity of multiple introductions (this suggestion is supported by the previous interceptions of this species in different european countries: EPPO 2008).

At the other extreme, the rice weevil *Sitophilus oryzae* has been found in 34 European countries, and two other seed feeders, *Sitophilus zeamais* and *Rhopalapion longirostre*, occur in 23 and 21 countries. Their feeding habits in association with frequently transported seeds or stored products presumably explain this broad distribution. Another eleven species are found in 10 or more countries. These include several long-established species: *Xyleborus pfeilii*[8], the wood-borer *Pentarthrum huttoni*, the palm seed borer *Coccotrypes dactyliperda* and the parthenogenetic weevil *Asynonychus godmani*. However, the relatively recently introduced (1993) palm weevil *Rhynchophorus ferrugineus* is also widely distributed, occurring in most of the Mediterranean region, which attests their high dispersal capabilities (natural and human-mediated). Overall, alien weevil species are more widespread in Europe than other alien terrestrial invertebrates, with 40% of species distributed in more than two countries vs. only 22% (Roques et al. 2009).

8.2.5. Main pathways and factors contributing to successful invasions

There are two components to successful invasion, dispersal and establishment. Dispersal to new continents by phytophagous arthropods is now almost entirely due to human transport, the magnitude of which has inceased exponentially in recent decades. Plant feeding arthropods are carried in and on live plants and fruits, in wood, and as stowaways in shipments and baggage. Deliberate introductions of arthropods are less frequent, and most involve exotic organisms imported for biological control. Establishment of new arrivals depends on availability of appropriate habitats near sites of introduction, ability to compete with similar species already present, and on a reasonable tolerance for the local climate.

All exotic species of Curculionoidea have been introduced accidentally in Europe, vs. only 90% for all alien terrestrial invertebrates (Roques et al. 2009). The lack of intentional introductions of weevils could be related to their poor potential for biological control. One exotic weevil species (*Stenopelmus rufinasus*) has been used successfully for biological control of the American water fern *Azolla filicoides* in South Africa and to a less extent in the British Isles, but its first introduction in Europe was accidental (Sheppard et al. 2006, Baars and Caffery 2008).

As is the case for other regions in the world, many of Europe's alien curculionoids have presumably arrived via the shipping of wooden materials: pallets, crating, and barked or unbarked timber (Brockerhoff et al. 2006, Haack 2001, 2006). Bark and wood boring species make up half of all alien weevils (50%); these have almost certainly been introduced with wood transport and solid wood packaging materials. Logs with bark are ideal for transporting bark beetles and other weevils. However, even debarked logs can contain live wood borers such as ambrosia beetles. Although some wood-boring beetles have more restrictive requirements (e.g. high humidity and decayed wood: *Euophryum confine*, *E. rufum*, *Pentarthrum huttoni*), even these can often survive a few days or even weeks of transport. The east Asian ambrosia beetle *X. germanus* provides a typical example for entry by wood-borers. It was introduced to the USA (1932), where it was discovered in imported wine stocks in greenhouses; the species spread rapidly and has become an important nursery pest in warmer parts of eastern North America (Ranger et al. 2010). In Europe, it was first recorded after World War II, in Germany, where the species probably had been introduced with wood imported from Japan to southern Germany early in the 20th century; the present distribution area includes twelve European countries (Table 8.2.1).

Seed feeders (20%) are introduced with the seeds, which are also an excellent way for transporting insects. Several of these species are associated with agricultural products (e.g. *Caulophilus oryzae*, *Sitophilus oryzae* and *S. zeamais*), however most species feed on ornamental or forest seeds (e.g. *Rhopalapion longirostre* on *Alcea*, *Lignyodes bischoffi* on ash seeds, *Dactylotrypes longicollis* on palm seeds).

Other alien species (30%) live on or inside leaves and nonwoody stems, or in the soil. The formers can be introduced with their host plants or with host plant products (e.g. *Gonipterus scutellatus* with eucalyptus, *Listroderes costirostris* with plants such as tobacco); weevils living around roots (e.g. *Asynonychus godmani*) are transported with living plants. These feeding habits (plus root boring, which doesn't exist among aliens *to* Europe) are more frequent among *presumed* aliens *to* Europe and among aliens *in* Europe (52%); both cases result from a rather short distance transport, which likely allows survival of less protected insects (among wood boring scolytines, *phloeophagous* species are similarly much more frequent than *xylomycetophagous* species among *presumed* aliens *to* Europe and among aliens *in* Europe, contrary to what is observed among other aliens *to* Europe).

Currently, most introductions are due to international trade, but the increasing movement of fruits and plants by travelers, which is much more difficult to check, may contribute to the future diffusion of new alien species.

Newly arrived phytophages must find suitable hosts. The likelihood of success is greatly enhanced if the species is not too host specific, or if its preferred hosts are abundant. Not surprisingly, the majority of established exotic weevils in Europe are polyphagous, and the hosts of others are often widespread and abundant plants (Table 8.2.1).

Parthenogenesis and inbreeding further increase the chances for successful colonization. When an exotic species is first introduced to a new area, it faces a variety of problems associated with low density which reduce the likelihood of successful establishment and slow the rate of invasion (Tobin et al. 2007, Liebhold and Tobin 2008, Contarini et al. 2009). New populations create problems for mate finding; parthenogenetic females do not mate, and inbreeding females mate with brothers while in the natal nest, before dispersal (Jordal et al. 2001); in both cases, there is no problem of mate location and new populations can be established by single females. Very small populations (such as those in recent colonizations) may suffer from high levels of inbreeding depression (Charlesworth and Charlesworth 1987); however, regular inbreeding species such as the invasive scolytines have presumably purged their genomes of the deleterious alleles responsible for inbreeding depression (Charlesworth and Charlesworth 1987, Jordal et al. 2001, Peer and Taborsky 2005). Only a few invasive curculionoid species are parthenogenetic: *Asynonychus godmani*, *Lissorhoptrus oryzophilus*, *Listroderes costirostris* (Morrone 1993) and *Naupactus leucoloma*, whose males are unknown outside its native range (Lanteri and Marvaldi 1995). However, over half of the alien scolytines inbreed (59%, *presumed* aliens excluded), compared with less than a third of scolytines native to Europe and about a fourth of Scolytinae species worldwide (Kirkendall 1993).

8.2.6. Most invaded ecosystems and habitats

All alien curculionoid species are phytophagous, as are nearly all curculionoids worldwide. Most of the species have a cryptic way of life, at least during larval stage, feeding inside plant tissues such as stems or seeds, or living in the soil; only 9% are *leaf/stem browsers*. Stems and trunks is the major feeding niche of most alien curculionoids (65%). Most of these are bark beetles, ambrosia beetles or other wood borers (50%); *herbiphagous* (15%) comprise the remaining. Seeds are the second most important feeding niche (18%), followed by leaves (9%; some species could also attack non woody stems) and roots (6%). Last species, *Neoderelomus piriformis*, feeds on flowers, and acts as pollinator in palm trees.

By contrast, of the curculionoids alien in Europe, only 33% are wood borers, among which most are *phloeophagous* (28%). A third (30%) attack roots, especially *root browsers* as *Otiorhynchus* and *Sitona* (26%), the remaining (4%) being *root borers*. *Herbiphagous* (18%), *spermatophagous* (15%) and *leaf/stem browsers* (4%) comprise the remaining.

Near half of the alien curculionoid species established in Europe colonize urban and peri-urban habitats, primarily parks and gardens (27%) and around buildings (11%). Woodlands is also a frequent habitat for the alien curculionoids (27%), beyond natural heathlands (16%), cultivated agricultural lands (9%) and greenhouses (5%). Only three species occur in wetland habitats, one in coastal and two in inland surface water (Fig. 8.2.5). The importance of natural heathlands is in fact mainly limited to specific areas, most of the species recorded in these habitats being *presumed* aliens attacking euphorbias in Macaronesian xerophytic heathlands.

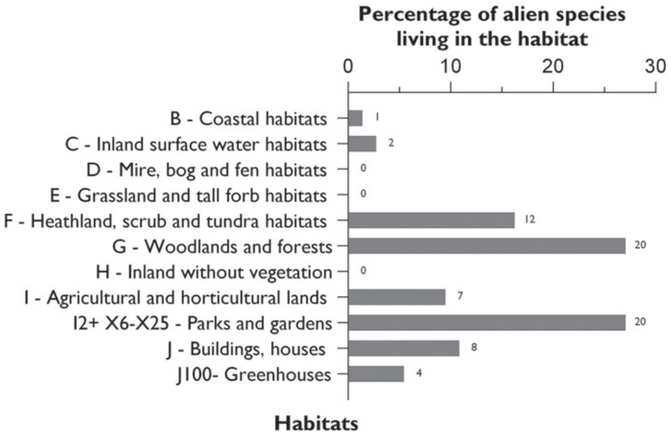

Figure 8.2.5. Main European habitats colonized by Curculionoidea species alien *to* Europe. The number besides each bar indicates the absolute number of alien curculionoids recorded per habitat. Note that a species may have colonized several habitats.

This pattern differs from the average value observed for all arthropods, where only a fourth of the species is recorded in natural or semi-natural habitats, and where agricultural lands and greenhouses contain more alien species than woodlands. That could be obviously related to the high frequency of xylophagous *sensu lato*[7] habits in alien curculionoids. Both deciduous trees, such as *Populus* sp. and *Fraxinus* sp, and conifers in the genera *Picea* and *Pinus* are colonized by several alien curculionoid species utilizing trees. *Eucalyptus* plantations are also affected by a defoliating curculionid, *Gonipterus scutellatus*, both host and weevil originating in Australia. In urban and suburban areas such as gardens and parks, other trees species, mainly exotics and in particular palm trees, are also affected by alien curculionoids.

8.2.7. Ecological and economic impact

Ecological impacts of alien insects are poorly known in general (Kenis et al. 2009), and the impacts of Curculionoidea species alien *to* Europe seem not to have been documented at all.

Their economic impact is better known, reflecting the economic importance of many of these alien species. A third of the Curculionoidea species alien *to* Europe (26 species) have a known economic impact, a much higher proportion than for native weevils, even though the latter contain numerous pests. Nevertheless, this high proportion may partly be an artefact, since pests have a higher probability of being detected.

The most damaging species are the four attacking stored products. The rice weevil *Sitophilus oryzae* and the maize weevil *S. zeamais* are among the main pests of stored grains worldwide, destroying significant amounts and incurring high pest management

Figure 8.2.6. Examples of alien curculionoids: *Gonipterus scutellatus.* Adult damage on *Eucalytus sp*. (Credit: Alain Roques).

costs[5] (Balachowsky 1963, Pimentel 1991). Larvae develop in cereal seeds and adults feed on these seeds as well as on a wide variety of stored products, products derived from cereal grains and even dried vegetables. Damages is exascerbated by incompletely dried stored products (Balachowsky 1963). In addition to their direct damage, these species facilitate attacks of grains by other pests. *Caulophilus oryzae*, a less widespread species, sporadically causes the same kind of damages, while *Araecerus coffeae* attacks grains but mainly less common products such as stored coffee and cocoa beans.

Five species attack native or introduced cultivated plants. *Listroderes costirostris* attacks a wide range of vegetables and weeds; adults can also damage foliage of fruit trees. The recently established whitefringed weevil, *Naupactus leucoloma*, is also highly polyphagous; its soil-inhabiting larvae are a serious pest of many agricultural crops. The banana root weevil, *Cosmopolites sordidus*, and *Paradiaphorus crenatus* are important pests of tropical cultures (banana and pineapple, respectively). Their economic impact is currently limited in Europe due to the limited distribution of their hosts in this area and a rather low aggressiveness in its climate, but it could increase later in the future according to the global warming. The last species is the rice water weevil, *Lissorhoptrus oryzophilus*. Recently introduced in Europe, it is a major pest of rice, but also attacks indigenous *Carex*.

Eight species damage different ornamental plants and trees, mainly introduced tropical or subtropical species. The palm weevil *Rhynchophorus ferrugineus* is a dangerous pest of palms which has rapidly colonized the Mediterannean basin. On the Canary Islands, palms are also attacked by the lesser coconut weevil *Diocalandra frumenti*. Even if damage are mainly esthetic, they are worrying because this insect princi-

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[5] Damages are also due to the grain weevil *S. granarius*, probably alien too, but not taken into account here because it has been established in Europe at least since Antiquity.

Figure 8.2.7. Examples of alien curculionoids: *Rhynchophorus ferrugineus*. Female, larvae and damage (Credit: Juan Antonio Ávalos, Universidad Politécnica de Valencia).

pally attacks *Phoenix canariensis*, an endemic palm which is emblematic of the Canary Islands where it is widely used for landscaping and is a major element of coastal landscape. *Asynonychus godmani* attacks roots of a large variety of ornamental shrubs and fruit trees, native or introduced. Others species are monophagous or oligophagous on introduced hosts: the tamarind seed borer *Sitophilus linearis* on *Tamarindus indica*, *Demyrsus meleoides* on cycadophyts, *Scyphophorus acupunctatus* on Agavaceae species, *Phloeotribus liminaris* on *Prunus serotina*, *Phloeosinus rudis* on Cupressaceae species.

Five species have an impact on forests or related habitats. Three attack live exotic or native trees. The Eucalyptus snout beetle *Gonipterus scutellatus* is an important pest of *Eucalyptus* everywhere it has been introduced (see factsheet 14.12). This defoliator causes severe damage and wood loss, particularly on *E. globulus*, the major cultivated *Eucalyptus* species in southern Europe. *Rhyephenes humeralis* attack another introduced tree, *Pinus radiata*, but causes less damage. *Megaplatypus mutatus* is one of the few platypodine beetles which breeds in live trees; it is highly polyphagous, but in Europe it has thus far only been found to damage *Populus* plantations in Italy (Alfaro et al. 2007). The two other species depreciate wood stock. *Gnathotrichus materiarius* is a common pest of a large variety of conifer wood, and *Xylosandrus germanus* sporadically attacks mainly broadleaf wood.

Pentarthrum huttoni and the two *Euophryum* species live in rotting wood, so their economic impact is generally low, though they do attack wood of historically signifi-

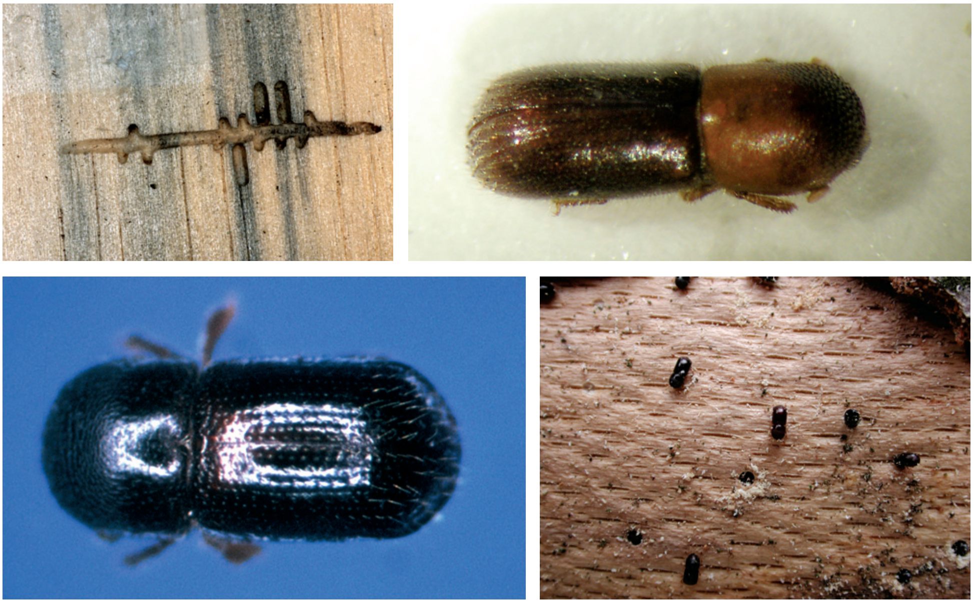

Figure 8.2.8. Examples of alien curculionoids: Scolytinae. Top left: *Gnathotrichus materiarius*: gallery in wood (Credit: Louis-Michel Nageleisen). Top right: *Cyclorhipidion bodoanus*: femelle (Credit: Louis-Michel Nageleisen). Bottom: *Xylosandrus germanus* (Blandford 1894): female (Credit: Daniel Adam), adults and gallery holes on wood (Credit: Louis-Michel Nageleisen).

cant artefacts or buildings. Finally, as opposed to all previous species, the introduced frond-feeding weevil *Stenopelmus rufinasus* has a positive impact due to its hability to control the invasive red water fern *Azolla filiculoides*.

8.2.8. Conclusion

The superfamily Curculionoidea is well represented among alien species now established in Europe. Alien weevils show specific characteristics comparing both native and world ones, which seem result from a selection of species having high capabilities to human-mediated dispersal and establishment in a new habitat. Thus, they have often cryptic habits, as seed boring or wood and plant boring, leading to over-representation of bark and ambrosia beetles and other xylophagous *sensu lato*[7] species; alien weevils are consequently more numerous in natural areas than other terrestrial invertebrate aliens. Seed feeders are the major alien pests. Alien species are mainly originated from Asia, which is related to the importance of trade with this continent, and many of them come from different tropical or subtropical areas.

The more worrying observation is the fast increase in the invasion rate during last decades, as noticed for all terrestrial invertebrate aliens. Without appropriate control, the invasive pressure will probably continue to increase in the future, further threatening European people and ecosystems, more especially as global warming may allow the naturalization of more tropical and subtropical species accidentally introduced into Europe and particularly the Mediterranean.

References

Abbazzi P, Osella G (1992) Elenco sistematico-faunistico degli Anthribidae, Rhinomaceridae, Attelabidae, Apionidae, Brentidae, Curculionidae Italiani (Insecta, Coleoptera, Curculionoidea): I Parte. *Redia* 75: 267–414.

Abbazzi P, Colonnelli E, Masutti L, Osella G (1994) Coleoptera Polyphaga XVI (Curculionoidea). In: Minelli A, Ruffo S, La Posta S (Eds) *Checklist delle specie della fauna italiana 61*. Bologna: Calderini, 35–64.

Alexander KNA (2002) The invertebrates of living & decaying timber in Britain and Ireland - a provisional annotated checklist. English Nature Research Reports 467. 142 pp.

Alfaro RI, Humble LM, Gonzalez P, Villaverde R, Allegro G (2007) The threat of the ambrosia beetle *Megaplatypus mutatus* (Chapuis) (=*Platypus mutatus* Chapuis) to world poplar resources. *Forestry* 80: 471–479.

Alonso-Zarazaga MA (Ed) (2004) Fauna Europaea: Coleoptera 1, Curculionoidea. Fauna Europaea version 1.1. http://www.faunaeur.org/.

Alonso-Zarazaga MA, Goldarazena A (2005) Presence in the Basque Country of *Rhyephenes humeralis* (Coleoptera, Curculionidae), a pest of *Pinus radiata* coming from Chile. *Boletin de la S.E.A.* 36: 143–146.

Alonso-Zarazaga MA, Lyal CHC (1999) A World Catalogue of Families and Genera of Curculionoidea (Insecta: Coleoptera) (excepting Scolytidae and Platypodidae). Barcelona: Entomopraxis S. C. P. 315 pp.

Angelov P (1960) Prouchvaniya vurkhu entomofaunata na parka Otdich I kultura (mestnostta Ostrova) kray Plovdiv s nyakoi faunistichni belezki. *Godishnik na muzeite v Plovdiv* 3: 7–40.

Arzone A (1976) Un nemico dell'Eucalipto nuovo per l'Italia. *Apicoltore Moderno* 67: 173–177.

Audisio P, Cornacchia P, Fattorini L, Franceschi S, Gatti E et al. (2008) Selected beetle families in natural forests and Norway spruce stands at Vincheto di Celarda Nature Reserve and the effects of conservation actions (Coleoptera). In: Hardersen S, Mason F, Viola F, Campedel D, Lasen C et al. (Eds) Research on the natural heritage of the Reserves Vincheto di Celarda and Val Tovanella (Belluno province, Italy). Conservation of two protected areas in the context of a LIFE project. Quaderni Conservazione Habitat, 5. Verona: Arti Grafiche Fiorini, 195–217.

Baars JR, Caffery J (2008) Water fern, *Azolla filiculoides* –Under biological control in Ireland. Invasive Species Ireland, Case study 4. 8: 12pp.

Balachowsky A (1949) Faune de France 50: Coléoptères Scolytides. Paris: Librairie de la faculté des sciences. 320 pp.

Balachowsky AS (1963) Entomologie appliquée à l'agriculture, Tome I, Coléoptères, Second Volume. Paris: Masson. 1391 pp.

Barclay MVL (2001) An exotic weevil *Otiorhynchus corruptor* Horst. (Curculionidae). *British Journal of Entomology and Natural History* 14: 160–161.

Barranco P, de la Peña J, Cabello T (1996) El picudo rojo de las palmeras, *Rhynchophorus ferrugineus* (Olivier), nueva plaga en Europa. *Phytoma-España* 67: 36–40.

Base de dados da biodiversidade dos Açores. http://www.azoresbioportal.angra.uac.pt/.

Bitton S, Nakache Y (2000) Red palm weevil in Israel. *Proceedings of date palm international symposium, 2000.02.22–25, Republic Of Namibia*.

Bolu H, Legalov AA (2008) On the Curculionoidea (Coleoptera) fauna of Almond (*Amygdalus communis* L.) orchards in South-eastern and Eastern Anatolia in Turkey. *Baltic J. Coleopterol.* 8: 75–86.

Borges PAV, Vieira V, Dinis F, Jarroca S (2005) List of arthropods (Arthropoda). In: Borges PAV, Cunha R, Gabriel R, Martins AF, Silva L, Vieira V (Eds) A list of terrestrial fauna (Mollusca and Arthropoda) and flora (Bryophyta, Pteridophyta and Spermatophyta) from the Azores. Lisboa: Direcção Regional do Ambiente & Universidade dos Açores, Horta, Angra do Heroísmo & Ponta Delgada, AAPP, 163–221.

Borisch D (1997) Edvard Anderson's Mediterranean greenhouse in Stockholm, an immigration gate for weevils (Curculionidae) from southern Europe. *Entomologisk Tidskrift* 118: 133–134.

Bouget C, Noblecourt T (2005) Short-term development of ambrosia and bark beetle assemblages following a windstorm in French broadleaved temperate forests. *Journal of Applied Entomology* 129: 300–310.

Bright DE (1987) A review of the Scolytidae (Coleoptera) of the Azores with description of a new species of *Phloeosinus*. *Museu Municipal Funchal* 107: 1–5.

Brockerhoff EG, Bain J, Kimberley M, Knizek M (2006) Interception frequency of exotic bark and ambrosia beetles (Coleoptera: Scolytinae) and relationship with establishment in New Zealand and worldwide. *Canadian Journal of Forest Research* 36: 289–298.

Bruge, H (1994) À propos de *Pentarthrum huttoni* Wollaston, 1854 (Coleoptera, Curculionidae, Cossoninae). *Bulletin et Annales de la Société Royale Belge d'Entomologie* 130: 313–323.

Buck FD (1948) *Pentarthrum huttoni* Woll. (Col., Curculionidae) and some imported Cossininae. *Entomologist's Monthly Magazine* 84: 152–154.

Caldara R, Diotti L, Regalin R (2004) Prima segnalazione per l'Europa di *Lissorhoptrus oryzophilus* Kuschel (Coleoptera, Curculionoidea, Erirhinidae), temibile parassita di *Oryza sativa* L. *Bollettino di Zoologia Agraria e di Bachicoltura, Serie II* 36: 165–171.

Carrillo AM (1999) El gorgojo del eucalipto en Canarias. *Diario de Avisos (Santa Cruz de Tenerife)*, 1999/07/12.

Charlesworth D, Charlesworth B (1987) Inbreeding depression and its evolutionary consequences. *Annual Review of Ecology and Systematics* 18: 237–268.

Chilahsayeva YA (2008) [First discovery of *Polygraphus proximus* Blandford (Coleoptera: Scolytidae) in Moscow Oblast]. *Bulletin of Moscow Society of Naturalists* 113: 39–41.

Contarini M, Onufrieva KS, Thorpe KW, Raffa KF, Tobin PC (2009) Mate-finding failure as an important cause of Allee effects along the leading edge of an invading insect population. *Entomologia Experimentalis et Applicata* 133: 307–314.

Covassi M (1974) Il *Demyrsus meleoides* Pascoe: un potenziale nemico delle cicadee ornamentali introdotto in Italia (Coleoptera, Curculionidae). *Redia* 55: 211–217.

Covassi M (1991) Il *Phloeosinus armatus* Reitter, coleottero scolitide del cipresso, nuovo per l'Italia. In *Atti del Convegno "Il Cipresso. Proposte di valorizzazione ambientale e produttiva nei paesi mediterranei della Comunità Economica Europea", Firenze (Italy) 12–13 dicembre 1991*, 190–196.

Dal Monte G (1972) Generalità sui principi scientifici e tecnici per una razionale conservazione dei cereali nei magazzini. *Atti del 1° Simposio „La difesa antiparassitaria nelle industrie alimentari e la protezione degli alimenti", Piacenza (Italy) 1972*. Tip. Edit. Piacentina, 91–107.

Dana ED, Viva S (2006) *Stenopelmus rufinasus* Gyllenhal 1835 (Coleoptera: Erirhinidae) naturalized in Spain. *Coleopterists Bulletin* 60: 41–42.

Dieckmann L (1983) Beiträge zur Insektenfauna der DDR, Coleoptera–Curculionidae (Tanymecinae, Leptopiinae, Cleoninae, Tanyrhynchinae, Cossoninae, Raymondionyminae, Bagoinae, Tanysphyrinae). *Beitr Entomol* 33: 257–381.

Duff AG (Ed) (2008) Checklist of Beetles of the British Isles, 2008 edition. Wells: Duff AG. 164 pp.

Ehret JM (1983) *Apion* (*Rhopalapion*) *longirostre*, espèce nouvelle pour la France (Coleoptera, Curculionidae). *L'Entomologiste* 39: 42.

Emerson BC (2008) Speciation on islands: what are we learning? *Biological Journal of the Linnean Society* 95: 47–52.

EPPO (2005) Datasheets on quarantine pests – *Ips cembrae* and *Ips subelongatus*. *EPPO Bulletin* 35: 445–449.

EPPO (2006) EPPO Reporting Services 2006/001, 2006/028, 2006/225, 2006/226, 2006/227.

EPPO (2008) EPPO Reporting Services 2008/220.

Essl F, Rabitsch W (2002) Neobiota in Osterreich. Wien: Umweltbundesamt. 432 pp.

Faccoli M (1998) The North American *Gnathotrichus materiarius* (Fitch) (Coleoptera Scolytidae): an ambrosia beetle new to Italy. *Redia* 81: 151–154.

Faccoli M (2008) First record of *Xyleborus atratus* Eichhoff in Europe, with an illustrated key to European Xyleborini (Coleoptera Curculionidae Scolytinae). *Zootaxa* 1772: 55–62.

Faccoli M, Frigimelica G, Mori N, Petrucco Toffolo E, Vettorazzo M et al. (2009): First record of *Ambrosiodmus* (Hopkins, 1915) (Coleoptera: Curculionidae, Scolytinae) in Europe. *Zootaxa* 2303: 57–60.

Fernandez Carrillo JL, Fernandez Carrillo E, Alonso-Zarazaga MA (2005) [First recording of *Stenopelmus rufinasus* Gyllenhal, 1835 in the Iberian Peninsula (Coleoptera, Erirhinidae)]. *Graellsia* 61: 139–140.

Foster AP, Morris MG, Whitehead PF (2001) *Ixapion variegatum* (Wencker, 1864) (Col., Apionidae) new to the British Isles, with observations on its European and conservation status. *Entomologist's Monthly Magazine* 137: 95–105.

FREDON-Corse (2007) Le charançon rouge du palmier a débarqué en Corse. http://www.fredon-corse.com/actions/surveillance_CR.htm.

Freude H, Harde KW, Lohse GA (1983) Die Kafer Mitteleuropas 11: Familienreihe: Rhynchophora (Schluß). Krefeld: Goecke & Evers Verlag. 342 pp.

Friedman ALL (2006) *Derelomus piriformis* Hoffmann (Curculionoidea: Curculionidae: Curculioninae: Derelomini), a new invasive species in Israel. *Phytoparasitica* 34: 357–359.

Friedman ALL (2009) The vegetable weevil, *Listroderes costirostris* Schoenherr (Curculionidae: Cyclominae): a new invasive pest in Israel. *Phytoparasitica* 37: 331–332.

García R (2003) Coleópteros: nuevos datos sobre la distribución en el archipiélago canario. *Zoras: revista del Centro Asociado Uned La Palma* mayo 2003: 29–36.

Germain JF, Bertaux F, Streito JC (2008) Attaque surprise de *Listroderes difficilis* Germain sur la Côte d'Azur (Coleoptera curculionidae). *L'Entomologiste* 64: 89–90.

Germain JF, Ramel JM, Maury A, Blanchon F (2008) Premier signalement en France d'un coléoptère ravageur des agaves. *PHM-Revue Horticole* 505: 34–36.

Germann C (2004) *Otiorhynchus pinastri* (Herbst, 1795) - ein invasiver Xenobiont aus dem östlichen Europa in der Schweiz (Coleoptera, Curculionidae). *Mitteilungen der Entomologischen Gesellschaft Basel* 54: 110–114.

Gillerfors G (1988) Coleoptera from pulpwood imported to South Sweden from France and Spain. *Entomologisk Tidskrift* 109: 42–45.

Gonzales et al (2002) *Bol. San. Veg. Plagas* 28: 347–355.

Gosik R, Letowski J, Mokrzycki T, Wanat, M (2001) *Lignyodes bischoffi* (Blatchley, 1916) (Coleoptera: Curculionidae) - new to the fauna of Poland. *Wiadomosci Entomologiczne* 20: 43–48.

Haack RA (2001) Intercepted Scolytidae (Coleoptera) at U.S. ports of entry: 1985–2000. *Integrated Pest Management Reviews* 6: 253–282.

Haack R.A (2006). Exotic bark- and wood-boring Coleoptera in the United States: recent establishments and interceptions. *Canadian Journal of Forest Research* 36: 269–288.

Hackett D (1998) The fern weevil, *Syagrius intrudens* Waterhouse (Curculionidae) in Cornwall. *The Coleopterist* 7: 20–21.

Haghebaert G (1991) Nieuwe adventieve Coleoptera uit België. *Bull. Annls. R Soc. Belge Entomol.* 127: 347–348.

Halmschlager E, Ladner C, Zabransky P, Schopf A (2007) First record of the wood boring weevil, *Pentarthrum huttoni*, in Austria (Coleoptera: Curculionidae). *Journal of Pest Science* 80: 59–61.

Hansen M (1996) Catalogue of the Coleoptera of Denmark / Katalog over Danmarks biller. Stenstrup: Apollo Books. 231 pp.

Heijerman T, Moraal L, Burgers J, de Goffau L (2003) *Otiorhynchus apenninus*, a new weevil for the Netherlands (Coleoptera: Curculionidae). *Nederlandse Faunistische Mededelingen* 19: 41–48.

Henin JM, Versteirt V (2004) Abundance and distribution of *Xylosandrus germanus* (Blandford 1894) (Coleoptera, Scolytidae) in Belgium: new observations and an attempt to outline its range. *Journal of Pest Science* 77: 57–63.

Hill M, Baker R, Broad G, Chandler PJ, Copp GH et al. (2005) Audit of non-native species in England. English Nature Research Reports 662, English Nature, Peterborough. 82 pp.

Hoffmann A (1950) Faune de France 52: Coléoptères Curculionides (Première partie). Paris: Lechevalier. 486 pp.

Hoffmann A (1954) Faune de France 59: Coléoptères Curculionides (Deuxième partie). Paris: Lechevalier. 722 pp.

Hoffmann A (1958) Faune de France 62: Coléoptères Curculionides (Troisième partie). Paris: Lechevalier. 631 pp.

Holzer (2007) Erstnachweise und Wiederfunde für die Käferfauna der Steiermark (X) (Coleoptera). *Joannea Zoologie* 9: 51–68.

Holzschuh C (1994) *Pityophthorus traegardhi*, ein neuer Borkenkäfer für Österreich und Mitteleuropa (Coleoptera: Scolytidae). *Forstschutz Aktuell, Wien* 15: 4.

Israelson G (1969) Some additions to the Coleopterous fauna of the Canary Islands (Coleoptera). *EOS* 44: 149–157.

Israelson G (1972) Male copulatory organs of Macronesian species of *Aphanarthrum* Wollaston. With designations of lectotypes and descriptions of new taxa (Col. Scolytidae). *Entomologica Scandinavica* 3: 249–257.

Israelson G (1980) Taxonomical and nomenclatural notes on some Canarian Coleoptera. *Vieraea* 9: 183–210.

Israelson G (1990) A key to the Macaronesian Hypoborini, with description of two new species (Coleoptera, Scolytidae). *Bocagiana* 137: 1–11.

Izquierdo I, Martin JL, Zurita N, Arechavaleta M (Eds) (2004) Lista de especies silvestres de Canarias (hongos, plantas y animales terrestres). 2nd, Consejería de Política Territorial y Medio Ambiente del Gobierno de Canarias. 500 pp.

Janson OE (1921) *Stenopelmus rufinasus* Gyll., an addition to the list of British Coleoptera. *Entomologist's Monthly Magazine* 57: 225–226.

Joakimow D (1904) Prinos kum Bulgarskata fauna na nasekomite Insecta I Coleoptera. *Sbornik narodni umotvoreniya nauka I knizhnina* 20:1–43.

Jordal BH, Beaver RA, Kirkendall LR (2001) Breaking taboos in the tropics: inbreeding promotes colonization by wood-boring beetles. *Global Ecology and Biogeography* 10: 345–357.

Juan C, Emerson BC, Oromi P, Hewitt GM (2000) Colonization and diversification: towards a phylogeographic synthesis for the Canary Islands. *Trends in Ecology and Evolution* 15: 104–109.

Kehat M (1999) Threat to date palms in Israel, Jordan and the Palestinian authority by the red palm weevil, *Rhynchophorus ferrugineus*. *Phytoparasitica* 27: 241–242.

Kenis M, Auger-Rozenberg MA, Roques A, Timms L, Péré C et al. (2009) Ecological effects of invasive alien insects. *Biological Invasions* 11: 21–45.

Kirkendall LR (1993) Ecology and evolution of biased sex ratios in bark and ambrosia beetles (Scolytidae). In: Wrensch DL, Ebbert MA (Eds) *Evolution and Diversity of Sex Ratio: Insects and Mites*. New York: Chapman and Hall, 235–345.

Kirkendall LR personal observations.

Kirkendall LR, Dal Cortivo M, Gatti E (2008) First record of the ambrosia beetle, *Monarthrum mali* (Curculionidae, Scolytinae) in Europe. *J. Pest Science* 80: 123–126.

Kirkendall LR, Faccoli M (2010) Bark beetles and pinhole borers (Curculionidae: Scolytinae, Platypodinae) alien to Europe. *ZooKey* (in press).

Knížek M (2004) Fauna Europaea: Scolytinae. In: Alonso-Zarazaga MA (Ed) Fauna Europaea: Curculionidae. Fauna Europaea version 1.1. http://www.faunaeur.org.

Kontodimas D, Oikonomou D, Thymakis N, Menti C, Anagnou-Veroniki M (2006) [New serious pest of palm trees, the coleopterous *Rhynchophorus ferrugineus* (Olivier)]. *Agriculture-crop & animal husbandry*, 1: 54–57.

Kozłowski MW, Knutelski S (2003) First evidence of an occurrence of *Rhopalapion longirostre* in Poland. *Weevil News* 13: 4 pp. http://www.curci.de/Inhalt.html.

Lanteri AA, Marvaldi AE (1995) *Graphognathus* Buchanan a new synonym of *Naupactus* Dejean and systematics of the *N. leucoloma* species group (Coleoptera: Curculionidae). *The Coleopterists Bulletin* 49: 206–228.

Liebhold AM, Tobin PC (2008) Population ecology of insect invasions and their management. *Annual Review of Entomology* 53: 387–408.

Lombardero MJ, Novoa F (1993) [*Liparthrum mandibulare* Wollaston, 1854 (Coleoptera: Scolytidae), the first record from continental Europe]. *Elytron (Barcelona)* 7: 105–110.

Lombardero MJ, Novoa F (1994) Datos faunísticos sobre escolítidos ibéricos (Coleoptera: Scolytidae). *Boletín de la Asociación Española de Entomología* 18: 181–186.

Longo S (2007) Black weevil of agave. *Informatore Agrario Supplemento* 63(39, Supplemento 1): 43.

Lucht W (1985) Überraschende Freilandfunde fremdländischer Käfer in Südhessen. Naturwissenschaftlicher verein Darmstadt Bericht N F 9, 29–32.

Lundberg S (1995) Catalogus Coleopterorum Sueciae. Version 2. Stockholm: Naturhistoriska Riksmuseet & Entomologiska Foreningen. 217 pp.en.

Lundberg S (2006) New and excluded beetle species since 1995 year's Catalogus Coleopterorum Sueciae. *Entomologisk Tidskrift* 127: 101–111.

Machado A, Oromí P (2000) Elenco de los Coleópteros de las Islas Canarias. Monografia 70. La Laguna: Instituto de Estudios Canarios. 308 pp.

Mandelshtam MY, Aguin-Pombo D, Nunes E (2006) *Hylastes attenuatus* Erichson 1836 (Coleoptera, Scolytidae), an exotic bark beetle new to Madeira Fauna. *Coleopterists Bulletin* 60: 297–298.

Mandelshtam MY, Popovichev BG (2000) [An annotated list of Scolytidae species of Leningradkaya Oblast]. *Entomological Review* 79: 599–618.

Mansilla JP (1992) Presencia sobre *Eucalyptus globulus* Labill de *Gonipterus scutellatus* Gyll. (Col. Curculionidae) en Galicia. *Boletin de Sanidad Vegetal, Plagas* 18: 547–554.

Mansilla JP, Pérez Otero R (1996) El defoliador del eucalipto *Gonipterus scutellatus*. *Phytoma España* 81: 36–42.

MAPA (2006) Orden de 10 de febrero de 2006 por la que se adoptan medidas fitosanitarias cautelares previas para evitar la propagación del curculiónido ferruginosos entre la palmera canaria. *Boletín Oficial de Canarias* 30: 3084–3085.

Markovich A (1909) Prinos za izuchaveneto na nasekomnata fauna v razgradksa okolnost. *Sbornik narodni umotvoreniya nauka I knizhnina* 25: 1–20.

Mazur M (2002) The distribution and ecology of weevils (Coleoptera: Nemonychidae, Attelabidae, Apionidae, Curculionidae) in western Ukraine. *Acta zoologica cracoviensia* 45: 213–244.

Menet D (1998) Confirmed presence of *Euophryum confine* (Broun) (Col. Curculionidae, Cossoninae) in France. *Bulletin de la Société Entomologique de France* 103: 286.

Meregalli M (2004) Fauna Europaea: Cyclominae. In: Alonso-Zarazaga MA (Ed) Fauna Europaea: Curculionidae. Fauna Europaea version 1.1. http://www.faunaeur.org.

Mifsud D, Knížek M (2009) The bark beetles (Coleoptera: Scolytidae) of the Maltese Islands (Central Mediterranean). *Bulletin of the Entomological Society of Malta* 2: 25–52.

Moncoutier B (1982) Un nouveau curculionide en France. *L'Entomologiste* 38: 206.

Moraal, LG (2006) Insectenplagen op bomen en struiken in 2005. *Vakblad Natuur, Bos en Landschap* 3: 12–15.

Moraal, LG (2009) Infestations of the Japanese thuja bark beetle *Phloeosinus rudis* (Col., Scolytidae) in The Netherlands. In *International Congress on Biological Invasions (ICBI), Fuzhou (China), 2–6 November, 2009.*

Morris MG (1990) Orthocerous weevils: Coleoptera: Curculionoidea (Nemonychidae, Anthribidae, Urodontidae, Attelabidae and Apionidae). Handbooks for the Identification of British Insects 5(16). 108 pp.

Morris MG (2002) True weevils (part I): Coleoptera: Curculionidae: (subfamilies Raymondionyminae to Smicronychinae). Handbooks for the Identification of British Insects 5(17b). 149 pp.

Morrone JJ (1993) Systematic revision of the *costirostris* species group of the weevil genus *Listroderes* Schoenherr (Coleoptera, Curculionidae). *Transactions of the American Entomological Society* 119: 271–315.

Mphuru AN (1974) *Araecerus fasciculatus* de Geer (Coleoptera: Anthribidae): A review. *Trop. Stored Prod. Inf.* 26: 7–15.

Neid J (2003) Présence en Haute-Corse de *Gonipterus scutellatus* Gyllenhal 1833 (Coleoptera, Curculionidae, Cyclominae, Gonipterini). *L'Entomologiste* 59: 103.

Noblecourt T (2004) Note sur les Coléoptères Scolytidae : espèces rares ou peu communes en France. *Coléoptériste* 7: 33–36.

O'Brien CW, Wibmer GJ (1982) Annotated checklist of the weevils (Curculionidae sensu lato) of North America, Central America, and the West Indies (Coleoptera: Curculionoidea). Memoirs of the American Entomological Institute (Gainesville) 34. 382 pp.

O'Connor JP (1977) Occurrence of *Euophryum rufum* Broun (Col., Curculionidae) in Ireland. *Entomologist's Monthly Magazine* 113: 56.

Oberprieler RG, Marvaldi AE, Anderson RS (2007) Weevils, weevils, weevils everywhere. *Zootaxa* 1668: 491–520.

Obretenchev D, Atanasov H, Tzalev M, Kirilov L (1990) Razprostranenie na nyakoi vunshnokarantinni vrediteli po skladiranite hrani I produkti ot rastitelen proizhod v Bulgaria. *Nauchni docladi i suobshteniya, SSA, S.* III: 172–178.

Ólafsson E (1991) A checklist of Icelandic insects. *Fjolrit Natturufraedistofnunar* 17: 1–69.

OPIE (2002) Listes de références - Faune de la France métropolitaine. Coléoptères Scolytidae. http://www.inra.fr/opie-insectes/observatoire/listes/l_scolyt.htm.

Oromí P, García R (1995) Contribución al conocimiento de la fauna de coleópteros de Canarias y su distribución. *Vieraea* 24: 175–186.

Paiva MR (1996) Management of forest insects in Portugal. *XX International Congress of Entomology, Firenze (IT), 1996/08/25–31*. Abstract 16–026, 510.

Palm, E (1996) Nordeuropas snudebiller 1: De kortsnudende arter (Coleoptera: Curculionidae) - med sarligt henblik pa den danske fauna. Danmarks Dyreliv 7. 356 pp.

Peer K, Taborsky M (2005) Outbreeding depression, but no inbreeding depression in haplodiploid ambrosia beetles with regular sibling mating. *Evolution* 59: 317–323.

Pennacchio F, Faggi M, Gatti E, Caronni F, Colombo M et al. (2004) First record of *Phloeotribus liminaris* (Harris) from Europe (Coleoptera Scolytidae). *Redia* 87: 85–89.

Pennacchio F, Roversi PF, Francardi V, Gatti E (2003) *Xylosandrus crassiusculus* (Motschulsky) a bark beetle new to Europe. *Redia* 86: 77–80.

Perrin H (1984) Présence en France d'*Apion* (*Rhopalapion*) *longirostre* (Olivier) (Coleoptera, Curculionidae, Apioninae) et répartition dans la région paléarctique. *L'Entomologiste* 40: 269–274.

Perrin H (1995) *Rhopalapion longirostre* (Olivier) (Coleoptera: Apionidae): 12 années de recoltes en France. *L'Entomologiste* 51: 220.

Pfeffer A (1995) Zentral- und westpaläarktische Borken- und Kernkäfer (Coleoptera: Scolytidae, Platypodidae). *Entomologica Basiliensia* 17: 5–310.

Piel F, Grégoire JC, Knížek, M (2006) New occurrence of *Ips duplicatus* Sahlberg in Herstal (Liege, Belgium). Bulletin *OEPP* 36: 529–530.

Pimentel D (1991) World resources and food losses to pests. In: Gorham JR (Ed) *Ecology and Management of Food Industry Pests, FDA Technical Bulletin 4*. Gaithersburg: of Official Analytical Chemists, 5–11.

Piry S, Gompel N (2002) Présence en France de *Neoderelomus piriformis* (Hoffmann, 1938) sur le palmier *Phoenix canariensis* Hort. (Coleoptera, Curculionidae, Derelomini). *Bulletin de la Société entomologique de France* 107: 529–534.

Rabasse JM, Perrin H (1979) Introduction en France du charançon de l'eucalyptus, *Gonipterus scutellatus* Gyll. (Col., Curculionidae). *Annales de Zoologie, Écologie Animale* 11: 336–345.

Ragusa E (1924) Gli Ipidae della Sicilia. *Bollettino Società Entomologica Italiana* 56: 114–118.

Ranger CM, Reding ME, Persad AB, Herms DA (2010) Ability of stress-related volatiles to attract and induce attacks by *Xylosandrus germanus* and other ambrosia beetles. *Agricultural and Forest Entomology* 12: 177–185.

Rasmussen, S (1976) Traeborende snudebille, *Pentarthrum huttoni* Woll. (Coleoptera, Curculionidae) ny for Danmark. *Entomologiske Meddr.* 44: 107–109.

Ratzeburg JTC (1837) Die Forst-Insecten oder Abbildung und Beschreibung der in den Wäldern Preussens und der Nachbarstaaten als schädlich oder nützlich bekannt gewordenen Insecten. Erster Theil, Die Käfer. Berlin: Nicolai. 212 pp.

Reitter E (1916) Fauna Germanica, Die Käfer des Deutschen Reiches, V. Band. Schriften des Deutschen Lehrervereins für Naturkunde, XXXIII. Stuttgart: Band. K. G. Lutz. 343 pp.

Roll E, Dayan T, Simberloff D (2007) Non-indigenous species in Israel and adjacent areas. *Biol. Inv.* 9: 629–643.

Roques A, Rabitsch W, Rasplus JY, Lopez-Vaamonde C, Nentwig W et al. (2009) Alien Terrestrial Invertebrates of Europe. In: DAISIE, *Handbook of Alien Species in Europe, Invading nature: springer series in invasion ecology 3*. Springer Science + Business Media B.V., 63–79.

Runge JB (2008) *Otiorhynchus apenninus* Stierlin, 1883, *Otiorhynchus dieckmanni* Magnano, 1979 and *Otiorhynchus aurifer* Boheman, 1843, three new weevils to the Danish fauna. *Entomologiske Meddelelser* 76: 69–78.

Sacchetti P, Camèra A, Granchietti A, Rosi MC, Marzialetti P (2005) Prima segnalazione in Italia del curculionide delle palme, *Rhynchophorus ferrugineus*. http://www.cespevi.it/art/rhynco.htm.

Salomone Suárez F, Carnero Hernández A, Marrero Ferrer M, González Hernández A (2000) Presence in the palearctic zone of *Diocalandra frumenti* Fabricius, (Coleoptera, Curculionidae). *Boletín de la asociación Española de Entomología* 24, 263–264.

Sampò A (1976) An Australian gonipterine weevil defoliator of eucalyptus in Europe for the first time (Coleoptera Curculionidae). *Il Floricultore* 13, 3 pp.

Sampò A, Olmi M (1975) Un pericoloso nenìico delle palme nuovo per l'Italia: *Dactylotrypes uyttenbogaarti* Eggers 1927 (Coleoptera Scolytidae). *Ann. Fac. Se. Agr. Univ. degli Studi di Torino* IX, 431–446.

Schedl KE (1946) Bestimmungstabellen der palaearktischen Borkenkäfer, I. Die Gattung *Crypturgus* Er. *Zentralblatt für das Gesamtgebiet der Entomologie* 1: 1–15.

Schedl KE (1963) XX. Scolytidae von Madeira. *Societas Scientiarum Fennica, Commentationes Biologicae* 25: 154–156.

Schedl KE (1970) Zur Synonymie der Borkenkäfer XX. 272. Beitrag zur Morphologie und Systematik der Scolytoidea. *Annales der Naturhististorische Museum Wien* 74, 221–231.

Schedl KE, Lindberg H, Lindberg H (1959) Coleoptera insularum Canariensium II. Scolytidae. *Societas Scientiarum Fennica, Commentationes Biologicae* 20: 1–34.

Schott C (2004) Sur la répartition de *Xyleborus peregrinus* Eggers en France et en Allemagne. *Bulletin de la Société Entomologique de Mulhouse* 60: 19–36.

Schott C, Callot HH (1994) Trois coléoptères scolytides nouveaux pour la faune de France observés en Alsace (*Xyleborus peregrinus* Eggers, *Lymantor aceris* Lindemann, *Phloeotribus caucasicus* Reitter, Col. Scolytidae). *Bulletin de la Société Entomologique de Mulhouse* 1994: 67–70.

Sebelin C (1951) Zum auftreten von *Araecerus fasciculatus* in Hamburg. *Zucker-u. Susswaren-Wirt* 4: 656–658.

Sheppard AW, Shaw RH, Sforza R (2006) Top 20 environmental weeds for classical biological control in Europe: a review of opportunities, regulations and other barriers to adoption. *Weed Research* 46, 93–117.

Silfverberg H (2004) Enumeratio nova Coleopterorum Fennoscandiae, Daniae et Baltiae. *Sahlbergia* 9: 1–111.

Silfverberg H (2004) Country records accidentally omitted from the new check list are added. *Sahlbergia* 9: 122.

Smith RM, Baker RHA, Malumphy CP, Hockland S, Hammon RP et al. (2007) Recent non-native invertebrate plant pest establishments in Great Britain: origins, pathways, and trends. *Agricultural and Forest Entomology* 9: 307–326.

Solari A, Solari F (1908) Segnalato come *Asynonychus godmani* Crotch, 1867. *Bollettino Società entomologica italiana* 40:268.

Stachowiak P, Wanat M (2001) Pierwsze stwierdzenie *Pentarthrum huttoni* Wollaston w Polsce, oraz klucz do oznaczania srodkowoeuropejskich rodzajów Cossoninae (Coleoptera, Curculionidae). *Wiad Ent Poznan* 20: 33–41.

Stauffer C, Kirisits T, Nussbaumer C, Pavlin R, Wingfield MJ (2001) Phylogenetic relationships between the European and Asian eight spined larch bark beetle populations (Coleoptera, Scolyltidae) inferred from DNA sequences and fungal associates. *European Journal of Entomology* 98: 99–105.

Strejček J (1993) Curculionidae. In Jelínek J (ed) *Check-list of Czechoslovak insects IV (Coleoptera). Seznam československých brouků*. Folia Heyrovskyana, Supplement 1, 135–152.

Stüben PE (2003) The Rediscovery of *Acalles droueti* Crotch 1867 and Curculionoidea collected on an excursion on the Azores: A Report (Coleoptera: Curculionidae: Cryptorhynchinae). Weevil News 16. 10 pp. http://www.curci.de/Inhalt.html.

Targioni Tozzetti A (1884) Relazioni intorno ai lavori della Regia Stazione di Entomologia Agraria di Firenze per gli anni 1879, 1880, 1881, 1882. *Annali di Agricoltura del R. Ministero Agricoltura, Industria e Commercio, Roma*: 1–645.

Telfer MG (2007) *Macrorhyncolus littoralis* (Broun) (Curculionidae) new to Ireland. *Coleopterist* 16: 118–119.

Teodorescu I, Manole T, Iamandei M (2006) The main alien/invasive insect species in Romania. *Romanian Journal of Biology - Zoology* 51: 43–61.

The World Factbook: Washington, DC: Central Intelligence Agency, 2009. https://www.cia.gov/library/publications/the-world-factbook/index.html.

Tobin PC, Whitmire SL, Johnson DM, Bjornstad ON, Liebhold AM (2007) Invasion speed is affected by geographical variation in the strength of Allee effects. *Ecology Letters* 10: 36–43.

Tomov R, Trencheva K, Trenchev G, Çota E, Ramafhi A et al. (2009) Non-Indigenous Insects and their Threat to Biodiversity in Albania, Bulgaria and Republic of Macedonia. Sofia: Pensoft Publishers.

Tremblay E, Espinosa B, Mancini D, Caprio G (2000) Un coleottero proveniente dal Sudamerica minaccia i pioppi. *L'informatore Agrario* 48: 89–90.

Valkama H, Martikainen P, Raty M (1997) First record of North American ambrosia beetle *Gnathotrichus materiarius* (Fitch) (Coleoptera, scolytidae) in Finland - a new potential forest pest? *Entomologica fennica* 8: 193–195.

Valladares L, Cocquempot C (2008) Présence en France d'Otiorhynchus (*Nehrodistus*) *corruptor* (Host, 1789) (Coleoptera Curculionidae). *L'Entomologiste*, 64: 129–130.

Welch RC (1990) *Macrorhyncolus littoralis* new record Broun Coleoptera Curculionidae, a littoral weevil new to the palearctic region from two sites in Kent England UK. *Entomologist's Monthly Magazine* 126: 97–101.

Whitehead PF, Zach P, Kulfan J, Cicak A, Cunderlik I (2000) *Dactylotrypes longicollis* (Wollaston 1864) (Coleoptera, Scolytidae) introduced to the Slovak Republic. *Anzeiger für Schadlingskunde*.

Table 8.2.1. Characteristics of the Curculionoidea species alien *to* Europe. Asterisks indicate *presumed* aliens. Feeding habits and hosts are those of larvae, which are generally the more damaging stage[6]. Country codes abbreviations refer to ISO 3166, with extensions (see Appendix I); main Atlantic and Mediterranean islands are treated separately as special „countries". **N/A** data non available. Status: **A** alien *to* Europe **C** *cryptogenic*. Feeding habits: abbreviations between brackets specify the feeding habits; **her** *herbiphagous* (larvae bore and feed inside non woody tissue of plant stems or leaves; stem includes branches, twigs, collar, bulb and rootstock) **lbw** *leaf/stem browser* (larvae externally feed on leaves or stems, as most caterpillars; early stages could be miner) **phl** *phloeophagous* (larvae bore and feed inside tree inner bark) **rbo** *root borer* (larvae bore and feed inside roots) **rbw** *root browser* (subterranean larvae externally feed on roots; early stages could be root miner) **spe** *spermatophagous* (larvae bore and feed inside reproductive organs, generally seeds) **xmp** *xylomycetophagous* (larvae live in galleries bored by females inside wood and mainly feed on wood-decaying symbiotic fungi) **xyl** *xylophagous* (larvae bore and feed inside wood, including woody materials such as palm stems)[7]. Native range: the field contains standardized range; if useful, native range could be specified between brackets. 1st record in Europe: date and countries of first known specimen, or first publication. Habitat: habitats in invaded countries; abbreviations refer to EUNIS (see Appendix II). Hosts: recorded hosts in invaded countries, and, between brackets, host breath in native range; host breath in native range is given as *monophagous*, *oligophagous* or *polyphagous* (abbreviated as **mp**, **op** and **pp**), depending if the species normally attacks hosts in one genera, one family or more; **hpp**: *highly polyphagous*.

Family / *subfamily* Species	**Status**	**Feeding habits**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Anthribidae								
Araecerus coffeae (Fabricius 1801)	A	phytophagous (spe)	Asia-Tropical	1951, DE	AT, BG, DE, FR, GB, IL, IT, MT, PL	J1	stored products (pp: *Coffea*, *Camellia sinensis*, stored products)	Essl and Rabitsch (2002), Mphuru (1974), Obretenchev et al. (1990), Sebelin (1951)
Apionidae								
Alocentron (*Alocentron*) *curvirostre* (Gyllenhal 1833)	A	phytophagous (spe)	Asia-Temperate	1904, BG	AT, BG, CH, CZ, HU, IT-SIC, MD, PL, RO, RS, SI, SK	I2, FA, FB	*Alcea rosae* (op: Malvaceae)	Essl and Rabitsch (2002), Joakimow (1904), Wittenberg (2005)
Aspidapion (*Aspidapion*) *validum* (Germar 1817)	A	phytophagous (spe)	Asia-Temperate	1960, BG	AT, BG, CH, CZ, DE, FR, HR, HU, IT, MD, PL, PT, RO, SK, UA	I2, FA, FB	*Alcea rosae* (op: Malvaceae)	Abbazzi et al. (1994), Angelov (1960), Essl and Rabitsch (2002), Wittenberg (2005)

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[6] Platypodines and scolytines adults generally feed as larvae, as do adults of many other species with *spermatophagous* or xylophagous *sensu lato*[7] larvae. Otherwise adults generally feed externally on leaf and stem regardless of the larval habits. Adults are often more polyphagous than larvae, except platypodines and scolytines.

[7] We use the term xylophagous *sensu lato* to gather species with *phloeophagous*, *xylomycetophagous* and *xylophagous* larvae.

Family / *subfamily* Species	**Status**	**Feeding habits**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Rhopalapion longirostre (Olivier 1807)	A	phyto-phagous (spe)	Asia-Temperate	1875, RO	AT, BG, CH, CY, CZ, ES, FR, FR-COR, DE, GR, GR-NEG, HR, HU, IT, MD, NL, PL, RO, RS, SK, UA	I2	*Alcea rosae* (op: Malvaceae)	Abbazzi et al. (1994), Ehret (1983), Essl and Rabitsch (2002), Kozłowski and Knutelski (2003), Markovich (1909), Mazur (2002), Perrin (1984), Perrin (1995), Wittenberg (2005)
Curculionidae								
Cossoninae								
Amaurorhinus (Amaurorhinus) monizianus (Wollaston 1860)*	A	phyto-phagous	Africa (ES-CAN)	N/A	PT-AZO, PT-MAD	B	N/A (*Suaeda*, *Salsola*)	Base de dados da biodiversidade dos Açores, Oromí and García (1995)
Caulophilus oryzae (Gyllenhal 1838)	A	phyto-phagous (spe)	North America	1982, PT-MAD	ES-CAN, GB, PT-MAD	J1	grain, stored products (pp: grain, *Persea* seed)	Izquierdo et al. (2004), Morris (2002), O'Brien and Wibmer (1982)
Euophryum confine (Broun 1880)	A	phyto-phagous (xyl)	Australasia	1937, GB	AD, AT, CZ, ES, ES-BAL, FR, GB, HU, PT, SE	J1, I2	decaying wood (pp: decaying wood)	Essl and Rabitsch (2002), Hill et al. (2005), Menet (1998)
Euophryum rufum (Broun 1880)	A	phyto-phagous (xyl)	Australasia	1934, GB	CH, DK, ES, GB, IE, SE	J1, I2	decaying wood (pp: decaying wood)	Hill et al. (2005), O'Connor (1977)
Macrorhyncolus littoralis (Broun 1880)	A	phyto-phagous (xyl)	Australasia	1987, GB	GB, IE	B2	driftwood (pp: decaying wood)	Morris (2002), Telfer (2007), Welch (1990)
Pentarthrum huttoni Wollaston 1854	A	phyto-phagous (xyl)	Australasia	1854, GB	AT, BE, CH, DE, DK, ES, FR, GB, IE, IT, NL, PL, RU, SK	J1	decaying wood (pp: decaying wood)	Abbazzi and Osella (1992), Bruge (1994), Buck (1948), Dieckmann (1983), Halmschlager et al. (2007), Hoffmann (1954), Rasmussen (1976), Stachowiak and Wanat (2001), Strejček (1993), Wittenberg (2005)

Family / *subfamily* Species	**Status**	**Feeding habits**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Pentatemnus arenarius Wollaston 1861*	A	phytophagous	Africa (North)	N/A	ES-CAN	N/A	N/A (N/A)	Machado and Oromí (2000)
Cryptorhynchinae								
Rhyephenes humeralis (Guérin-Méneville 1830)	A	phytophagous (phl)	C & S America	2003, ES	ES	G1, G5, X11	*Pinus radiata* (pp: broadleaf trees)	Alonso-Zarazaga and Goldarazena (2005)
Curculioninae								
Lignyodes (*Lignyodes*) *bischoffi* (Blatchley 1916)	A	phytophagous (spe)	North America	2001, PL	AT, PL	G, I2	*Fraxinus* (op: *Fraxinus*, *Syringa*)	Essl and Rabitsch (2002), Freude et al. (1983), Gosik et al. (2001)
Neoderelomus piriformis (Hoffmann 1938)	A	phytophagous (spe)	Africa (North)	1992, IT, IT-SIC	ES, ES-CAN, FR, IL, IT, IT-SIC, PT-MAD	I2	*Phoenix canariensis* (*Phoenix*)	Abbazzi and Osella (1992), Alonso-Zarazaga and Lyal (1999), Friedman (2006), Machado and Oromí (2000), Piry and Gompel (2002)
Tychius (Tychius) antoinei Hustache 1932*	A	phytophagous	Africa (North)	N/A	ES-CAN	N/A	N/A (Fabaceae)	Machado and Oromí (2000)
Tychius (Tychius) depauperatus Wollaston 1864*	A	phytophagous	Africa (North)	N/A	ES-CAN	N/A	N/A (Fabaceae)	Machado and Oromí (2000)
Cyclominae								
Asperogronops inaequalis (Boheman 1842)	A	phytophagous (lbw)	Asia-Temperate	1946, SE	DE, DK, FI, FR, GB, LT, LV, NL, SE	I2	*Atriplex* (op: Chenopodiaceae)	Meregalli (2004)
Gonipterus scutellatus Gyllenhal 1833	A	phytophagous (lbw)	Australasia	1975, IT	ES, ES-CAN, FR, FR-COR, IT, PT	I2, G2	*Eucalyptus* (mp: *Eucalyptus*)	Abbazzi and Osella (1992), Arzone (1976), Carrillo (1999), Machado and Oromí (2000), Mansilla (1992), Mansilla and Pérez Otero (1996), Neid (2003), Paiva (1996), Rabasse and Perrin (1979), Sampò (1976)

Family / *subfamily* Species	**Status**	**Feeding habits**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Listroderes costirostris Schoenherr 1826	A	phyto-phagous (lbw)	C & S America	1950, ES-CAN	ES-BAL, ES-CAN, FR, IL, PT	I, J100	N/A (hpp: vegetables, weeds)	Balachowsky (1963), Friedman (2009), Germain et al. (2008a), Machado and Oromí (2000), Moncoutier (1982)
Entiminae								
Asynonychus godmani Crotch 1867	A	phyto-phagous (rbw)	C & S America	1908, IT	DK, ES, ES-BAL, ES-CAN, FR, IT, IT-SAR, IT-SIC, MT, PT, PT-AZO, PT-MAD, SE	I	N/A (pp: *Rosa*, ornamentals, fruit trees)	Hoffmann (1950), Machado and Oromí (2000), Solari and Solari (1908), Stüben (2003)
Naupactus leucoloma Boheman 1840	A	phyto-phagous (rbw)	C & S America	2003, PT-AZO	PT-AZO	I, G	N/A (hpp: Fabaceae, vegetables, *Zea mays*)	Borges et al. (2005)
Sitona (Sitona) latipennis Gyllenhal 1834*	A	phyto-phagous (rbw)	Africa (PT-MAD)	N/A	ES-CAN	N/A	*Foeniculum* (N/A)	García (2003), Machado and Oromí (2000)
Hyperinae								
Donus (Donus) fallax (Capiomont 1868)*	A	phyto-phagous (lbw)	Africa (North)	N/A	ES-CAN	N/A	N/A (N/A)	Machado and Oromí (2000)
Donus (Antidonus) isabellinus (Boheman 1834)*	A	phyto-phagous (lbw)	Africa (North)	N/A	ES-CAN	N/A	N/A (N/A)	Machado and Oromí (2000)
Lixinae								
Pycnodactylopsis (Louwia) tomentosa (Fåhraeus 1842)*	A	phyto-phagous	Africa (North)	N/A	ES-CAN	N/A	N/A (N/A)	Machado and Oromí (2000)
Molytinae								
Demyrsus meleoides Pascoe 1872	A	phyto-phagous (xyl)	Australasia	1974, IT	IT	I2	Cycadales (op: Cycadales)	Covassi (1974)

Family / *subfamily* Species	**Status**	**Feeding habits**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Styphloderes (Parastyphloderes) lindbergi Roudier 1963*	A	phyto-phagous	Africa (ES-CAN)	N/A	PT-MAD	N/A	N/A (N/A)	Oromí and García (1995)
Syagrius intrudens Waterhouse 1903	A	phyto-phagous (her)	Australasia	1998, GB	GB	J100	Pteridopsida (op: Pteridopsida)	Hackett (1998), Hill et al. (2005)
Platypodinae								
Megaplatypus mutatus (Chapuis 1865)	A	phyto-phagous (xmp)	C & S America	2000, IT	IT	G1, I2	*Populus* (pp: broadleaf trees)	Tremblay et al. (2000)
Scolytinae								
Ambrosiodmus rubricollis Eichhoff 1875	A	phyto-phagous (xmp)	Asia	2008, IT	IT	G	*Aesculus hippocastanum, Prunus persica* (pp: broadleaf trees)	Faccoli et al. (2009)
Aphanarthrum affine Wollaston 1860*	A	phyto-phagous (her)	Africa	1860, ES-CAN	ES-CAN	F8	*Euphorbia* (mp: *Euphorbia*)	Israelson (1972)
Aphanarthrum bicinctum Wollaston 1860*	A	phyto-phagous (her)	Africa	1860, ES-CAN	ES-CAN	F8	*Euphorbia* (mp: *Euphorbia*)	Israelson (1972)
Aphanarthrum bicolor Wollaston 1860*	A	phyto-phagous (her)	Africa (ES-CAN)	1972, PT-MAD	PT-MAD	F8	*Euphorbia* (mp: *Euphorbia*)	Israelson (1972)
Aphanarthrum mairei Peyerimhoff 1923*	A	phyto-phagous (her)	Africa	1928, ES-CAN	ES-CAN	F8	*Euphorbia* (mp: *Euphorbia*)	Israelson (1980)
Aphanarthrum piscatorium Wollaston 1860*	A	phyto-phagous (her)	Africa (ES-CAN)	1972, PT-MAD	PT-MAD	F8	*Euphorbia* (mp: *Euphorbia*)	Israelson (1972)

Family / *subfamily* Species	**Status**	**Feeding habits**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Cisurgus wollastonii (Eichhoff 1878)*	A	phytophagous (her)	Africa	1860, ES-CAN	ES-CAN	F8	*Euphorbia* (mp: *Euphorbia*)	Schedl (1946)
Coccotrypes carpophagus (Hornung 1842)	A	phytophagous (spe)	Tropical, subtropical	N/A	ES-CAN, PT-AZO, PT-MAD	I2	*Phoenix*, *Washingtonia*, Arecaceae, *Dracaena* (pp: Arecaceae, woody seeds)	Bright (1987), Kirkendall per. obs.
Coccotrypes dactyliperda (Fabricius 1801)	A	phytophagous (spe)	Tropical, subtropical	1884, IT	ES-CAN, FR, FR-COR, HU, IT, IT-SAR, IT-SIC, MT, PT-MAD	I2	*Phoenix*, *Chamaerops umilis*, Arecaceae (pp: Arecaceae, woody seeds)	Kirkendall and Faccoli (2010), Schedl (1963), Schedl et al. (1959), Targioni Tozzetti (1884)
Coleobothrus alluaudi (Peyerimhoff 1923)*	A	phytophagous (her)	Africa	1928, ES-CAN	ES-CAN	F8	*Euphorbia* (mp: *Euphorbia*)	Israelson (1980)
Cyclorhipidion bodoanus (Reitter 1913)	A	phytophagous (xmp)	Asia	1960, FR	BE, CH, DE, FR, IT, NL	G1	*Quercus* (op: Fagaceae)	Audisio et al. (2008), Bouget and Noblecourt (2005), Kirkendall and Faccoli (2010), Schott (2004), Schott and Callot (1994)
Dactylotrypes longicollis (Wollaston 1864)	A	phytophagous (spe)	Africa (ES-CAN)	1949, FR-COR	ES, FR, FR-COR, HR, IT, IT-SIC, PT-MAD	I2	*Phoenix canariensis*, Arecaceae, *Dracaena draco* (op: Arecaceae, Dracaenaceae)	Balachowsky (1949), Lombardero and Novoa (1994), Sampò and Olmi (1975), Whitehead et al. (2000)
Dryocoetes himalayensis Strohmeyer 1908	A	phytophagous (phl)	Asia-Temperate	2004, FR	CH, FR	G	N/A (pp: *Juglans regia*, *Pyrus lanata*)	Knížek (2004)
Gnathotrichus materiarius (Fitch 1858)	A	phytophagous (xmp)	North America	1933, FR	BE, CH, CZ, DE, ES, FI, FR, IT, NL, SE	G	*Picea*, *Pinus* (pp: conifers)	Balachowsky (1949), Faccoli (1998), Kirkendall and Faccoli (2010), Valkama et al. (1997), Wittenberg (2005)

Family / *subfamily* Species	**Status**	**Feeding habits**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Hypocryphalus scabricollis (Eichhoff 1878)	A	phytophagous (phl)	Asia	1991, MT	MT	I2	*Ficus* (pp)	Mifsud and Knížek (2009)
Hypothenemus crudiae (Panzer 1791)	A	phytophagous (phl)	C & S America (+ North Am.)	N/A	PT-AZO	G1	N/A (hpp)	Base de dados da biodiversidade dos Açores
Hypothenemus eruditus Westwood 1836	A	phytophagous (phl, spe)	C & S America (+ North Am.)	1924, IT-SIC	ES, ES-CAN, FR, FR-COR, IL, IT, IT-SIC, MT, PT-AZO, PT-MAD	J1	N/A (hpp)	Balachowsky (1949), Machado and Oromí (2000), Noblecourt (2004), Pfeffer (1995), Ragusa (1924), Roll et al. (2007)
Liparthrum artemisiae Wollaston 1854*	A	phytophagous (phl)	Africa (ES-CAN)	N/A	PT-MAD	F5	*Artemisia* (mp: *Artemisia*)	Schedl (1963)
Liparthrum bituberculatum Wollaston 1854*	A	phytophagous (phl)	Africa (North)	N/A	ES-CAN, PT-MAD	G1	*Laurus* (mp: *Laurus*)	Israelson (1990)
Liparthrum curtum Wollaston 1854*	A	phytophagous (phl)	Africa (ES-CAN)	N/A	PT-AZO, PT-MAD	G1	*Castanea*, *Ficus* (pp: Euphorbiaceae, Moraceae, Fabaceae, Fagaceae)	Israelson (1990)
Liparthrum inarmatum Wollaston 1860*	A	phytophagous (her)	Africa	N/A	ES-CAN, PT-MAD	F8	*Euphorbia* (mp: *Euphorbia*)	Israelson (1990)
Liparthrum mandibulare Wollaston 1854	A	phytophagous (phl)	Africa (ES-CAN)	N/A	ES, GB, PT-MAD	G1	*Alnus*, *Betula*, *Castanea*, *Euphorbia*, *Erica*, *Quercus*, *Rubus* (hpp)	Israelson (1990), Lombardero and Novoa (1993)
Monarthrum mali (Fitch 1855)	A	phytophagous (xmp)	North America	2007, IT	IT	G	N/A (pp: broadleaf trees)	Kirkendall et al. (2008)

Family / *subfamily* Species	**Status**	**Feeding habits**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Phloeosinus rudis Blandford 1894	A	phyto-phagous (phl)	Asia	1940, FR	FR, NL	FA, G5	*Thuja*, *Chamaecyparis*, *Juniperus chinensis*, Cupressaceae (op: Cupressaceae)	Balachowsky (1949), Moraal (2009)
Phloeotribus liminaris (Harris 1852)	A	phyto-phagous (phl)	North America	2004, IT	IT	I2	*Prunus serotina* (mp: *Prunus*)	Pennacchio et al. (2004)
Polygraphus proximus Blandford 1894	A	phyto-phagous (phl)	Asia	2000, RU	RU	G3	*Abies* (mp: *Abies*)	Chilahsayeva (2008), Mandelshtam and Popovichev (2000)
Xyleborinus attenuatus Wood & Bright 1992	A	phyto-phagous (xmp)	Asia	1987, AT, CZ	AT, CH, CZ, DE, ES, HU, NL, PL, RU, SE, SK, UA	G1	*Alnus*, *Betula*, *Salix*, *Tilia*, *Quercus*, *Corylus*, broadleaf trees (pp: broadleaf trees)	Essl and Rabitsch (2002), Kirkendall and Faccoli (2010)
Xyleborus affinis Eichhoff 1868	A	phyto-phagous (xmp)	C & S America (+ North Am.)	2006, AT	AT	I	*Dracaena* (pp: broadleaf trees)	Holzer (2007)
Xyleborus atratus Eichhoff 1875	A	phyto-phagous (xmp)	Asia	2007, IT	IT	G	N/A: *Quercus*? (pp: broadleaf trees)	Faccoli (2008)
Xyleborus pfeilii (Ratzeburg 1837)[8]	A	phyto-phagous (xmp)	Asia	1837, DE	AT, BG, CH, CZ, DE, ES, FR, HR, HU, IT, PL, SI, SK, UA	G	*Alnus*, *Betula*, *Populus* (pp: broadleaf trees)	Kirkendall and Faccoli (2010), Ratzeburg (1837)
Xylosandrus crassiusculus (Motschulsky 1866)	A	phyto-phagous (xmp)	Asia	2003, IT	IT	G2, J100	*Ceratonia siliqua* (pp: broadleaf trees, *Pinus*)	Pennacchio et al. (2003)

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[8] *Xyleborus pfeilii* was until recently treated as native to Europe, but is now thought to be introduced (Kirkendall and Faccoli 2010).

Family / *subfamily* Species	**Status**	**Feeding habits**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Xylosandrus germanus (Blandford 1894)	A	phyto-phagous (xmp)	Asia	1950, DE	AT, BE, CH, CZ, DE, FR, HU, IT, NL, PL, RU, SI	G	*Fagus*, *Castanea*, *Buxus*, *Ficus*, *Carpinus*, *Quercus*, *Juglans*, *Picea*, *Pinus* (pp: broadleaf trees, conifers)	Henin and Versteirt (2004), Kirkendall and Faccoli (2010)
Xylosandrus morigerus (Blandford 1894)	A	phyto-phagous (xmp)	Asia	1916, AT, CZ, FR, GB	AT, CZ, FR, GB, IT	J100	greenhouse orchids as *Dendrobium* (pp: broadleaf trees)	Kirkendall and Faccoli (2010), Reitter (1916)
Dryophthoridae								
Cosmopolites sordidus (Germar 1824)	A	phyto-phagous (xyl)	Asia-Tropical	2004, ES-CAN	ES-CAN, PT-AZO, PT-MAD	I	N/A (op: *Musa*, *Ensete*)	Machado and Oromí (2000)
Diocalandra frumenti (Fabricius 1801)	A	phyto-phagous (xyl)	Asia-Tropical	1998, ES-CAN	ES-CAN	I2	*Phoenix*, Arecaceae (op: Arecaceae)	Gonzales et al. (2002), Machado and Oromí (2000), Salomone Suárez et al. (2000)
Paradiaphorus crenatus (Billberg 1820)	A	phyto-phagous (xyl)	C & S America	2004, ES-CAN	ES-CAN	I1	N/A (*Ananas*)	Machado and Oromí (2000)
Rhynchophorus ferrugineus (Olivier 1790)	A	phyto-phagous (xyl)	Asia-Tropical	1993, ES	CY, ES, ES-CAN, FR, FR-COR, GR, GR-CRE, GR-SEG, IL, IT, IT-SAR, IT-SIC	X24, I2	Arecaceae (op: Arecaceae)	Barranco et al. (1996), Bitton and Nakache (2000), EPPO (2006), FREDON-Corse (2007), Kehat (1999), Kontodimas et al. (2006), MAPA (2006), Sacchetti et al. (2005)
Scyphophorus acupunctatus Gyllenhal 1838	A	phyto-phagous (her)	C & S America	2006, IT-SIC	FR, IT-SIC	I2	*Agave* (pp: Agavaceae, Dracaenaceae)	Germain et al. (2008b), Longo (2007)

Family / *subfamily* Species	**Status**	**Feeding habits**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Sitophilus linearis (Herbst 1797)	A	phyto-phagous (spe)	Tropical, subtropical	1954, FR-COR	AL, AT, ES-CAN, FR, FR-COR, IT, PL	J1	*Tamarindus indica* (mp: *Tamarindus indica*)	Abbazzi et al. (1994), Essl and Rabitsch (2002), Hoffmann (1954), Machado and Oromí (2000), Tomov et al. (2009)
Sitophilus oryzae (Linnaeus 1763)	A	phyto-phagous (spe)	Asia-Tropical	1896, SE	AL, AT, BG, BY, CH, CY, CZ, DE, DK, EE, ES, ES-CAN, FI, FR, FR-COR, GB, GL, HR, HU, IS, IT, IT-SAR, IT-SIC, LT, LV, MT, NL, NO, PL, PT, PT-AZO, RO, SE, UA	J1	grain (op: cereal grain)	Abbazzi et al. (1994), Balachowsky (1963), Essl and Rabitsch (2002), Hoffmann (1954), Joakimow (1904), Machado and Oromí (2000), Silfverberg (2004a), Silfverberg (2004b), Teodorescu et al. (2006), Tomov et al. (2009), Wittenberg (2005)
Sitophilus zeamais Motschulsky 1855	C	phyto-phagous (spe)	*Cryptogenic*	1927, DE	AD, AL, AT, BE, BG, CH, CZ, DE, DK, EE, ES-CAN, FI, FR, GB, IT, IT-SAR, IT-SIC, PL, PT, PT-AZO, PT-MAD, RU, SE	J1	grain (op: cereal grain)	Balachowsky (1963), Dal Monte (1972), Essl and Rabitsch (2002), Haghebaert (1991), Lundberg (1995), Machado and Oromí (2000), Obretenchev et al. (1990), Tomov et al. (2009), Wittenberg (2005)
Erirhinidae								
Lissorhoptrus oryzophilus Kuschel 1952	A	phyto-phagous (rbw)	North America	2004, IT	IT	I1	*Oryza*, *Carex* (pp: Gramineae, Cyperaceae)	Caldara et al. (2004)
Stenopelmus rufinasus Gyllenhal 1835	A	phyto-phagous (lbw)	North America	1900, FR	BE, DE, ES, FR, GB, IE, IT, NL	C1, C2	*Azolla* (mp: *Azolla*)	Baars and Caffery (2008), Dana and Viva (2006), Fernandez Carrillo et al. (2005), Hill et al. (2005), Janson (1921)

Table 8.2.2. Characteristics of the Curculionoidea species alien *in* Europe. See Table 8.2.1 legend. Native range: „Mediterranean“ refers to southern Europe, North Africa and western Asia; „West Mediterranean“ refers to southern Europe and North Africa.

Family / *subfamily* Species	**Feeding habits**	**Native range**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Anthribidae						
Bruchela rufipes (Olivier 1790)	phytophagous (spe)	Europe	GB	I2	N/A (mp: *Reseda lutea*)	Hill et al. (2005), Morris (1990)
Apionidae						
Aspidapion (Aspidapion) radiolus (Marsham 1802)*	phytophagous (her)	Europe, Mediterranean, Asia	ES-CAN, PT-AZO	N/A	N/A (op: Malvaceae)	Base de dados da biodiversidade dos Açores, Machado and Oromí (2000)
Catapion pubescens (W. Kirby 1811)*	phytophagous (her)	Europe, Mediterranean	ES-CAN	N/A	N/A (mp: *Trifolium*)	Machado and Oromí (2000)
Eutrichapion (Cnemapion) vorax (Herbst 1797)*	phytophagous	Europe, West Mediterranean	ES-CAN	N/A	N/A (op: Fabaceae)	Machado and Oromí (2000)
Holotrichapion (Holotrichapion) ononis (W. Kirby 1808)*	phytophagous (spe)	Europe, Mediterranean, Asia	ES-CAN	N/A	N/A (mp: *Ononis*)	Machado and Oromí (2000)
Ischnopterapion (Ischnopterapion) plumbeomicans (Rosenhauer 1856)*	phytophagous (spe)	Mediterranean	ES-CAN	N/A	N/A (mp: *Lotus*)	Machado and Oromí (2000)
Ischnopterapion (Chlorapion) virens (Herbst 1797)*	phytophagous (her)	Europe, Mediterranean, Asia	ES-CAN	N/A	N/A (mp: *Trifolium*)	Machado and Oromí (2000)
Ixapion variegatum (Wencker 1864)	phytophagous (her)	Europe	GB	I2, H5	*Viscum album* (mp: *Viscum album*)	Duff (2008), Foster et al. (2001)
Kalcapion semivittatum (Gyllenhal 1833)*	phytophagous (her)	Europe, Mediterranean	ES-CAN, PT-AZO	N/A	N/A (mp: *Mercurialis*)	Base de dados da biodiversidade dos Açores, Machado and Oromí (2000)
Brachyceridae						
Brachycerus plicatus Gyllenhal 1833*	phytophagous (her?)	Mediterranean	ES-CAN	N/A	N/A (op: Liliaceae?)	Machado and Oromí (2000)

Family / *subfamily* Species	**Feeding habits**	**Native range**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Curculionidae						
Bagoinae						
Bagous exilis Jacquelin du Val 1854*	phytophagous	West Mediterranean	ES-CAN	B	N/A (coastal shrubs: *Frankenia*, Chenopodiaceae)	Machado and Oromí (2000)
Baridinae						
Melaleucus sellatus (Boheman 1844)*	phytophagous	West Mediterranean	ES-CAN	N/A	N/A (N/A)	Machado and Oromí (2000)
Melanobaris quadraticollis (Boheman 1836)*	phytophagous (her)	West Mediterranean	ES-CAN	I, J	N/A (op: Cruciferae)	Machado and Oromí (2000)
Ceutorhynchinae						
Ceutorhynchus assimilis (Paykull 1800)	phytophagous (spe)	Europe, West Mediterranean	PT-AZO	I, J	N/A (op: *Brassica*, Cruciferae)	Borges et al. (2005)
Micrelus ferrugatus (Perris 1847)*	phytophagous (spe)	West Mediterranean	ES-CAN	E	N/A (mp: *Erica*)	Machado and Oromí (2000)
Mogulones geographicus (Goeze 1777)	phytophagous (rbo)	Europe, West Mediterranean	PT-AZO	I, G	*Echium* (mp: *Echium*)	Borges et al. (2005)
Rhinoncus pericarpius (Linnaeus 1758)	phytophagous (rbo)	Europe, West Mediterranean, Asia	FÖ	E, I	N/A (mp: *Rumex*)	N/A
Cossoninae						
Brachytemnus porcatus (Germar 1824)	phytophagous (xyl)	Europe, West Mediterranean	PT-AZO	I2	N/A (op: Pinaceae)	Borges et al. (2005)
Pselactus spadix (Herbst 1795)	phytophagous (xyl)	Europe	PT-AZO	B, E	marine driftwood (pp: decaying wood)	Stüben (2003)
Pseudophloeophagus aeneopiceus (Boheman 1845)*	phytophagous (xyl)	Europe	PT-AZO	N/A	N/A (pp: decaying wood)	Base de dados da biodiversidade dos Açores
Rhopalomesites tardyi (Curtis 1825)	phytophagous (xyl)	Europe	PT-AZO	G	N/A (pp: dead wood)	Borges et al. (2005)
Cryptorhynchinae						
Dichromacalles (Dichromacalles) dromedarius (Boheman 1844)*	phytophagous (her?)	West Mediterranean	ES-CAN, PT-AZO	N/A	N/A (op: Compositae)	Base de dados da biodiversidade dos Açores, Machado and Oromí (2000)

Family / *subfamily* Species	**Feeding habits**	**Native range**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Curculioninae						
Mecinus circulatus (Marsham 1802)*	phytophagous (her)	Europe, Mediterranean	ES-CAN	I, J	N/A (mp: *Plantago*)	Machado and Oromí (2000)
Mecinus longiusculus Boheman 1845*	phytophagous (her)	West Mediterranean	ES-CAN	I, J	N/A (op: Scrophulariaceae)	Machado and Oromí (2000)
Mecinus pascuorum (Gyllenhal 1813)	phytophagous (spe)	Europe, Mediterranean	ES-CAN, PT-AZO	I, J	*Plantago* (mp: *Plantago*)	Borges et al. (2005), Machado and Oromí (2000)
Pachytychius aridicola (Wollaston 1864)*	phytophagous (spe)	Mediterranean	ES-CAN	N/A	N/A (N/A)	Machado and Oromí (2000)
Philernus farinosus Gyllenhal 1835*	phytophagous	Europe, Asia	ES-CAN	N/A	N/A (N/A)	Machado and Oromí (2000)
Sibinia (Dichotychius) albosquamosa Pic 1904*	phytophagous (spe?)	Mediterranean	ES-CAN	N/A	*Limonium* (N/A)	Machado and Oromí (2000)
Sibinia (Dichotychius) planiuscula (Desbrochers 1873)*	phytophagous (spe?)	Mediterranean	ES-CAN	N/A	N/A (N/A)	Machado and Oromí (2000)
Sibinia (Sibinia) primita (Herbst 1795)*	phytophagous (spe)	Europe, West Mediterranean	ES-CAN	N/A	N/A (pp: Caryophyllaceae, Plumbaginaceae, Thymelaeaceae)	Machado and Oromí (2000)
Smicronyx albosquamosus Wollaston 1854*	phytophagous (her?)	West Mediterranean	ES-CAN, PT-MAD	N/A	N/A (N/A)	Hoffmann (1958), Machado and Oromí (2000)
Smicronyx brevicornis Solari 1952*	phytophagous (her)	West Mediterranean	ES-CAN	N/A	N/A (mp: *Cuscuta*)	Machado and Oromí (2000)
Tychius (*Tychius*) *cuprifer* (Panzer 1799)	phytophagous (spe)	Europe, Mediterranean	PT-AZO	I1	N/A (mp: *Trifolium*)	Borges et al. (2005), Stüben (2003)
Tychius (*Tychius*) *picirostris* (Fabricius 1787)	phytophagous (spe)	Europe, Mediterranean, Asia	PT-AZO	I1, E	N/A (mp: *Trifolium*)	Borges et al. (2005)
Tychius (Tychius) stephensi Schonherr 1836*	phytophagous (spe)	Europe, Mediterranean, Asia	ES-CAN	N/A	N/A (mp: *Trifolium*)	Machado and Oromí (2000)

Family / *subfamily* Species	**Feeding habits**	**Native range**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Tychius (Tychius) striatulus Gyllenhal 1836*	phytophagous (spe)	Mediterranean	ES-CAN	N/A	N/A (mp: *Ononis*)	Machado and Oromí (2000)
Cyclominae						
Gronops fasciatus Kuster 1851*	phytophagous	Mediterranean	ES-CAN	N/A	Opuntia (N/A)	Machado and Oromí (2000)
Entiminae						
Barynotus squamosus Germar 1824	phytophagous	Europe	FÖ	G	N/A (N/A)	N/A
Barypeithes (*Exomias*) *pellucidus* (Boheman 1834)	phytophagous (rbw?)	Europe	IS	I	*Medicago* (mp: *Medicago*)	Ólafsson (1991)
Cathormiocerus (*Cathormiocerus*) *curvipes* (Wollaston 1854)	phytophagous	Europe	PT-AZO	F5	*Pittosporum*? (N/A)	Stüben (2003)
Otiorhynchus (*Otiorhynchus*) *apenninus* Stierlin 1883	phytophagous (rbw)	Europe (Alps)	DK, GB, MT, NL, SE	I2	N/A (pp: *Acer*, *Camelia*, *Prunus*, *Rhododendron*)	Heijerman et al. (2003), Hill et al. (2005), Runge (2008)
Otiorhynchus (*Otiorhynchus*) *armadillo* (Rossi 1792)	phytophagous (rbw)	Europe (central)	GB, SE	I2, J4	N/A (*Alnus*)	Borisch (1997), Hill et al. (2005)
Otiorhynchus (*Nehrodistus*) *armatus* Boheman 1843	phytophagous (rbw)	Europe (southern)	SE	J100	*Fragaria*, *Vitis*, *Carduus*, *Rumex* (N/A)	Borisch (1997), Silfverberg (2004a), Silfverberg (2004b)
Otiorhynchus (*Otiorhynchus*) *aurifer* Boheman 1843	phytophagous (rbw)	Mediterranean	DK	N/A	N/A (N/A)	Runge (2008)
Otiorhynchus (*Pocodalemes*) *crataegi* Germar 1824	phytophagous (rbw)	Europe, Mediterranean	GB	I2	N/A (*Cyclamen*)	Hill et al. (2005)
Otiorhynchus (*Nehrodistus*) *corruptor* (Host 1789)	phytophagous (rbw)	Europe (southern)	DE, DK, FR, GB	I	*Pyrus*? (N/A)	Barclay (2001), Lucht (1985), Palm (1996), Valladares and Cocquempot (2008)
Otiorhynchus (*Arammichnus*) *cribricollis* Gyllenhal 1834	phytophagous (rbw)	West Mediterranean	ES-CAN, PT-AZO	I, J	N/A (mp: *Artemisia*)	Borges et al. (2005), Machado and Oromí (2000), Stüben (2003)
Otiorhynchus (*Arammichnus*) *dieckmanni* Magnano 1979	phytophagous (rbw)	Europe (western)	DK, SE	G, I2	N/A (N/A)	Borisch (1997), Runge (2008), Silfverberg (2004a), Silfverberg (2004b)

Family / *subfamily* Species	**Feeding habits**	**Native range**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Otiorhynchus (*Padilehus*) *pinastri* (Herbst 1795)	phytophagous (rbw)	Europe (eastern)	CH	J	*Vincetoxicum* (N/A)	Germann (2004)
Otiorhynchus (Zustalestus) rugosostriatus (Goeze 1777)*	phytophagous (rbw)	Europe, West Mediterranean	PT-AZO	N/A	N/A (pp: *Rumex*, *Dactylis*, *Trifolium*...)	Base de dados da biodiversidade dos Açores
Otiorhynchus (*Metopiorrhynchus*) *singularis* (Linnaeus 1767)	phytophagous (rbw)	Europe	FÖ, IS	I2	N/A (N/A)	Ólafsson (1991)
Otiorhynchus (*Dorymerus*) *sulcatus* (Fabricius 1775)	phytophagous (rbw)	Europe	PT-AZO	F5	*Pittosporum*? (pp: *Vitis*...)	Borges et al. (2005), Stüben (2003)
Philopedon plagiatum (Schaller 1783)	phytophagous (rbw?)	Europe, West Mediterranean	PT-AZO	I,G	N/A (*Ammophila*)	Borges et al. (2005)
Psallidium (*Psallidium*) *maxillosum* (Fabricius 1792)	phytophagous	Europe (southcentral, southeastern)	SE	I1	N/A (N/A)	Lundberg (2006)
Rhytideres (Rhytideres) plicatus (Olivier 1790)*	phytophagous (rbw)	Mediterranean	ES-CAN	N/A	N/A (pp: Resedaceae, Cruciferae)	Machado and Oromí (2000)
Sitona (Charagmus) cachectus Gyllenhal 1834*	phytophagous (rbw)	West Mediterranean	ES-CAN	N/A	N/A (mp: *Astragalus*)	Machado and Oromí (2000)
Sitona (*Sitona*) *cinnamomeus* Allard 1863	phytophagous (rbw)	Mediterranean	PT-AZO	I, G	N/A (op: *Lotus*, *Trifolium*, Fabaceae)	Borges et al. (2005)
Sitona (*Sitona*) *discoideus* Gyllenhal 1834	phytophagous (rbw)	Mediterranean	ES-CAN, PT-AZO	I, G	N/A (mp: *Medicago*)	Borges et al. (2005), Machado and Oromí (2000)
Sitona (Charagmus) gressorius (Fabricius 1792)*	phytophagous (rbw)	Mediterranean, Asia	ES-CAN, PT-AZO	N/A	N/A (mp: *Lupinus*)	Base de dados da biodiversidade dos Açores, Machado and Oromí (2000)
Sitona (*Sitona*) *lepidus* Gyllenhal 1834	phytophagous (rbw)	Europe, Mediterranean	PT-AZO	I, J	N/A (op: *Lotus*, *Trifolium*, Fabaceae)	Borges et al. (2005)
Sitona (Sitona) lineatus (Linnaeus 1758)*	phytophagous (rbw)	Europe, Mediterranean, Asia	ES-CAN, PT-AZO	I, J	N/A (op: Fabaceae)	Base de dados da biodiversidade dos Açores, Machado and Oromí (2000)
Sitona (Sitona) macularius (Marsham 1802)*	phytophagous (rbw)	Europe, Mediterranean, Asia	ES-CAN	I, J	N/A (mp: *Trifolium*)	Machado and Oromí (2000)

Family / *subfamily* Species	**Feeding habits**	**Native range**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Sitona (Sitona) ocellatus Kuster 1849*	phytophagous (rbw)	Mediterranean	ES-CAN	N/A	N/A (Fabaceae?)	Machado and Oromí (2000)
Sitona (*Sitona*) *puberulus* Reitter 1903	phytophagous (rbw)	Mediterranean	ES-CAN, PT-AZO, PT-MAD	I, J	N/A (mp: *Lotus*)	Borges et al. (2005), Hoffmann (1950), Machado and Oromí (2000), Stüben (2003)
Sitona (*Sitona*) *puncticollis* Stephens 1831	phytophagous (rbw)	Europe, Mediterranean, Asia	FÖ, PT-AZO	I	N/A (op: *Trifolium*, *Melilotus*?)	Borges et al. (2005)
Sitona (Charagmus) variegatus Fåhraeus 1840*	phytophagous (rbw)	West Mediterranean	ES-CAN	N/A	N/A (mp: *Astragalus*)	Machado and Oromí (2000)
Strophosoma (*Strophosoma*) *melanogrammum melanogrammum* (Forster 1771)	phytophagous (rbw?)	Europe	PT-AZO	G, I2	N/A (pp: *Rumex*, *Aira*...)	Borges et al. (2005)
Trachyphloeus (Trachyphloeus) angustisetulus Hansen 1915*	phytophagous (rbw?)	Europe	ES-CAN	N/A	N/A (N/A)	Machado and Oromí (2000)
Trachyphloeus (Trachyphloeus) laticollis Boheman 1843*	phytophagous (rbw?)	Mediterranean	ES-CAN	N/A	*Mercurialis*, *Bidens* (N/A)	Machado and Oromí (2000)
Trachyphloeus (Trachyphloeus) spinimanus Germar 1824*	phytophagous (rbw)	Europe, Asia	ES-CAN	N/A	N/A (mp: *Cynodon*)	Machado and Oromí (2000)
Hyperinae						
Coniatus (Coniatus) tamarisci (Fabricius 1787)*	phytophagous	Mediterranean	ES-CAN	N/A	N/A (mp: *Tamarix*)	Machado and Oromí (2000)
Donus (*Antidonus*) *lunatus* (Wollaston 1854)*	phytophagous (lbw)	Europe, Mediterranean, Asia	ES-CAN	E	N/A (op: Geraniaceae)	Machado and Oromí (2000)
Hypera (Hypera) melancholica (Fabricius 1792)*	phytophagous (lbw)	Europe, Mediterranean, Asia	ES-CAN	I, J	N/A (op: *Medicago*, *Trifolium*)	Machado and Oromí (2000)

Family / *subfamily* Species	**Feeding habits**	**Native range**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Hypera (Hypera) nigrirostris (Fabricius 1775)*	phytophagous (lbw)	Europe, Mediterranean, Asia	ES-CAN	E, J	N/A (op: *Ononis*, *Trifolium*)	Machado and Oromí (2000)
Hypera (Hypera) ononidis (Chevrolat 1863)*	phytophagous (lbw)	Europe, West Mediterranean	ES-CAN	E	N/A (mp: *Ononis*)	Machado and Oromí (2000)
Hypera (*Hypera*) *postica* (Gyllenhal 1813)	phytophagous (lbw)	Europe, Mediterranean, Asia	ES-CAN, PT-AZO	I, J	N/A (op: Fabaceae)	Borges et al. (2005), Machado and Oromí (2000)
Lixinae						
Coniocleonus excoriatus (Gyllenhal 1834)*	phytophagous	Europe, Mediterranean	ES-CAN, PT-AZO	N/A	N/A (N/A)	Base de dados da biodiversidade dos Açores, Machado and Oromí (2000)
Coniocleonus variolosus (Wollaston 1864)*	phytophagous	West Mediterranean	ES-CAN	N/A	N/A (N/A)	Machado and Oromí (2000)
Conorhynchus (Pycnodactylus) brevirostris (Gyllenhal 1834)*	phytophagous (rbo)	Mediterranean, Africa	ES-CAN	B	N/A (op: Chenopodiaceae)	Machado and Oromí (2000)
Conorhynchus (Pycnodactylus) conicirostris (Olivier 1807)*	phytophagous	Mediterranean	ES-CAN	N/A	N/A (N/A)	Machado and Oromí (2000)
Lixus (Compsolixus) anguinus (Linnaeus 1767)*	phytophagous (her)	West Mediterranean	ES-CAN	E?	N/A (op: *Cheiranthus*, *Sinapis*)	Machado and Oromí (2000)
Lixus (Eulixus) brevirostris Boheman 1835*	phytophagous (her)	West Mediterranean	ES-CAN	N/A	N/A (mp: *Atriplex*)	Machado and Oromí (2000)
Lixus (Epimeces) filiformis (Fabricius 1781)*	phytophagous (her)	Europe, Mediterranean	ES-CAN	I, J	N/A (mp: *Carduus*)	Machado and Oromí (2000)
Lixus (Compsolixus) juncii Boheman 1835*	phytophagous (her)	Mediterranean, Asia	ES-CAN	N/A	N/A (op: Chenopodiaceae)	Machado and Oromí (2000)
Lixus (Dilixellus) linearis Olivier 1807*	phytophagous (her)	Europe, Mediterranean	ES-CAN	I, J	N/A (mp: *Rumex*)	Machado and Oromí (2000)
Lixus (Dilixellus) pulverulentus (Scopoli 1763)*	phytophagous (her)	Europe, Asia, North Africa	ES-CAN	N/A	N/A (op: Malvaceae, Fabaceae)	Machado and Oromí (2000)

Family / *subfamily* Species	**Feeding habits**	**Native range**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Rhinocyllus conicus (Froelich 1792)	phytophagous (spe)	Europe, Mediterranean	LT, LV, SE	E, I	N/A (op: *Carduus*, *Cirsium*, *Galactites*, *Cynara*...)	Gillerfors (1988), Lundberg (2006)
Mesoptiliinae						
Magdalis (*Magdalis*) *memnonia* (Gyllenhal 1837)	phytophagous (her)	Europe, Mediterranean, Asia	GB	G3	*Pinus* (mp: *Pinus*)	Hill et al. (2005)
Molytinae						
Anisorhynchus hespericus Desbrochers 1875*	phytophagous	Europe (southwestern)	ES-CAN	N/A	N/A (N/A)	Machado and Oromí (2000)
Ita crassirostris Tournier 1878*	phytophagous	Europe (southern)	ES-CAN	N/A	N/A (N/A)	Machado and Oromí (2000)
Liparus (*Liparus*) *glabrirostris* Küster 1849	phytophagous	Europe (Alps)	DK	G	N/A (mp: *Heracleum*)	Hansen (1996)
Pissodes (Pissodes) castaneus (De Geer 1775)*	phytophagous (phl)	Europe, Mediterranean, Asia	ES-CAN, PT-AZO	G	N/A (mp: *Pinus*)	Base de dados da biodiversidade dos Açores, Machado and Oromí (2000)
Scolytinae						
Chaetoptelius vestitus (Mulsant & Rey 1860)*	phytophagous (phl)	Mediterranean, Asia	ES-CAN	G1, I2	*Laurus* (pp: *Pistacia*, *Cotinus*, *Olea*, *Smilax*)	Schedl et al. (1959)
Crypturgus subcribrosus Eggers 1933	phytophagous (phl)	Europe (central, eastern)	GB	G3	*Picea* (op: *Pinus*, *Abies*, *Picea*)	Alexander (2002)
Dendroctonus micans (Kugelann 1794)	phytophagous (phl)	Europe, Asia	GB	G3	*Picea* (mp: *Picea*)	Alexander (2002), Hill et al. (2005)
Dryocoetes villosus (Fabricius 1792)*	phytophagous (phl)	Europe, West Mediterranean	ES-CAN, PT-MAD	G1	*Laurus* (pp: *Laurus*, *Alnus*)	Schedl (1963), Schedl et al. (1959)
Hylastes angustatus (Herbst 1793)	phytophagous (phl)	Europe (southern, central), Asia	GB	G3	*Pinus* (mp: *Pinus*)	Alexander (2002)
Hylastes ater (Paykull 1800)	phytophagous (phl)	Europe, Asia	GB, PT-AZO	G3, I2	*Pinus* (mp: *Pinus*)	Alexander (2002), Bright (1987)

Family / *subfamily* Species	**Feeding habits**	**Native range**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Hylastes attenuatus Erichson 1836	phytophagous (phl)	Europe, Mediterranean, Asia	GB, PT-AZO, PT-MAD	G3	*Pinus* (mp: *Pinus*)	Alexander (2002), Bright (1987), Mandelshtam et al. (2006)
Hylastes cunicularius Erichson 1836	phytophagous (phl)	Europe, Asia	GB	G3	*Picea* (mp: *Picea*)	Alexander (2002)
Hylastes linearis Erichson 1836*	phytophagous (phl)	Europe, West Mediterranean	ES-CAN, PT-MAD	G3	*Pinus* (mp: *Pinus*)	Schedl (1963), Schedl et al. (1959)
Hylastinus obscurus (Marsham 1802)*	phytophagous (phl, rbo)	Europe, West Mediterranean	ES-CAN, PT-MAD	F5, F7	*Cytisus*, *Laurus*, *Castanea* (op: *Trifolium*, Fabaceae);	Schedl (1963), Schedl et al. (1959)
Hylurgops palliatus (Gyllenhal 1813)	phytophagous (phl)	Europe, Mediterranean, Asia	GB	G3	N/A (op: Pinaceae)	Alexander (2002)
Hylurgus ligniperda (Fabricius 1787)*	phytophagous (phl)	Europe, Mediterranean, Asia	ES-CAN, PT-AZO, PT-MAD	G3	*Pinus* (mp: *Pinus*)	Bright (1987), Schedl (1963), Schedl et al. (1959)
Hypoborus ficus Erichson 1836*	phytophagous (phl)	Europe, West Mediterranean	ES-CAN, PT-AZO, PT-MAD	I2	*Echium*, *Ficus* (mp: *Ficus*)	Bright (1987), Schedl (1963), Schedl et al. (1959)
Ips cembrae (Heer 1836)	phytophagous (phl)	Europe (central)	DK, GB, NL	G3	*Larix* (op: *Larix*, *Pinus cembra*)	EPPO (2005), Hill et al. (2005), Stauffer et al. (2001)
Ips duplicatus (Sahlberg 1836)	phytophagous (phl)	Europe (northeastern, Russia)	AT, BE, SK	G3	*Picea abies* (mp: *Picea*)	Essl and Rabitsch (2002), OPIE (2002), Piel et al. (2006)
Orthotomicus erosus (Wollaston 1857)*	phytophagous (phl)	Europe, Mediterranean, Asia	PT-MAD	G3	*Pinus* (mp: *Pinus*)	Schedl (1963)
Phloeosinus armatus Reitter 1887	phytophagous (phl)	Mediterranean (eastern)	IT	FA, G5	*Cupressus* (op: Cupressaceae)	Covassi (1991)
Phloeosinus aubei (Perris 1855)[9]	phytophagous (phl)	Europe, West Mediterranean	ES-CAN, NL	G3	*Juniperus* (op: Cupressaceae)	Moraal (2006), Oromí and García (1995)

Family / *subfamily* Species	**Feeding habits**	**Native range**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Phloeosinus thujae (Perris 1855)	phytophagous (phl)	Europe, West Mediterranean	ES-CAN, GB	FA, G5	*Juniperus* (op: Cupressaceae)	Alexander (2002), Machado and Oromí (2000)
Phloeotribus caucasicus Reitter 1891	phytophagous (phl)	Europe (eastern), Asia	AT, CZ, FR	FA, G5	*Fraxinus* (mp: *Fraxinus*)	Bouget and Noblecourt (2005), Essl and Rabitsch (2002), Schott and Callot (1994)
Phloeotribus cristatus (Fauvel 1889)*	phytophagous (phl)	West Mediterranean	ES-CAN	F5, F7	N/A: Fabaceae? (op: Fabaceae)	Machado and Oromí (2000)
Phloeotribus rhododactylus (Marsham 1802)*	phytophagous (phl)	Europe, West Mediterranean	PT-MAD	F5, F7	*Cytisus* (op: Fabaceae)	Schedl (1963)
Phloeotribus scarabaeoides (Bernard 1788)*	phytophagous (phl)	Europe, West Mediterranean	ES-CAN	I2	N/A: Oleaceae? (op: Oleaceae)	Machado and Oromí (2000)
Pityophthorus traegardhi Spessivtseff 1921	phytophagous (phl)	Europe (northern), Asia	AT	G3	*Picea* (mp: *Picea*)	Holzschuh (1994)
Polygraphus poligraphus (Linnaeus 1758)	phytophagous (phl)	Europe (central, northern, eastern)	GB	G3	N/A (op: Pinaceae)	Alexander (2002)
Pteleobius kraatzii (Eichhoff 1864)*	phytophagous (phl)	Europe, West Mediterranean	ES-CAN	I2, G1, G5, FA	N/A: *Ulmus*? (mp: *Ulmus*)	Pfeffer (1995)
Scolytus amygdali Guérin-Méneville 1847*	phytophagous (phl)	Europe, Mediterranean, Asia	ES-CAN	I2	*Prunus* (op: Rosaceae trees)	Israelson (1969)
Scolytus laevis Chapuis 1869	phytophagous (phl)	Europe	GB	G1, G5, I2	*Ulmus* (mp: *Ulmus*)	Hill et al. (2005)
Scolytus pygmaeus (Fabricius 1787)	phytophagous (phl)	Europe	GB	G1, I2, FA, FB	*Ulmus* (mp: *Ulmus*)	Hill et al. (2005)
Scolytus rugulosus (Muller 1818)*	phytophagous (phl)	Europe, Mediterranean, Asia	PT-AZO	I2	N/A (op: Rosaceae trees)	Bright (1987)

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[9] This species was incorrectly reported from the Canary Islands (Oromí and García 1995) as *P. gillerforsi* Bright, an Azores endemic. Specimens so identified have been examined by Kirkendall, and they belong to the common Mediterranean species *P. aubei*.

Family / *subfamily* Species	**Feeding habits**	**Native range**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Tomicus destruens (Wollaston 1865)[10]	phytophagous (phl)	Europe, Asia	PT-MAD	G3, I2	*Pinus* (mp: *Pinus*)	Schedl (1963)
Xyleborinus saxesenii (Ratzeburg 1837)[11]	phytophagous (xmp)	Europe, Mediterranean, Asia	ES-CAN, PT-AZO, PT-MAD	I2	*Laurus*, *Pinus*, *Castanea* (pp: broadleaves, conifers)	Bright (1987), Schedl et al. (1959)
Dryophthoridae						
Sphenophorus meridionalis Gyllenhal 1838	phytophagous (rbo?)	West Mediterranean	ES-CAN	E6	N/A (N/A)	Machado and Oromí (2000)
Erirhinidae						
Procas armillatus (Fabricius 1801)*	phytophagous	Europe, Mediterranean	ES-CAN	N/A	N/A (N/A)	Machado and Oromí (2000)
Nanophyidae						
Dieckmanniellus nitidulus (Gyllenhal 1838)*	phytophagous (her)	Europe, Mediterranean	ES-CAN	N/A	N/A (mp: *Lythrum*)	Machado and Oromí (2000)
Nanodiscus transversus (Aube 1850)	phytophagous (spe)	West Mediterranean	ES-CAN	N/A	N/A (op: *Juniperus*, *Cupressus*)	Machado and Oromí (2000)
Nemonychidae						
Cimberis attelaboides (Fabricius 1787)	phytophagous (spe)	Europe, Mediterranean, Asia	GB	G3	*Pinus sylvestris* (mp: *Pinus sylvestris*)	Duff (2008)

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[10] Early records from Madeira refer to *T. piniperda*, but specimens collected by Kirkendall in 1999 are *T. destruens*; as the two species had been mixed up for a long time we think all records correspond to *T. destruens*

[11] This species has been improperly recorded in the Canary Islands as *Xyleborus xylographus*. *Xyleborus xylographus* (Say 1826), an oak specialist from the eastern United States, does not occur in any recent collections from the archipelago (or elsewhere in Europe), whereas *X. saxesenii* does (Kirkendall, unpublished data). The presence of *X. xylographus* on all Canary Islands species lists (Schedl et al. 1959, Oromi and Garcia 1995, Machado and Oromi 2000, Izquierdo et al. 2004), and the absence of *X. saxesenii*, seems to stem from an early mistaken treatment of *X. saxesenii* as a junior synonym of *X. xylographus* (Schedl 1970). To verify this, Kirkendall located one specimen recently determined as *X. Xylographus* (Oromi and Garcia 1995), and confirmed that it is *X. saxesenii*.

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Leaf and Seed Beetles (Coleoptera, Chrysomelidae) Chapter 8.3

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Abstract

The inventory of the leaf and seed beetles alien to Europe revealed a total of 25 species of which 14 seed beetles (bruchids) and 11 leaf beetles mostly belonging to the subfamilies Alticinae and Chrysomelinae. At present, aliens account for 9.4% of the total fauna of seed beetles in Europe whereas this percentage is less than 1% for leaf beetles. Whilst seed beetles dominated the introductions in Europe until 1950, there has been an exponential increase in the rate of arrival of leaf beetles since then. New leaf beetles arrived at an average rate of 0.6 species per year during the period 2000–2009. Most alien species originated from Asia but this pattern is mainly due to seed beetles of which a half are of Asian origin whereas leaf beetles predominantly originated from North America (36.4%). Unlike other insect groups, a large number of alien species have colonized most of Europe. All but one species have been introduced accidentally with either the trade of beans or as contaminants of vegetal crops or stowaway. Most aliens presently concentrate in man-made habitats but little affect natural habitats (<6%). Highly negative economic impacts have been recorded on stored pulses of legumes and crops but very little is known about possible ecological impact.

Keywords

Coleoptera, Chrysomelidae, Bruchidae, seed beetle, leaf beetle, bioinvasion, alien, Europe, translocation, introduction

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8.3.1 Introduction

The family Chrysomelidae is one of the largest Coleopteran families, including ca. 37 000 described species in the world and perhaps the same number as yet undescribed (Jolivet and Verma 2002). Bruchidae, or seed beetles, is a relatively small family. Kingsolver (2004), referring to the most recent world catalogue, mentions 1,346 valid bruchid species. Although there are good arguments to treat Bruchidae as a subfamily of Chrysomelidae and raise some leaf beetle subfamilies to family rank (Reid 1995), this is still not common practice among leaf beetle researchers. We treat Bruchidae and Chrysomelidae in this contribution as families, merely for practical reasons. According to *Fauna Europaea*, the fauna presently observed in Europe includes 1532 leaf beetles and 145 seed beetles.

Except for important agricultural pests such as the Colorado potato beetle, *Leptinotarsa decemlineata*, and more recently, the western corn rootworm, *Diabrotica virgifera virgifera*, little was known about introductions of alien leaf beetles until Beenen (2006) revealed that 126 species have been translocated at least once from one continent to another. More information on alien seed beetles has been available in the literature mainly because of their potential impact on stored products (Southgate 1979). In the present work, we will show that 25 non-native species of leaf and seed beetles of which one is of unknown origin (cryptogenic) have already established in Europe (Table 8.3.1). Thus, aliens still represent only a very small proportion (1.5%) of the total fauna of leaf and seed beetles in Europe. By comparison, approximately 71 alien leaf beetle species have been recorded from North America (Beenen 2006, Beenen, unpubl.).

Within Europe, changes in the distribution of native leaf beetles have also been noticed which can be partly associated either to human activity or to natural trends such as delayed post-glacial expansion and global warming. For example, the recent northwards expansion of a flea beetle, *Longitarsus dorsalis,* seems to result from both the introduction of a rapidly expanding invasive plant originating from South Africa, *Senecio inaequidens* DC., on which *L. dorsalis* thrives (Beenen 1992), and from increasing temperatures during the past years. However, the role of human activity is often difficult to ascertain in such observed range expansions of native species. We will essentially consider the species alien *to* Europe, a summary of the species alien *in* Europe (Table 8.3.2) and will present their characteristics at the end of the chapter.

8.3.2 Taxonomy

A total of 25 alien species of which 14 seed beetles and 11 leaf beetles have been recorded as established in Europe (Table 8.3.1). Thus, bruchids represent more than a half (56.0%) of the alien species whereas they account for only 8.1% of the native fauna of seed and leaf beetles (Figure 8.3.1). This arrival of alien seed beetles has

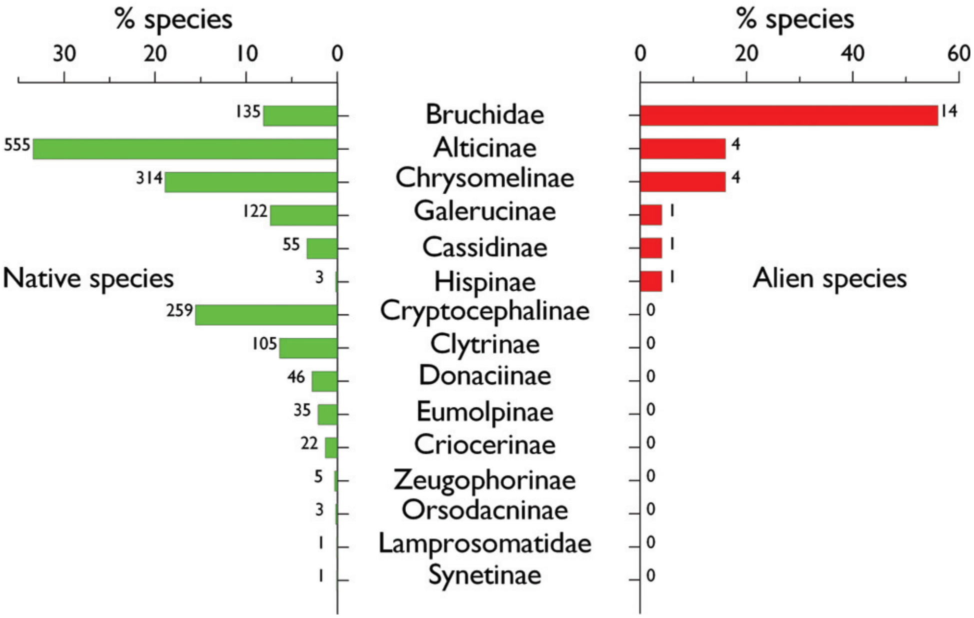

Figure 8.3.1. Comparison of the relative importance of the subfamilies of Chrysomelidae and Bruchidae in the alien and native entomofauna in Europe. Subfamilies are presented in a decreasing order based on the number of alien species. The number right to the bar indicates the number of species per family.

significantly modified the composition of the total fauna of seed beetles observed in Europe, where aliens account for 9.4% at present. The pattern is rather different for Chrysomelidae. Although this family includes 13 subfamilies in Europe the alien entomofauna is only distributed among five of these subfamilies. Large differences are observed in the contribution of each subfamily without any apparent correlation to its numerical importance in the native fauna. The recent arrival in France of an alien palm hispine beetle, *Pistosia dactylifera* (Drescher and Martinez 2005), largely modified the composition of the Hispinae subfamily which includes only three native species (Fauna Europaea 2009). However, aliens represent much less so for the two major subfamilies of leaf beetles, Alticinae flea beetles (four species- 0.7% of the total) and Chrysomelinae (four species- 1.3% of the total). Other alien species include one skeletonizing leaf beetle (Galerucinae) and one tortoise leaf beetle (Cassidinae). The same subfamily pattern is observed for translocations of leaf beetles at world level but Beenen (2006) also noticed other species belonging to Hispinae (e.g. *Brontispa* palm leaf beetles) and Criocerinae. It is noticeable that representatives from some important subfamilies such as Cryptocephalinae and Donaciinae have never been introduced, or never established at least.

Leaf beetles and seed beetles largely differ in biological traits that may be involved in the relative success of seed beetle invaders compared to other groups. Seed beetles have several ways of egg-laying. Most species deposit their eggs on mature pods of legumes (Fabaceae), the eggs being cemented to the pod or dropped in a self- made hole in the pod wall. Other species lay eggs on mature seeds that are still attached to the inside of a partly opened pod. A third group of species oviposit on mature seeds that have fallen to the ground from a fully dehisced pod. However, some species such as *Acantoscelides obtectus* use different life history strategies. Early in the season in this species, oviposition occurs on green pods of *Phaseolus*, while later in the season, the eggs are deposited on mature seeds that have fallen to the ground. These biological features make *A. obtectus* fully capable of completing cycle after cycle on naked seeds in storage (Kingsolver 2004). The larvae of seed beetles entirely develop within the seeds until pupation and their presence cannot be recognized before adult emergence, unless the seed is X-rayed.

In contrast, leaf beetles show a large variety of reproductive traits. Many Galerucinae (e.g., *Diabrotica* species) and Alticinae larvae (e.g., *Epitrix* species) develop in or at the roots of plants and adults feed from leaves of a specific host plant or a wide variety of plant species. Other Chrysomelidae feed both as larva and adult externally on leaves of their host plants. Although practically no plant species is free of leaf beetles, most leaf beetles need fresh plant products in all or at least in the adult stage. Stored dry plant products are not suitable for leaf beetles to complete their life cycle.

8.3.3 Temporal trends

Chrysomelids probably began to be introduced thousands of years ago. It is likely that leaf beetles associated with crops have taken the same route as herbs associated with cereals which are supposed to have entered Europe from the Near East (Pinhasi et al. 2005). Beenen (2006) argued that the combination of *Buglossoides arvensis* (L.) Johnston and *Longitarsus fuscoaeneus* Redtenbacher 1849 might have taken the route from southwest Asia where they spread with agriculture to large parts of the temperate parts of the Northern hemisphere. Thus, a number of species which are at present considered as native may indeed be originally alien. Bruchidae must have infested pulses grown by man since the dawn of agriculture. Southgate (1979) also mentioned infestations of lentils from the Egyptian Ptolemaic period (305 BC – 30 BC). Relatively little is known of these ancient introductions. More recent ones are much better documented as in the case of the potato Colorado beetle (*Leptinotarsa decemlineata*) (see factsheet 14.10).

From a global point of view, new records of alien species in Europe were relatively important during the 2nd half of the 19th century, due to seed beetle species. The most important being *Acanthoscelides obtectus*, *Callosobruchus chinensis* and *C. maculatus*. However, these species may have been introduced well before their first record. Since ca. 1900, the rate of seed and leaf beetle introductions severely decreased until 1975 when it began to increase again with globalization, essentially through the arrival of leaf beetles. The last seven years since 2000 corresponded to an acceleration of introductions, with an average of 0.8 new species of Chrysomelidae per year, again mostly leaf beetles (Figure 8.3.2)

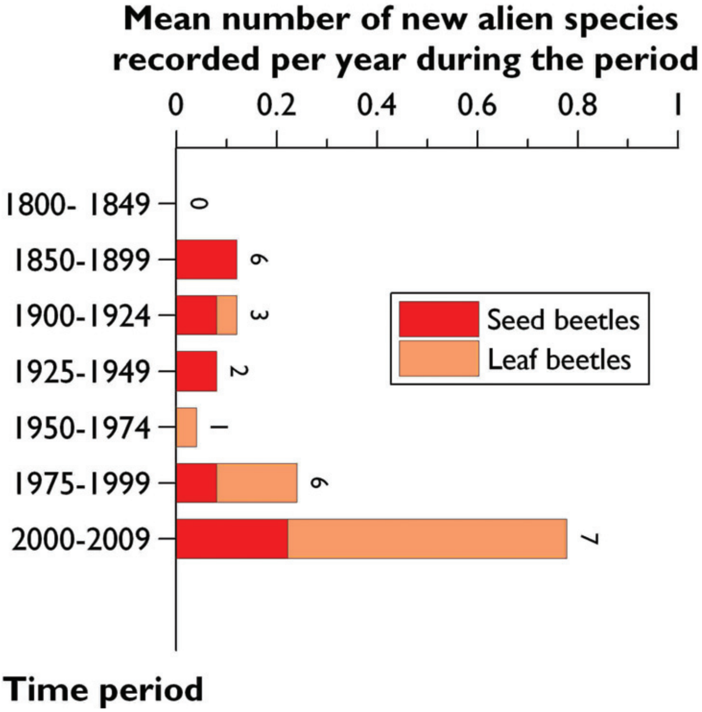

Figure 8.3.2. Temporal changes in the mean number of new records per year of seed and leaf beetle species alien *to* Europe from 1800 to 2009. The number right to the bar indicates the total number of seed and leaf beetle species recorded per time period.

8.3.4 Biogeographic patterns

Asia supplied the major proportion of the alien seed and leaf beetles that have established in Europe (Figure 8.3.3). However, this pattern is mainly due to seed beetles of which a half are of Asian origin whereas leaf beetles predominantly originated from North America (36.4%). No seed and leaf beetle species of Australasian origin have yet established in Europe.

Alien species are not evenly distributed in Europe, and leaf and seed beetles do not show the same pattern of expansion. Half of the alien seed beetles have colonized more than ten countries with four of them present in more than 50 countries and the main islands of Europe. In contrast, 63.6% of the alien leaf beetles have not yet spread out of the country where they have been initially introduced. Only two species, *Leptinotarsa decemlineata* and *Diabrotica virgifera*, are presently encountered in 38 and 20 countries respectively (EPPO 2009, Gödöllo University 2004, Grapputo et al. 2005, Purdue University 2008) (see maps in the spreadsheets 8 and 10). Owing to climate change, *L. decemlineata* may extend its range to Finland (Valosaari et al. 2008).

Alien seed and leaf beetles appear to be concentrated in southern Europe with 18 species observed in mainland Italy and more than 10 species in continental France

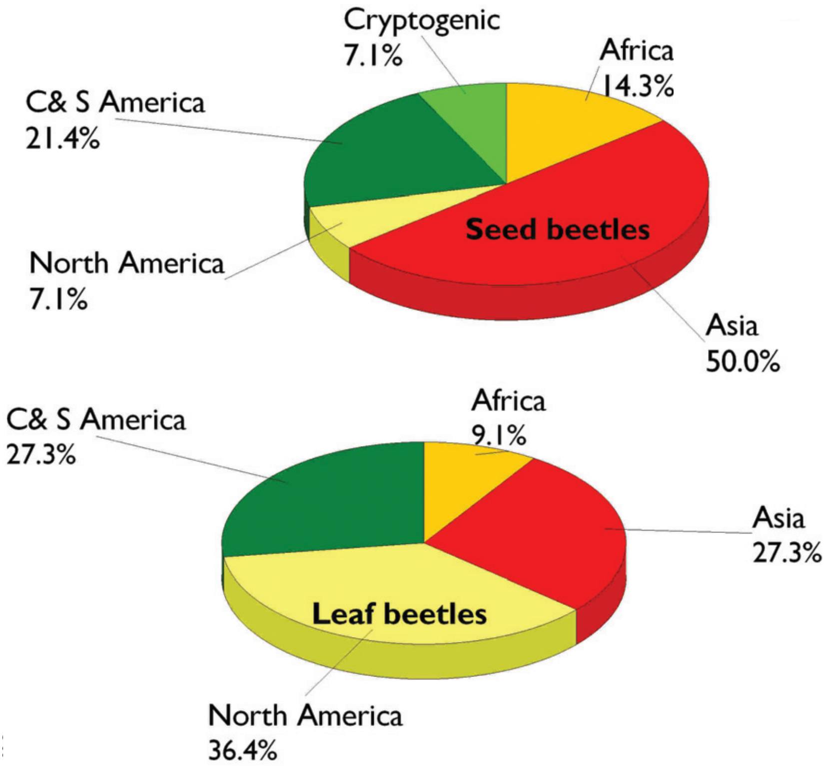

Figure 8.3.3. Comparative origin of seed and leaf beetle species alien *to* Europe

and mainland Greece. Central Europe usually hosts less than 10 species except Czech Republic (11 species), whereas aliens have been little recorded in Northern Europe (Figure 8.3.4).

8.3.5 Main pathways and vectors to Europe

All alien species of seed and leaf beetle except one (i.e., 95.7%) have been introduced accidentally to Europe. Unlike North America and South Africa, where a number of alien species were released for biological control of weeds (Beenen 2006), only the ragweed leaf beetle, *Zygogramma suturalis*, has been intentionally introduced from North America for the biological control of common ragweed, *Ambrosia artemisifolia* L., since 1978 in Russia (Reznik et al. 2004) and several countries of southeastern Europe, and subsequently established in the wild especially in the Caucasus (Kovalev 2004). A flea beetle native of Continental Europe, *Altica carduorum* (Guérin- Méneville), has also been introduced in Britain and Wales in 1969–1970 to control creeping thistles, *Cirsium arvense* (L.) Scop. but none apparently established (Baker et al. 1972, Cox 2007). Although it is difficult to ascertain the exact pathway of introduction for most of the

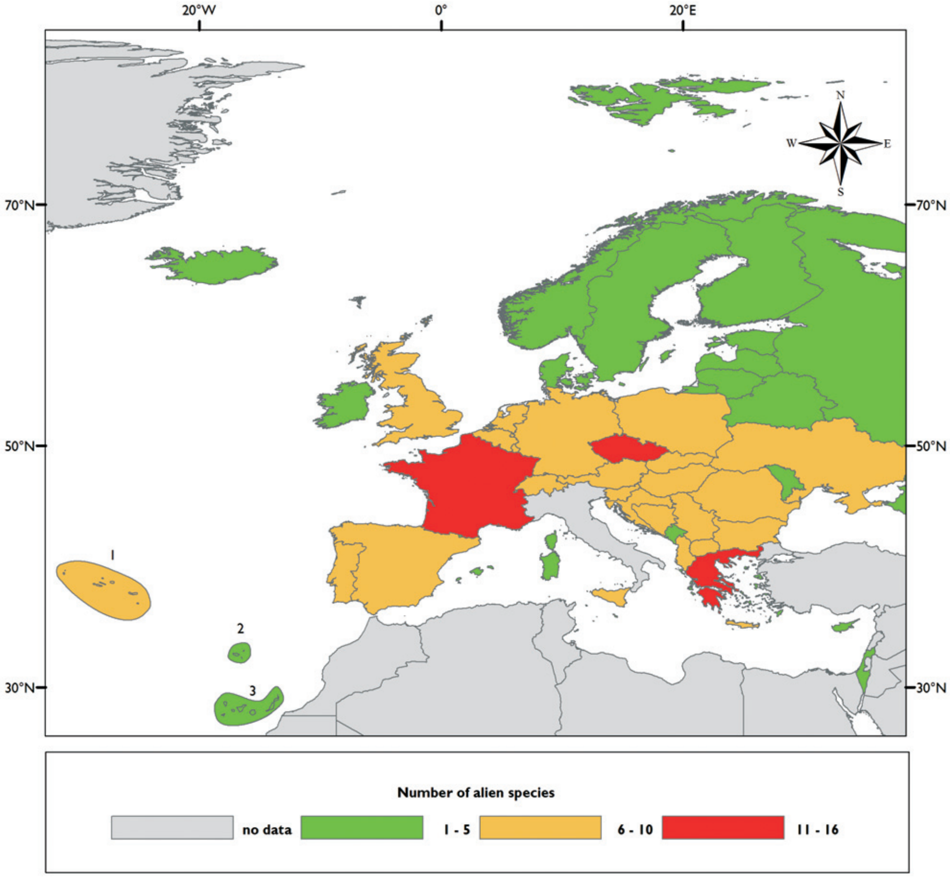

Figure 8.3.4. Colonization of continental European countries and main European islands by seed and leaf beetle species alien *to* Europe.

other species introduced accidentally, the general behaviour of chrysomelids suggests that most introductions are related to trade of plants and stored products, although some may have arrived as stowaways in all forms of packaging and transport, or even as wind-borne organisms.

The world trade of beans for agricultural purposes is probably responsible for the nowadays wide distribution in Europe of most alien species of seed beetles, such as *Acanthoscelides obtectus*, *Bruchus* species *Callosobruchus* species and *Zabrotes subfasciatus* (Figure 8.3.8) which develop in legume seeds of the subfamily Papilionoideae (*Phaseolus, Lathyrus, Pisum, Vicia)* (Böhme 2001, Kingsolver 2004). However, the arrival of other seed beetles of the genera *Bruchidius*, *Caryedon*, *Megabruchidius* and *Mimosestes* seems to be more related to the trade in legume tree seeds of Mimosoideae (*Albizzia, Acacia*) and Caesalpinoideae (*Cassia, Cercis, Tamarindus*) used as ornamentals in parks and gardens. *Megabruchidius tonkineus* was at first suspected to have been introduced from Vietnam to Germany with white beans (Wendt 1980) but it was later found to be associated with pods of honey locust trees, *Gleditsia triacanthos* L. (Papilionoideae), and not capable of complete development in beans (Guillemaud et al. 2010). Similarly, *Acanthoscelides pallidipennis* was probably introduced with seeds of false indigo bush (*Amorpha fructicosa* L., Papilionoideae) (Tuda et al. 2006) and *Bruchidius siliquastri* with these of redbuds (*Cercis*; Caesalpinoideae) from China (Kergoat et al. 2007). Seeds imported for ornamental purposes may also serve as the vector of seed beetles. *Specularius impressithorax* (Pic) sustained several generations indoors in the Netherlands after having been introduced from South Africa along with seeds of *Erythrina* (Papilionoideae) used for decoration, but did not eventually establish (Heetman and Beenen 2008) (Figure 8.3.7).

Most alien leaf beetles are associated with vegetable crops (Solanaceae, Brassicaceae, Gramineae including maize). With both larvae and adults feeding on foliage, these species probably entered Europe as plant contaminants (eggs, larvae) or crop contaminants (adults). The Colorado potato beetle has frequently been intercepted with potato plants and tubers, but also in all forms of packaging and transport. For example, it usually arrived to Great Britain with commercial freight among vegetable crops such as lettuce, *Lactuca sativa* L., or on ships, aircraft or private cars traveling from the continent (Cox 2007). Indeed, fresh vegetables grown on land harbouring overwintering beetles are common means of beetle transport in international trade (Bartlett 1980). The African tortoise beetle *Aspidimorpha fabricii* (= *A. cincta* Fabricius) was believed to be imported in Italy as a contaminant of bananas in the late 1950s but it became a problem in cultures of *Beta vulgaris* L. (Zangheri 1960). A hispine palm leaf beetle, *Pistosia dactyliferae* was also probably introduced as a contaminant of palms imported for ornamental purposes (Drescher and Martinez 2005).

The means of introduction appears different when larvae are root-feeding as in *Diabrotica* and *Epitrix* species. Unless soil infested with larvae has been imported with host plants, which is usually prohibited, these species probably travel as stowaways. The western corn rootworm, *Diabrotica virgifera virgifera*, proved to have been translocated from North America to Europe at least three times in aircraft laden with goods and materials, but probably not with maize plants (Ciosi et al. 2008, Miller et al. 2005). The outbreaks in Northwestern Italy and Central Europe probably resulted from introductions of individuals originating in northern USA (Delaware) (Guillemaud et al. 2010).

However, another pest species related to tobacco, *Epitrix hirtipennis*, is assumed to have arrived in Europe as aerial plankton with easterly trade winds blowing from the New World to Europe (Döberl 1994b). Similarly, Jolivet (2001) reported the translocation of the Sweet potato flea beetle, *Chaetocnema confinis* Crotch, from the USA to several tropical destinations by hurricanes. Adults of Colorado potato beetle are also assumed to be capable of migrating across the Channel although this beetle does not fly strongly (Cox 2007) or from Russia (the St Petersburg region) to Finland (Grapputo et al. 2005).

The collection and trade of orchids for greenhouses has also resulted in the arrival of several species which caused severe damage without persisting such as a flea beetle, *Acrocrypta purpurea* Baly, a species from Southeast Asia which was accidentally introduced with plant collections into a greenhouse of Leiden University in the Netherlands (Döberl 1994a). Likewise, larvae of a criocerine species, the yellow orchid beetle *Lema pectoralis* Baly, were imported to the Netherlands with an orchid collected in 1988 in Thailand (Beenen, unpubl.). Originating of the Peninsula Malaysia and Singapore (Mohamedsaid 2004), *L. pectoralis* is a major pest ('orchid lema') of orchid cultures, particularly *Vanda* and *Dendrobium*, in the Philippines (de la Cruz 2003).

Pathways within Europe are a source of particular concern because of the waiver of formerly routine phytosanitary inspections on goods transported within the European Union. Thus, alien species once introduced into one European country along with alien plants or seeds, can freely move to other European countries. Spread may combine long-distance, human-mediated dispersal and natural dispersal by adult flight, as it is the case for *Leptinotarsa decemlineata* (Grapputo et al. 2005). Another significant example is the present northwards expansion of a species alien in Europe, *Chrysolina americana*. This leaf beetle originates from the Mediterranean Basin where it is associated to *Rosmarinus* and *Lavendula.* Because both plants are popular garden plants throughout Europe, *C. americana* has been translocated outside its native range along with its host plants, e.g. to the Netherlands along with potted *Lavendula* plants imported from Italy (Beenen, unpubl.). Once introduced, this species, which has good flight capacities, disperses naturally by flight.

8.3.6 Most invaded ecosystems and habitats

All alien Chrysomelidae are phytophagous. As expected from the numerical importance of Bruchidae within aliens, seeds constitute the most important larval feeding niche (56.0%), far more important than leaves (24.0%) and roots (20.0%). Almost all these species are only present in man-made habitats which represent 94.1% of the colonized habitats, essentially agricultural lands, parks and gardens, glasshouses, and warehouses for seed beetles (Figure 8.3.5). Natural and semi-natural habitats have been very little colonized yet.

In addition to these strong habitat trends, about 40% of the alien chrysomelid species remain strictly related to their original, alien plants. This is especially true for leaf beetles, where only *Epitrix hirtipennis* out of the 11 alien species has been observed to shift onto native Solanaceae in Italy (Beenen 2006). In contrast, most alien seed beetles found outdoors have already switched to seeds of native plants, for example *Bruchidius siliquastri* on the native redbud, *Cercis siliquastrum,* in France (Kergoat et al. 2007), and *Acanthoscelides obtectus* and *Callosobruchus chinensis* on wild legumes (Tuda et al. 2001). Under outdoor conditions, a strict dependency to the original alien host was only observed for two *Megabruchidius* species, *M. tonkineus* and *M. dorsalis*, associated with seeds of honey locust tree, *Gleditsia triacanthos,* in parks and gardens. However, a number of seed beetle species still confined to greenhouses and warehouses only develop on alien hosts of tropical origin, such as *Caryedon serratus* associated with

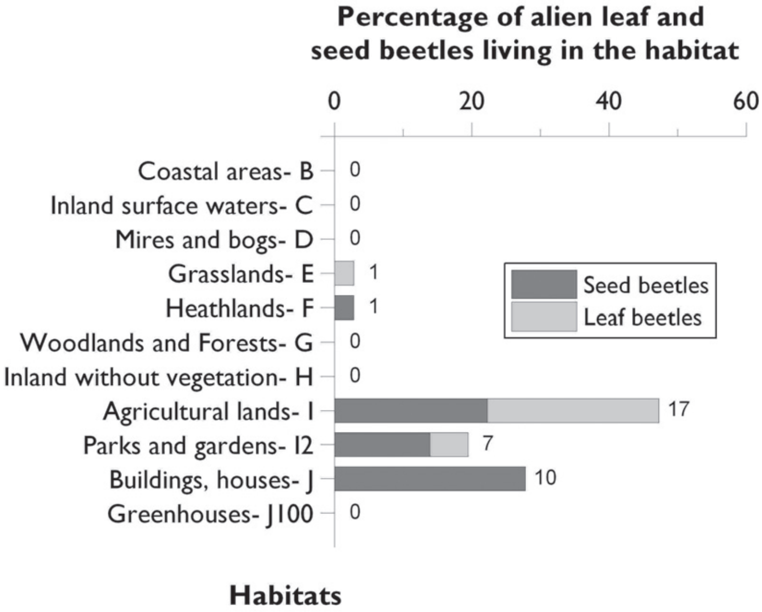

Figure 8.3 5. Main European habitats colonized by the established alien species of Chrysomelidae and Bruchidae. The number over each bar indicates the absolute number of alien species recorded per habitat. Note that a species may have colonized several habitats.

groundnuts (*Arachis hypogaea* L.), tamarind (*Tamarindus indica* L.) and other seeds of alien Caesalpinioideae (Kingsolver 2004). Such species still cannot establish outdoors because none of their alien hosts can survive in the wild at the present time.

8.3.7 Ecological and economic impact

Threats due to alien chrysomelid species were first pointed out by Linnaeus in a lecture in 1752, referring to his observation of asparagus plants (*Asparagus officinalis* L.) that were heavily infested in the vicinity of Hamburg by *Crioceris asparagi,* a species introduced from Russia at this time (Aurivillius 1909).

Alien chrysomelid species are better known for their economic impact than for their ecological impact. Indeed, possible ecological impacts on native flora and fauna are very little documented. Positive impact can be appreciated for only one alien species, *Zygogramma suturalis*, a strict monophagous species deliberately introduced to Europe for the control of the invasive ragweed (cf above).

Negative economic impacts have been recorded in seven of the alien seed beetle species which may severely affect stored pulses of economically-important legumes (*Acanthoscelides obtectus, A. pallidipennis, Bruchus pisorum, B. rufimanus, Callosobruchus chinensis, C. maculatus, C. phaseoli*, and *Zabrotes subfasciatus*; see (Borowiec 1987, Hoffmann et al. 1962)). Most of them are capable of re-infesting stored legumes until the food reserves are exhausted. In leaf beetles, large economic impacts have been shown for the Colorado potato beetle, *L. decemlineata*, affecting potato crops (see factsheet 14.10) and the western corn rootworm, *D. virgifera virgifera* affecting maize roots and foliage (see factsheet 14.8). However, It must be stressed that economic damage has only been seen on maize in Serbia, and in some bordering areas in Croatia, Hungary, Romania, and small areas in Bosnia-Herzegovina and Bulgaria (EPPO 2009). In the United Kingdom, yield losses to be expected from the arrival and spread of *D. virgifera virgifera* have been estimated to range from 0.9 to 4.1 million € over 20 years in absence of obligatory campaign to prevent spread of western corn rootworm but the costs of such a campaign could also range from 3.7 to 10.5 million € (Central Science Laboratory 2007). *Epitrix hirtipennis* may also impact tobacco crops (Sannino et al. 1984, Sannino et al. 1985) as well as *E. cucumeris* these of potato and tomato (Borges and Serrano 1989), and *Phaedon brassicae* the cabbage crops (Limonta and Colombo 2004). Alien foliage-feeding chrysomelids may also act as vectors for plant diseases, for example *D. virgifera* which transmits several cowpea virus strains in North America (Lammers 2006). However, little is yet known in this field (Jolivet and Verma 2002). Besides such economic damage, aesthetic impacts are recorded on ornamental plants, such as these of the leaf beetle *Pistosia dactylifera* on palm trees in southern France (Drescher and Martinez 2005).

8.3.8 Expected trends

Introduction of alien chrysomelids is still an ongoing process, especially through the trade of ornamentals via garden centers. For example, an alien species of the genus *Luperomorpha* was recently imported to Europe. *L. xanthodera*, originating from China, was first found in Great Britain feeding in flowers of several plant species in garden centers (Johnson and Booth 2004). Later it was observed in Switzerland (F. Köhler, personal communication), Germany (Döberl and Sprick 2009) and the Netherlands (Beenen et al. 2009), and also in garden centers, especially on rose flowers (Figure 8.3.6). Other alien specimens of *Luperomorpha* observed in Italy (Conti and Raspi 2007) and France (Doguet 2008) were first identified as *L. nigripennis*, from India and Nepal, but finally identified as *L. xanthodera* (Döberl and Sprick 2009). Plants cultivated in the Mediterranean area, then transported without severe pest control and sold in Central, Western and Northern Europe also constitute a serious threat for the expansion of species alien *in* Europe. The risks associated to this pathway were estimated for Norway (Staverløkk and Saethre 2007).

Species originating from subtropical and tropical regions have also been translocated such as *Aspidimorpha nigropunctata* (Klug) from tropical Africa to The Netherlands and *Macrima pallida* (Laboissière) from the Himalayan region to Cyprus. These introductions usually have not led to establishment (Beenen 2006). However, they do indicate a potential risk, especially in the context of global warming which may facilitate establishments of such species in the near future. The arrival in southern Europe of additional species associated with ornamental palms such as the hispine leaf beetle, *Brontispa longis-*

Figure 8.3.6. Adult of alien flea beetle, *Luperomorpha xanthodera* (Credit: Urs Rindlisbacher- Foto: www.insektenwelt.ch)

Figure 8.3.7. Adult of alien seed beetle, *Specularius impressithorax*; a- dorsal view; b- lateral view (credit: C. van Achterberg; photo taken using Olympus stereomicroscope SZX12 with AnalySIS Extended Focal Imaging software).

Figure 8.3.8. Adult of Mexican bean weevil, *Zabrotes subfasciatus*. a- dorsal view; b- lateral view (credit: C. van Achterberg; photo taken using Olympus stereomicroscope SZX12 with AnalySIS Extended Focal Imaging software)

sima (Gestro), already invasive in other parts of the world (Nakamura et al. 2006), is thus probable, considering the current increase in alien pests related to palms (see Chapter X).

Finally, it is difficult to make serious predictions about the results of future translocations because the species may react differently to the new habitats and hosts when compared with the situation in their native environment. Furthermore, translocations may enhance evolutionary changes partly because of founder effects and genetic bottlenecks and partly because of the triggering of evolution by new environmental factors (Whitney and Gabler 2008). *Zygogramma suturalis* when introduced to the Northern Caucasus for biological control of ragweed, showed rapid evolutionary changes in flight capacity (development of flight ability and morphological changes) within only five generations (Kovalev 2004).

References

Aurivillius C (1909) Carl von Linné als Entomolog. Verlag von Gustav Fischer.

Baca F (1994) [New member of the harmful entomofauna of Yugoslavia, *Diabrotica virgifera virgifera* LeConte (Coleoptera, Chrysomelidae)] (in serbo-croatian). *Zastita Bilja* 45: 125–131.

Baker CRB, Blackman RL, Claridge MF (1972) Studies on *Haltica carduorum* Geurin (Colepotera: Chrysomelidae) an alien beetle released in Britain as a contribution to the biological control of creeping thistle, *Cirsium arvense* (L.) Scop. *Journal of Applied Ecology* 9: 819–830.

Bartlett PW (1980) Interception and eradication of Colorado beetle in England and Wales, 1958–1977. *Bulletin OEPP/EPPO Bulletin* 10: 481–490.

Beenen R (1992) Een bijzondere voedselplant voor een bijzondere bladkever. *Natuurhistorisch Maandblad* 81: 220.

Beenen R (2006) Translocation in leaf beetles (Coleoptera: Chrysomelidae). *Bonner zoologische Beiträge* 54 [2005]: 179–199.

Beenen R, unpublished records.

Beenen R, Winkleman JK (2001) Aantekeningen over Chrysomelidae in Nederland 5. *Entomologische Berichten, Amsterdam* 61: 63–67.

Beenen RJ, Winkelman F van Nunen, Vorst O (2009) Aantekeningen over Chrysomelidae (Coleoptera) in Nederland 9. *Entomologische Berichten, Amsterdam* 69: 9–12.

Binaghi G (1947) Un nuovo tonchio introdotto dal Brasile. *Giornale di Agricoltura* 57: 4.

Biondi B, Daccordi M, Regalin R, Zampetti M (1994) Coleoptera Polyphaga XV (Chrysomelidae, Bruchidae). In: Minelli A, Ruffo S, La Posta (Eds) *Check list delle specie della fauna italiana 60*. Bologna: Calderini. 34 pp.

Böhme J (2001) Phytophage Käfer und ihre Wirtspflanzen in Mitteleuropa. Ein Kompendium. Heroldsberg: Bioform.

Borges PAV, Serrano ARM (1989) New records of the Coleopterous fauna (Insecta, Coleoptera) from the Azores. *Boletim do Museu Municipal do Funchal* 41: 5–24.

Borges PAV, Vieria V, Dinis F, Jarroca S (2005) *A list of terrestrial fauna (Mollusca and Arthropoda) and flora (Nryophyta, Pteridophyta and Spermatophyta) from the Azores*. Horta, Angra do Hero: Direcçao Regional do Ambiente and Unversidade dos Açores.

Borowiec, L. (1983) A survey of seed-beetles of Bulgaria (Coleoptera, Bruchidae). *Polsk. Pismo Entomol.* 53: 107–127.

Borowiec L (1987) The genera of seed-beetles (Coleoptera, Bruchidae). *Polskie Pismo Entomologiczne* 57: 3–207.

Borowiec L (1988) *Fauna Polski, Tom 11, Bruchidae*. Polska Akad. Nauk. Inst. Zool., Warszawa. 225 pp.

Bouchelos CT, Chalkia CA (2003) [First record in Greece of seed-eating insect of Gazia] (in Greek). *Georgia Ktinotrofia,* 3: 22–24.

Buckland PC, Skidmore P (1999). *Xanthogaleruca luteola* (Müller) (Chrysomelidae) in Britain. *The Coleopterist* 8: 97–99.

CABI/EPPO, 2003. *Leptinotarsa decemlineata, Distribution Maps of Plant Pests 139*. Wallingford, UK: CAB International.

Central Science Laboratory (2007) Cost Benefit Analysis for *Diabrotica virgifera virgifera.* http://www.defra.gov.uk/planth/phnews/diab07.pdf.

Ciosi M, Miller NJ, Kim KS, Giordano R, Estoup A, Guillemaud T (2008) Invasion of Europe by the western corn rootworm, *Diabrotica virgifera virgifera*: multiple transatlantic introductions with various reductions of genetic diversity. *Molecular Ecology* 17: 3614–3627.

Conti B, Raspi A (2007) Prima segnalazione in Italia di *Luperomorpha nigripennis* Duvivier (Coleoptera Chrysomelidae). *Informatore Fitopatologico* 57: 51–52.

Cox ML (1995) *Psylliodes cucullata* (Illiger, 1807) (Coleoptera: Chrysomelidae: Alticinae) - a species new to Britain. *Entomologist's Gazette* 46*:* 271–276.

Cox ML (2007) *Atlas of the seed and leaf-beetles of Britain and Ireland*. Oxford: Information Press. 336 pp.

Cruz RT de la (2003) Understanding 'Orchid lema'. BAR digest 5, no 3. Available at [www.bar.gov.ph/bardigest/2003/julsep03_orchidlema.asp]. Retrieved August 4 2008.

Del Bene G, Conti B (2009). Notes on the biology and ethology of *Luperomorpha xanthodera*, a flea beetle recently introduced into Europe. *Bulletin of Insectology 62: 61–68***.**

Delobel A, Delobel B (2003) Les plantes hôtes des bruches (Coleoptera Bruchidae) de la faune de France, une analyse critique. *Bulletin de la Société linnéenne de Lyon* 72: 199–221

Döberl M (1994a) Bemerkenswerte Alticinenfunde aus Westeuropa (Col., Chrysomelidae). *Entomologische Nachrichten und Berichte* 38: 179–182.

Döberl M (1994b) Auffällige Ausbreitung einiger Alticinen-Arten in Westeuropa (Coleoptera, Chrysomelidae, Alticinae). *Verhandlungen des 14. Internationalen Symposiums für Entomofaunistiek in Mitteleuropa, München, SIEEC*: 276–280.

Döberl M (2000) Beitrag zur Kenntnis der Gattung *Epitrix* Foudras, 1860 in der Paläarktis. Mitt. Internat. *Mitteilungen des internationalen Entomologischen Vereins Frankfurt* 25: 1–23.

Döberl M, Sprick P (2009). *Luperomorpha* Weise, 1887 in Western Europe (Coleoptera: Chrysomelidae: Alticinae). *Entomologische Blätter* 105: 51–56.

Doguet S (2008) Présence en France de *Luperomorpha nigripennis* Duvivier, 1892. (Col. Chrysomelidae, Alticinae). *Le Coléoptériste* 11: 62–63.

Doguet S (2009) Présence en Europe de deux espèces nord-américaines d'*Epitrix* (Coleoptera Chrysomelidae Alticinae). *L'Entomologiste* 65 : 89–90.

Drescher J, Martinez M (2005) Le coléoptère *Pistosia dactyliferae* menace les palmiers du sud de la France. *PHM - Revue Horticole* 468: 34–35.

EPPO, 2006. *Leptinotarsa decemlineata*. In: *PQR database (version 4.5)*. Paris, France: European and Mediterranean Plant Protection Organization. www.eppo.org.

EPPO (2009). Present situation of Diabrotica virgifera in Europe. 2008. http://www.eppo.org/QUARANTINE/Diabrotica_virgifera/diabrotica_virgifera.htm#map-dia. [accessed March 1, 2010].

Essl F, Rabitsch W (Eds) (2002) Neobiota in Österreich. Wien: Umweltbundesamt. 432 pp.

Fauna Europaea. http://www.faunaeur.org/.

Gobierno de Canarias (2010). Especies introducidas en Canarias. http://www.interreg-bionatura.com/especies/index.php?opt=verDatos#. [accessed March 1, 2010].

Gödöllo University. Spread of Western Corn Rootworm in Europe. Maps 2000–2004. http://w3.mkk.szie.hu/dep/nvtt/wcrnet/wcrnet-2.htm.

Grapputo A, Boman S, Lindström L, Lyytinen A, Mappes J (2005) The voyage of an invasive species across continents: genetic diversity of North American and European Colorado potato beetle populations. *Molecular Ecology* 14: 4207–4219.

Gruev B (1981) A new species of *Epitrix* Foudras from the Azores (Insecta, Coleoptera, Chrysomelidae). *Boletim da Sociedade Portuguesa de Entomologia* 10: 1–2.

Gruev B, Döberl M (2005) *General distribution of the flea beetles in the Palaearctic subregion (Coleoptera, Chrysomelidae: Alticinae*. Sofia and Moscow: Pensoft, Supplement Series Faunistica No 42. 239 pp.

Gu J, Mao YQ, Wang LP, Xu JJ, Zhang Y, Du YZ (2009) [Genetic differentiation among different geographic populations of the cowpea weevil, *Callosobruchus maculatus* (Coleoptera: Bruchidae)] (in Chinese, English abtsract). *Acta Entomologica Sinica* 52: 1349–1355.

Guillemaud T, Beaumont MA, Ciosi M, Cornuet JM, Estoup A (2010) Inferring introduction routes of invasive species using approximate Bayesian computation on microsatellite data. *Heredity* 104: 88–99.

György Z (2007) To the biology of the honey locust seed beetle, *Megabruchidius tonkineus* (Pic, 1904) (Coleoptera: Chrysomelidae: Bruchinae). *Folia Entomologica Hungarica* 68 : 89–96.

Hansen M (1996) [Katalog over Danmarks biller] Catalogue of the Coleoptera of Denmark. *Entomologiske Meddelelser* 64: 1–231.

Hansen V. (1964) [Fortegelse over Danmarks biller] Catalogue of the Coleoptera of Denmark. *Entomologiske Meddelelser* 33: 1–507.

Heetman AJA, Beenen R (2008) Twee exotische zaadkevers ingevoerd met bonen (Coleoptera, Bruchidae). *Entomologische Berichten*, 68: 187–188.

Hill M, Baker R, Broad G, Chandler PJ, Copp GH, Ellis J, Jones D, Hoyland C, Laing I, Longshaw Moore N, Parrott D, Pearman D, Preston C, Smith RM, Waters R (2005) *Audit of non-native species in England*. Peterborough, UK: Report to English Nature N°662.

Hodge PJ (1997) *Bruchidius varius* (Olivier) (Chrysomelidae) new to the British. Isles. *The Coleopterist* 5: 65–68.

Hoffmann A (1945) *Coléoptères Bruchidae et Anthribidae*. Faune de France 44. Paris: Lechevallier. 184 pp.

Hoffmann J, Labeyrie V Balachowsky AS (1962) Les Bruchidae. In: Balachowsky AS (Ed) *Entomologie appliquée à l'agriculture*, Tome 1, Volume 2. Paris : Masson, 434–494.

Hurst GW (1970) Can the Colorado potato beetle fly from France to England ? Entomologist's Monthly Magazine 105: 269–272.

Igrc J, Deloach CJ, Zlof V (1995) Release and Establishment of *Zygogramma suturalis* F (Coleoptera: Chrysomelidae) in Croatia for Control of Common Ragweed (*Ambrosia artemisiifoli*a L.). *Biological Control* 5: 203–208.

Izquierdo I, Martín JL, Zurita N, Arechavaleta M (2004) Lista de especies silvestres de Canarias (hongos, plantas y animales terrestres). Consejería de Medio Ambiente y Ordenación Territorial, Gobierno de Canarias; Santa Cruz de Tenerife.

Jermy T, Szentesi Á, Anton KW (2002) *Megabruchidius tonkineus* (Pic, 1904) (Coleoptera: Bruchidae) first found in Hungary. *Folia entomologica hungarica* 63: 49–51.

Johnson C (1963) *Chrysolina americana* (L.) (Col. Chrysomelidae) in Britain. *Entomologist's Monthly Magazine* 99: 228–229.

Johnson C, Booth RG (2004) *Luperomorpha xanthodera* (Fairmaire): a new British flea beetle (Chrysomelidae) on garden centre roses. *The Coleopterist* 13: 81–86.

Jolivet P (2001) Vers la mondialisation des Chrysomelides? *L 'Entomologiste* 57: 123–141.

Jolivet P, Verma KK (2002) Biology of Leaf Beetles. Andover, Hampshire, UK: Intercept Publishers. 332 pp.

Kergoat GJ, Delobel P, Delobel A (2007) Phylogenetic relationships of a new species of seed-beetle infesting *Cercis siliquastrum* L. in China and in Europe (Coleoptera: Chrysomelidae: Bruchinae: Bruchini). *Annales de la Société Entomologique de France* 43: 265–271.

Kingsolver JM (2004) *Handbook of the Bruchidae of the United States and Canada (Insecta, Coleoptera)*. United States Department of Agriculture: Technical Bulletin 1912. 324 pp.

Kovalev OV (2004) The solitary population wave, a physical phenomenon accompanying the introduction of a chrysomelid. In: Jolivet P, Santiago-Blay JA, Schmitt M (Eds) *New developments in the biology of Chrysomelidae*. Amsterdam: SPB Academic Publishing, 591–601.

Lammers W (2006) *Report of a Pest Risk Analysis*. Netherlands Plant Protection Service.

Lays P (1988) *Chrysolina americana* (Linné) Belg. nov. sp. (Coleoptera, Chrysomelidae, Chrysomelinae), une espèce mediterranéenne en Belgique. *Bulletin et Annales de la Société Royale. Belge d'Entomologie* 124: 29–33.

Limonta L, Colombo M (2004) Record in Italy of *Phaedon brassicae* Baly (Coleoptera Chrysomelidae Chrysomelinae). *Bollettino di Zoologia Agraria e di Bachicoltura* Serie II 36(3), 369–371.

Michieli G (1957) Ricerche sulla biologia della *Phytodecta fornicata* Bruggem. (Col. Chrysomelidae) e del suo parassita *Meigenia floralis* Fall. (Diptera Larvevoridae). *Bollettino del Museo Civico di Storia Naturale di Venezia* 10: 49–86.

Migliaccio E, Zampetti MF (1989) *Megabruchidius dorsalis* e *Acanthoscelides pallidipennis*, specie nuove per la fauna italiana (Coleoptera, Bruchidae). *Bollettino Associazione Romana di Entomologia* 43: 63–69.

Miller N, Estoup A, Toepfer S, Bourguet D, Lapchin L, Derridj S, Kim KS, Reynaud P, Furlan L, Guillemaud T (2005) Multiple transatlantic introductions of the western corn rootworm. *Science* 310: 992.

Mohamedsaid MS (2004) Catalogue of the Malaysian Chrysomelidae (Insecta: Coleoptera). Sofia & Moscow: Pensoft. 239 pp.

Nakamura S, Konishi K, Takasu K (2006) Invasion of the coconut beetle, *Brontispa longissima*: Current situation and control measures in Southeast Asia. In: *Food and Fertilizer Technology Center (FFTC) meeting 'Development of Database (APASD) for Biological Invasion'*, Taichung, Taiwan September 2006, ROC. www.agnet.org/activities/sw/2006/589543823/paper-899851121.pdf .

Oliviera R, Chatot C, Dedryver CA (2008) Détectée en Europe, une nouvelle altise. *Potato Planet*: 30–34.

Pinhasi R, Fort J, Ammerman AJ (2005) Tracing the origin and spread of agriculture in Europe. *PLoS Biology* 3: e410.

Purdue University. Map of expansion of Western Corn Rootworm in Europe in 2008. http://extension.entm.purdue.edu/wcr/images/jpg/2008/EUROPE08.jpg.

Ramos YR, Fernández-Carrillo JL, Fernández-Carrillo E (2007) Sobre la presencia del gorgojo de las acacias, *Pseudopachymerina spinipes* (Erichson, 1833) en la Península Ibérica (Coleoptera: Bruchidae). *Boletín la Sociedad Entomologica Aragonese* 40: 511–522.

Reid CAM (1995) A cladistic analysis of subfamilial relationships in the Chrysomelidae sensu lato (Chrysomeloidea). In: Pakaluk J, Slipinski SA (Eds) *Biology, phylogeny, and classification of Coleoptera*. Papers celebrating the 80th birthday of Roy A. Crowson. Warszawa: Muzeum i Ynstitut Zoologii PAN, 559–631.

Reznik SYa, Volkovitsh MG, Dolgovskaya MYu, Cristofaro M (2004) Introduction of the ragweed leaf beetle *Zygogramma suturalis* (Coleoptera, Chrysomelidae) into Russia for biological control of common ragweed *Ambrosia artemisiifolia* (Asteraceae) as a model of biological invasion. In: *Abstract Proceedings of Neobiota, 3rd International Conference on Biological Invasions,* Bern, Switzerland, September - October 2004, 111.

Sainte-Claire Deville J (1938) Catalogue raisonné des Coléoptères de France. *L'Abeille* 36: 373–467.

Sannino L, Balbiani A, Espinosa B (1984) Un nuovo fitofago devasta il tabacco nel beneventano: *Epithrix hirtipennis* Melsch. *Informatore Agrario* 29: 55–57.

Sannino L, Balbiani A, Biondi M (1985) *Epitrix hirtipennis* (Melsheimer, 1847) (Coleoptera, Chrysomelidae): Considerazioni tassonomiche, ecologich ed etologiche. Atti XIV Congresso nazionale Italiano Entomologia, Palermo: 285–292.

Simmonds MSJ, Blaney WM, Birch ANE (1989) Legume Seeds: the Defences of Wild and Cultivated Species of *Phaseolus* Against Attack by Bruchid Beetles. *Annals of Botany* 63: 177–184.

Southgate BJ (1979) Biology of the Bruchidae. *Annual Review of Entomology* 24: 449–473.

Staverløkk A, Saethre MG (2007) Stowaways in imported horticultural plants: alien and invasive species – assesing their bioclimatic potential in Norway. *Bioforsk Report* 2, N°66. 70 pp.

Stephens JF (1839) A Manual of British Coleoptera or Beetles. London: Longman, Orme Brown, Green & Longmans. 443 pp.

Strejček J (1990) *Brouci celedí Bruchidae, Urodontidae a Anthribidae*. Praha : Academia. 88 pp.

Strejček J (1993) Faunistic records from the Czech Republic 9. *Klapalekiana* 29: 169–171

Szentesi, A. (1999) Predispersal seed predation of the introduced false indigo, *Amorpha fruticosa* L. in Hungary. *Acta Zool. Acad. Sci. Hung*. 45: 125–141.

Tomov R, Trencheva K, Trenchev G, Kenis M (2007) A review of the non-indigenous insects of Bulgaria. *Plant Science* 44: 199–204.

Tuda M, Shima K, Johnson CD, Morimoto K (2001) Establishment of *Acanthoscelides pallidipennis* (Coleoptera: Bruchidae) feeding in seeds of the introduced legume *Amorpha fruticosa*, with a new record of its *Eupelmus* parasitoid in Japan. *Applied Entomology and Zoology* 36: 269–276.

Tuda M, Rönn J, Buranapanichpan S, Wasano N, Arnqvist G (2006) Evolutionary diversification of the bean beetle genus *Callosobruchus* (Coleoptera: Bruchidae): traits associated with stored-product pest status. *Molecular Ecology* 15: 3541–3551.

Valosaari KR, Aikio S, Kaitala V (2008) Spatial simulation model to predict the Colorado potato beetle invasion under different management strategies. *Annales Zoologici Fennici* 45: 1–14.

Wendt H (1980) Erstmaliges Auftreten des Vorratsschädlings, *Bruchidius tonkineus* (Pic, 1904) in der DDR. *Deutsche Entomologische Zeitschrift* 27: 317–318.

Wendt, H. (1981) Eine für Sudost-Europa neue Samenkäfer-Art (Coleoptera: Bruchidae). *Folia Entomologica Hungarica* 42: 223–226.

Whitney KD, Gabler CA (2008) Rapid evolution in introduced species, 'invasive traits' and recipient communities: challenges for predicting invasive potential. *Diverstity and Distributions* 14: 569–580.

Zangheri S (1960) L'*Aspidimorpha cincta* F. (Coleoptera Chrysomelidae, Cassidinae) in Italia. *Bollettino di Zoologia agraria e di Bachicoltura Ser. II* 3: 219–220.

Table 8.3.1. List and characteristics of the established Chrysomelidae species alien to Europe. Status: **A** Alien to Europe **C** cryptogenic species. Country codes abbreviations refer to ISO 3166 (see appendix I). Habitat abbreviations refer to EUNIS (see appendix II). Last update 1 February 2010.

Family or subfamily *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat***	**Hosts**	**References**
Alticinae- flea beetles								
Epitrix cucumeris (Harris, 1851)	A	Phyto-phagous	Central and South America	1987, PT-AZO	PT-AZO	I1	*Nicotiana* and other Solanaceae	Borges and Serrano (1989)
Epitrix hirtipennis (Melsheimer, 1847)	A	Phyto-phagous	Southern USA, Central and South America.	1984, IT	BG, GR, IT, MK, PT-AZO	I1	*Nicotiana* and other Solanaceae	Döberl (1994b), Döberl (2000), Sannino et al. (1984), Sannino et al. (1985)
Epitrix similaris Gentner, 1944	A	Phyto-phagous	USA	2008, PT	PT	I1	*Solanum tuberosum*	Doguet (2009), Oliviera et al. (2008)
Luperomorpha xanthodera (Fairmaire, 1888)	A	Phyto-phagous	China, Korea	2003, GB	CH, DE, FR, GB, IT, NL	I2	*Iris* and *Euonymus* roots (larva); adult polyphagous	Beenen, unpubl., Conti and Raspi (2007), Del Bene and Conti (2009), Delobel and Delobel (2003), Doguet (2008), Johnson and Booth (2004)
Bruchidae – seed beetles								
Acanthoscelides obtectus Say, 1831	A	Phyto-phagous	C & S America	1889, IT	AL, AD, AT, BA, BE, BG, BY, CH, CY, CZ, DE, DK, EE, ES, ES-BAL, ES-CAN, FR, FR-COR, GB, GR, GR-CRE, GR-NEG, GR-SEG, HR, HU, IE, IL, IS, IT, IT-SAR, IT-SIC, LI, LT, LU, LV, MD, MK, MT, NL, NO, NO-SVL, PT, PT-AZO, PT-MAD, RO, RS, RU, SE, SI, SK, UA	J1, I	*Phaseolus* seeds, wild and cultivated legumes outdoors	Borges et al. (2005), Delobel and Delobel (2003), Hoffmann et al. (1962), Tomov et al. (2007)

Family or subfamily *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat***	**Hosts**	**References**
Acanthoscelides pallidipennis (Motschulsky, 1874)	A	Phyto-phagous	North America	1980, BG	AT, BA, BG, CH, CZ, DE, HR, HU, IT, LU, MK,PL, RO, RS	I, J	*Amorpha fruticosa* (indigobush) and other legumes	Borowiec (1983), Borowiec (1988), Migliaccio and Zampetti (1989), Szentesi (1999), Wendt (1981)
Bruchidius siliquastri Delobel 2007	C	Phyto-phagous	Crypto-genic	2003, FR	FR	I2	*Cercis* seeds	Kergoat et al. (2007)
Bruchus pisorum (Linnaeus, 1758)	A	Phyto-phagous	Asia-Temperate	1850, CZ	AD, AL, AT, BA, BE, BG, BY, CH, CY, CZ, DE, DK, EE, ES, ES-BAL, ES-CAN, FI, FR, FR-COR, GB, GR, GR-CRE, GR-NEG, GR-SEG, HR, HU, IE, IS, IT, IT-SAR, IT-SIC, LI, LT, LU, LV, MD, MK, MO, MT, NL, NO, NO-SVL, PL, PT, PT-AZO, PT-MAD, PT, RO, RS, RU, SE, SI, SK, UA	I, J1	Dried peas; *Lathyrus, Pisum, Vicia*	Delobel and Delobel (2003), Fauna Europaea (2009), Gobierno de Canarias (2010), Hoffmann (1945), Sainte-Claire Deville (1938)
Bruchus rufimanus Bohemann, 1833	A	Phyto-phagous	Africa	1894, PT	AD, AL, AT, BA, BE, BG, BY, CH, CY, CZ, DE, DK, EE, ES, ES-BAL, ES-CAN, FI, FR, FR-COR, GB, GR, GR-CRE, GR-NEG, GR-SEG, HR, HU, IE, IS, IT, IT-SAR, IT-SIC, LI, LT, LU, LV, MD, MK, MT, NL, NO, NO-SVL, PL, PT, PT-AZO, PT-MAD, RO, RS, RU, SE, SI, SK, UA	I, J1	Stored beans; *Phaseolus, Vicia, Lathyrus, Lupinus, Pisum, Lens, Cicer* (wild and cultivated)	Delobel and Delobel (2003), Fauna Europaea (2009), Gobierno de Canarias (2010), Hoffmann (1945), Sainte-Claire Deville (1938)

Family or subfamily *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat***	**Hosts**	**References**
Callosobruchus chinensis (Linnaeus, 1758)	A	Phytophagous	Asia-Temperate	1878, FR	AD, AL, AT, BA, BE, BG, BY, CH, CY, CZ, DE, DK, EE, ES, ES-BAL, ES-CAN, FI, FR, FR-COR, GB, GR, GR-CRE, GR-NEG, GR-SEG, HR, HU, IE, IL, IS, IT, IT-SAR, IT-SIC, LI, LT, LU, LV, MD, MK, MT, NL, NO, NO-SVL, PT, PT-AZO, PT-MAD, RO, RS, RU, SE, SI, SK, UA	I, J1	Stored legumes (capable of re-infesting)	Biondi et al. (1994), Essl and Rabitsch (Eds) (2002), Fauna Europaea (2009), Gobierno de Canarias (2010), Hoffmann (1945), Sainte-Claire Deville (1938), Tomov et al. (2007)
Callosobruchus maculatus (Fabricius, 1775)	A	Phytophagous	Africa	1878, FR	AL, BG, CZ, ES, FR, GR, GR-CRE, IL, IT, IT-SIC, IT, PT, PT-AZO	I, J1	*Phaseolus* and other stored legumes (capable of re-infesting)	Binaghi (1947), Delobel and Delobel (2003), Fauna Europaea (2009), Gu et al. (2009), Hoffmann (1945), Tomov et al. (2007)
Callosobruchus phaseoli (Gyllenhal, 1833)	A	Phytophagous	Asia-Temperate	1945, FR	AL, CZ, ES, FR, GR, GR-CRE, IL, IT, IT-SIC	I, J1	*Phaseolus, Lupinus* and other stored legumes (capable of re-infesting)	Delobel and Delobel (2003), Hoffmann (1945), Tomov et al. (2007)
Caryedon serratus (Olivier, 1790)	A	Phytophagous	Africa	1900, CZ	CY, CZ, DE, GR, GR-CRE	I1, I2, F, J1	*Acacia, Cassia, Prosopis* seeds	Delobel and Delobel (2003)
Megabruchidius dorsalis (Fahreus, 1839)	A	Phytophagous	Asia (Japan)	1989, IT	IT	I2	*Gleditsia* seeds	Migliaccio and Zampetti (1989)
Megabruchidius tonkineus György 2007	A	Phytophagous	Asia-tropical (Vietnam)	2001, HU	HU	I2	*Gleditsia* seeds	György (2007), Jermy et al. (2002)

Family or subfamily *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat***	**Hosts**	**References**
Mimosestes mimose (Fabricius, 1781)	A	Phytophagous	Asia-Temperate	1945, FR	DE, DK, FR, IT	J1	*Acacia, Phaseolus, Vicia, Ciser* (chickpea) seeds	Hansen (1996), Hoffmann (1945)
Pseudopachymerina spinipes (Erichson, 1833)	A	Phytophagous	C & S America	1919, ES	ES, FR, GR, GR-CRE, IT, IT-SIC	I2	*Acacia farnesiana* seeds	Bouchelos and Chalkia (2003), Fauna Europaea (2009), Ramos et al. (2007)
Zabrotes subfasciatus (Bohemann, 1833)	A	Phytophagous	C & S America	1858, FR	AL, CZ, ES, ES-CAN, FR, GR, GR-CRE, IT, IT-SIC, NL, PT, PT-AZO	J1	*Phaseolus* and other stored legumes (capable of re-infesting)	Delobel and Delobel (2003), Hoffmann (1945)
Cassidinae – Tortoise leaf beetles								
Aspidomorpha fabricii Sekerka, 2008	A	Phytophagous	Africa	1957, IT	IT	I1	*Beta vulgaris*	Zangheri (1960)
Chrysomelinae – leaf beetles								
Leptinotarsa decemlineata (Say, 1824)	A	Phytophagous	North and Central America	1922, FR	AD, AL, AT, BA, BE, BG, BY, CH, CZ, DE, EE, ES, ES-BAL, FR, FR-COR, GR, HR, HU?, IT, IT-SAR, IT-SIC, LI, LT, LU, LV, MD, MK, MO, NL, PL, PT, RO, RS, RU, SE, SI, SK, UA	I1	*Solanum tuberosum* and other Solanaceae	CABI/EPPO (2003), EPPO (2006), Fauna Europaea, Grapputo et al. (2005), Tomov et al. (2007)
Phaedon brassicae Baly, 1874	A	Phytophagous	China, Japan, Taiwan, Vietnam.	2000, IT	IT	I1	Brassicaceae	Limonta and Colombo (2004)
Calligrapha polyspila (Germar, 1821)	C	Phytophagous	North America	> 2001, PT-AZO	PT-AZO		*Sida rhombifolia*	Jolivet (2001)

Family or subfamily *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat***	**Hosts**	**References**
Zygogramma suturalis (Fabricius, 1775)	A	Phytophagous	North America	1985, HR	HR		*Ambrosia artemisiifolia*	Igrc et al. (1995)
Galerucinae – Skeletonizing leaf beetles								
Diabrotica virgifera virgifera LeConte, 1868	A	Phytophagous	Central America	1992, RS	AT, BA, BE, BG, CH, CZ, DE, FR, GB, HR, HU, IT, MO, NL, PL, RO, RS, SI, SK, UA.	I1	*Zea mays.*	Baca (1994), Ciosi et al. (2007), EPPO (2009), Gödöllo University (2009), Guillemaud et al. (2010), Purdue University (2009)
Hispinae – Hispine leaf beetles								
Pistosia dactyliferae (Maulik, 1919)	A	Phytophagous	India	2004, FR	FR	I2	Palms	Drescher and Martinez (2005)

Table 8.3.2. List and characteristics of the Chrysomelidae species alien *in* Europe. Country codes abbreviations refer to ISO 3166 (see appendix I). Habitat abbreviations refer to EUNIS (see appendix II). Last update 1 February 2010.

Family or subfamily *Species*	**Regime**	**Native range**	**Invaded countries**	**Habitat***	**Hosts**	**References**
Alticinae- flea beetles						
Altica ampelophaga Guérin-Méneville, 1858	Phytophagous	Western, Southern and Central Europe	PT-AZO	I	*Vitis*	Borges and Serrano (1989)
Altica carinthiaca Weise, 1888	Phytophagous	Continental Europe	GB	I2	*Lathyrus pratensis* (meadow vetchling)	Cox (2007)
Chaetocnema hortensis (Geoffroy, 1785)	Phytophagous	Continental Europe	PT-AZO	I	Graminae	Borges and Serrano (1989)
Epitrix pubescens (Koch, 1803)	Phytophagous	Continental Europe	PT-AZO	I	*Solanum*	Borges and Serrano (1989)
Longitarsus kutscherae (Rye, 1872)	Phytophagous	Continental Europe	PT-AZO	I	*Plantago*	Borges and Serrano (1989)
Longitarsus lateripunctatus lateripunctatus (Rosenhauer, 1856)	Phytophagous	Mediterranean region	PT-AZO	I	*Borago officinalis* and other Boraginaceae	Borges and Serrano (1989)
Longitarsus obliteratoides Gruev, 1973	Phytophagous	Continental Europe	GB	I2	*Thymus, Rosmarinus*	Cox (2007)
Neocrepidodera brevicollis (J. Daniel, 1904)	Phytophagous	Alps	DK	G3, G4	*Cirsium*	Hansen (1964)
Neocrepidodera ferruginea (Scopoli, 1763)	Phytophagous	Continental Europe, Caucasus	PT-AZO	I	Asteraceae and Poaceae	Borges and Serrano (1989)
Psylliodes chrysocephalus (Linnaeus, 1758)	Phytophagous	Continental Europe	PT-AZO	I	Brassicaceae	Borges and Serrano (1989)
Psylliodes cucullata (Illiger, 1807)	Phytophagous	Continental Europe	GB	I2	*Spergula arvensis* (Corn spurrey)	Cox (1995), Cox (2007)
Bruchidae – seed beetles						
Bruchidius foveolatus (Gyllenhal, 1833)	Phytophagous	Continental Europe	PT-AZO	I1	*Sarothamnus scoparius* seeds	Borges et al. (2005)

Family or subfamily *Species*	**Regime**	**Native range**	**Invaded countries**	**Habitat***	**Hosts**	**References**
Bruchidius lividimanus (Gyllenhal, 1833)	Phyto-phagous	Mediterranean region	PT-AZO	I1	*Genistea, Ononis, Cytisus* seeds	Borges et al. (2005)
Bruchidius varius (Olivier)	Phyto-phagous	Continental Europe	GB	E, G	*Trifolium pratens* (red clover), *T. medium* (zig-zag clover), *Ulex europaeus* (gorse), *Bolboschoenus maritimus* (sea club-rush) seeds	Cox (2007), Hodge (1997)
Bruchus ervi Frölich, 1799	Phyto-phagous	Mediterranean region	BE, CH, CZ, DE, DK, ES-CAN, FI, GB, HU, IE, LI, LU, LV, NL, NO, PT-AZO, PT-MAD, RO, SE, SK, UA	I, J1	*Lens* seeds	Fauna Europaea (2009), Gobierno de Canarias (2010), Strejček (1990)
Bruchus lentis Fröhlich, 1799	Phyto-phagous	Southern Europe	ES-CAN	I, J1	*Lens, Vicia* seeds	Gobierno de Canarias (2010), Igrc et al. (1995)
Bruchus rufipes Herbst, 1783	Phyto-phagous	West Palaearctic	PT-AZO, ES- CAN	I	*Lathyrus, Pisum, Vicia* seeds	Borges et al. (2005), Gobierno de Canarias (2010)
Bruchus signaticornis Gyllenhal, 1833	Phyto-phagous	Mediterranean region	BE, CH, CZ, DE, DK, EE, FI, GB, HU, IE, LI, LT, LU, LV, MD, NL, NO, RU, SE, SK, UA	I, J1	*Lathyrus, Lens, Vicia* seeds	Strejček (1990)
Criocerinae- leaf beetles						
Crioceris asparagi (Linnaeus, 1758)	Phyto-phagous	Continental Europe, Central Asia	GB	I, J	*Asparagus officinalis officinalis* (garden asparagus), *A. officinalis prostratus* (wild asparagus)	Cox (2007), Hill et al. (2005)

Family or subfamily *Species*	**Regime**	**Native range**	**Invaded countries**	**Habitat***	**Hosts**	**References**
Lilioceris lilii (Scopoli, 1763)	Phytophagous	Continental Europe	GB, IE	I2, I1	*Lilium, Fritillaria* and other Liliaceae; *Arum maculatum*	Cox (2007), Stephens (1839)
Cryptocephalinae – casebearers						
Cryptocephalus sulphureus G. A. Olivier, 1808	Phytophagous	Western Mediterranean	PT- AZO	I2	*Pulmonaria*	Borges and Serrano (1989)
Chrysomelinae – leaf beetles						
Chrysolina americana Linnaeus, 1758	Phytophagous	Mediterranean region	BE, GB, NL	I1, I2	*Rosmarinus, Lavandula, Salvia, Thymus*	Beenen and Winkleman (2001), Cox (2007), Johnson (1963), Lays (1988)
Chrysolina bankii (Fabricius, 1775)	Phytophagous	Mediterranean region	GB	I2	*Plantago lanceolata* (ribwort plantain), *Ballota nigra* (black horehound), *Mentha* spp., and other Lamiaceae	Cox (2007)
Gonioctena fornicata (Bruggemann, 1873)	Phytophagous	Eastern Europe	IT	I	*Medicago*	Michieli (1957)
Galerucinae- Skeletonizing leaf beetles						
Xanthogaleruca luteola (Müller, 1766)	Phytophagous	Europe	GB	I2	*Ulmus*	Buckland and Skidmore (1999)

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Ladybeetles (Coccinellidae)
Chapter 8.4

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Abstract

The majority of Coccinellidae are beneficial predators and they have received considerable research attention because of their potential as biological control agents. Indeed the role of coccinellids as predators of pest insects has been a major factor in the movement of coccinellids between countries. The commercial production of coccinellids by biological control companies and local producers led to a rapid increase in distribution thoughout the 1990's. To date, 13 alien coccinellid species have been documented in Europe; 11 of these are alien to Europe (two are alien to Great Britain and Sweden but native within Europe). The distribution of alien coccinellids in Europe mirrors the biogeographical distribution and patterns of introduction. Some species have dispersed widely; *Harmonia axyridis* has spread rapidly from countries where it was deliberately introduced to many others across Europe. The ecological and economic impacts of alien coccinellids are not well documented. In this chapter we provide an overview of the temporal and spatial patterns of alien coccinellids in Europe.

Keywords

Coccinellid, ladybird, alien, Europe, biological control agent, *Harmonia axyridis*, distribution patterns

8.4.1 Introduction

The Coccinellidae are commonly referred to as ladybirds (Britain, Australia, South Africa), ladybugs (North America) or ladybeetles (various countries). Coccinellids have received considerable research attention because of their role as predators of pest

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insects. The Coccinellidae comprises over 4200 species worldwide (Iperti 1999, Majerus et al. (2006a)). Audisio and Canepari 2009 report that there are approximately 253 species and subspecies of Coccinellid in Europe. However, a review in 1999 documented only 110 species including species acclimatized through the 1900s: *Rodolia cardinalis*, *Cryptolaemus montrouzieri*, *Rhyzobius (Lindorus) lophanthae*, *Rhyzobius forestieri* and *Serangium parcestosum* (Iperti 1999). The discrepancy in species number from these different sources can not solely be accounted for by the addition of new species arriving in Europe but is an indication of the dynamic state of coccinellid taxonomy and the difficulty of establishing a checklist for Europe. Not only is the taxonomy of coccinellids under review but also the arrival of new species is ongoing; recently the UK Ladybird Survey (www.ladybird-survey.org) reported the first British record of *Cynegetis impunctata* (Thomas et al. 2009). There is also considerable variation in reported coccinellid diversity between countries. Great Britain is relatively species poor with only 46 species (Majerus et al. 2006b) whereas in contrast the Netherlands have 86 native coccinellid species. The proportion of alien species for this group is quite high in Europe, with 13 species observed in the wild to date. Two of these are native to Europe but alien within Great Britain (*Henosepilachna argus*, *Scymnus impexus*) and Sweden (*Scymnus impexus*). For the remainder of this section only the 11 species alien *to* Europe (and not the three alien species *in* Europe) will be considered.

The majority of coccinellid species (about 90 %) are beneficial predators (others are phytophagous or mycophagous); consequently coccinellids have played a significant role in the development of biological control strategies (Berthiaume et al. 2007, Brown and Miller 1998, Galecka 1991, Gurney and Hussey 1970, Iperti 1999, Obrycki and Kring 1998). This has been a major factor in the movement of coccinellids between countries worldwide.

8.4.2 Taxonomy of the coccinellid species alien to Europe

The family Coccinellidae belongs to the coleopteran superfamily Cucujoidea and is a member of the phylogenetic branch of Coleoptera termed the Cerylonid complex of families (Cerylonidae, Discolomidae, Alexiidae, Corylophidae, Endomychidae and Lathridiidae). Worldwide there are six subfamilies of Coccinellidae: Sticholotidinae, Chilocorinae, Scymninae, Coccidulinae, Coccinellinae and Epilachninae although a recent phylogeny suggests a seventh subfamily, Ortaliinae (Fürsch 1990, Kovář 1996). European species are mainly represented by three subfamilies: Scyminae, Chilocorinae and Coccinellinae. There are very few European Sticholotinae, very few Coccidulinae and only three species of Epilachninae (Iperti 1999). Although the species list for Coccinellidae in Fauna Europaea (Audisio and Canepari 2009) includes representatives from all six subfamilies.

Species alien *to* Europe are quite evenly represented between five of the six subfamilies. Three species are observed in the subfamily Coccidulinae (two Coccidulini and one Noviini) and in the Scymninae (two Scymnini and one Hyperaspidini). Two species are in the Chilocorinae (two Chilocorini) and Coccinellinae (two Coccinellini). One species is in the Sticholotidinae (Sticholotidini). There are no Epilachninae that are alien to Europe (although *Henosepilachna argus* is alien *in* Europe).

Most species in the Epilachninae are phytophagous, while the majority of species in the other subfamilies are predatory. The preferred diets of the two feeding stages in the life-cycle, the larval and adult stages, are generally the same. Most predatory ladybirds feed on either aphids or coccids (a few feed on both), however some predatory species feed on mites, adelgids, aleyrodids, ants, chrysomelid larvae, cicadellids, pentatomids, phylloxera, mycophagous coccinellids and psyllids (Dixon 2000). Indeed, a small number of species within the Coccinellinae and Epilachninae are mycophagous, feeding on the hyphae and spores of fungi. There is also considerable variability in the degree of dietary specialisation between species (Hodek 1996). Some species have a very narrow preferred prey range, such as a single species of mite, aphids of a single genus, or plants of a single family, other species have a wide prey range. *Harmonia axyridis*, for example, will feed on aphids, coccids, adelgids, psyllids, and the eggs and larvae of many other insects, including other coccinellids and lepidopterans (Legaspi et al. 2008, Ware and Majerus 2008). Ladybirds exhibit complex adaptations to specific or more general diets such as mandibular dentition, gut length and structure, and morphological features that affect mobility (Hodek 1996). Many predatory coccinellids will feed on alternative foods, such as pollen, nectar, honey-dew and fungi (many also resort to cannibalism) when preferred prey are scarce (De Clercq et al. 2005, Hodek 1996).

Coccinellids are distinguished from the remainder of the Cerylonid complex of families by a number of adult characteristics: five pairs of abdominal spiracles, tentorial bridge is absent, anterior tentorial branches are separated, frontoclypeal suture absent, apical segment of maxillary palpus never aciculate, galea and lacinia separated, mandible with reduced mola, front coxal cavities open posteriorly, middle coxal cavities open outwardly, metaepimeron parallel-sided, femoral lines present on abdominal sternite 2, tarsal formula 4-4-4 or 3-3-3, tarsal segment 2 usually strongly dilated below (Kovář 1996). In Europe, the diagnostic features of the family Coccinellidae can be considered in more simple terms (Majerus 2004). They are small to medium sized beetles (1.3–10 mm in length). There body shape is oval, oblong oval or hemispherical (upper surface convex and lower surface flat). They have large, compound eyes. The antennae are often 11-segmented but this figure varies and can be as low as seven. The mouthparts consist of large, strong mandibles; four-segmented maxillary palps (terminal segment axe shaped) behind the mandibles; labium divided into the pre-labium and post-labium; three-segmented labial palps; and the labrum. The head can be partly withdrawn under the pronotum. The pronotum is broader than long and has anterior extensions at the margin. The legs are short and can be retracted into depressions under the body. The tarsi are usually four segmented but the third segment is small and hidden in the end of the second segment. Each tarsus bears two claws. The abdomen has ten segments (Kovář 1996, Majerus et al. 2006a).

8.4.3 Temporal trends of introduction in Europe of alien coccinellids

The first species of coccinellid to be introduced into Europe was the vedalia beetle, *R. cardinalis,* for the control of the cottony cushion scale (coccid), *Icerya purchasi* (Figure 8.4.1). Two further species were introduced during the early twentieth century (mainly to the Mediterranean regions including France, Portugal and Italy) but there then followed a period of stagnation and respect to biological control in general. This correlates with the trend towards chemical insect pest control with the development of synthetic pesticides. From the 1980's onwards there were a considerable number of introductions on an extensive scale across Europe through the use of tropical coccinellids to control glasshouse pest insects.

8.4.4 Biogeography of the coccinellid species alien *to* Europe

Each continent has a specific fauna of coccinellidae. Belicek (1976) stated that "many species develop their cycles in life zones delineated by the general physiography of the continents (mountainous barriers) and climatic patterns combined with the types of vegetation in a given zone". Glaciation had profound effects on the distribution of coccinellids and the level of endemism is further controlled by ecological factors including temperature, food and natural enemies.

The temperate zones of Europe and North America are heavily infested by Aphidae and grasslands in these regions contain coccinellids from the tribus Coccinellini (*Coccinella* spp., *Adalia* spp., *Harmonia* spp.) and Hippodamiini, Cheilomenini and Scymnini. Open deciduous and coniferous forests in this temperate zone contain other genera of Coccinellini (*Anatis* spp., *Myrrha* spp., *Myzia* spp.). Tropical zones in central and South Africa, South America, India and China where Coccidae are abundant are characterised by coccinellids from the tribus Chilocorini (*Chilocorus* spp., *Exochomus* spp., *Brumus* spp.), Scymnini, Hyperaspini, Coccidulini and Noviini. In the Mediterranean regions of Europe, aphids and coccids are found together and are attacked by coccinellids from the temperate and tropical zones (Iperti 1999).

It is interesting to note that coccinellids native to temperate zones enter either simple quiescence or intense diapause as adults. In contrast, exotic species such as *Rhyzobius lophanthae* and *Cryptolaemus montrouzieri* do not enter quiescence or diapause but instead resist drastic changes in climate by reducing the speed of development during winter but not entirely stopping it (Iperti 1999).

The early introductions of alien coccinellids were characteristically as classical biological control agents; the predatory coccinellid originated from the same country as the target pest insect. So, for example, both *R. cardinalis* and *I. purchasi* originated from Australia; *R. lophanate* and various Diaspididae (*Pseudolacaspis pentagona*, *Quadraspidiotus perniciosus*, *Chrysomphalus dictyospermi*, *Parlatoria blanchardi*) from Australia and New Zealand; *C. montrouzieri* and *Planococcus citri* from Australia. Notably all these species are from tropical regions and were introduced into Mediterranean regions for

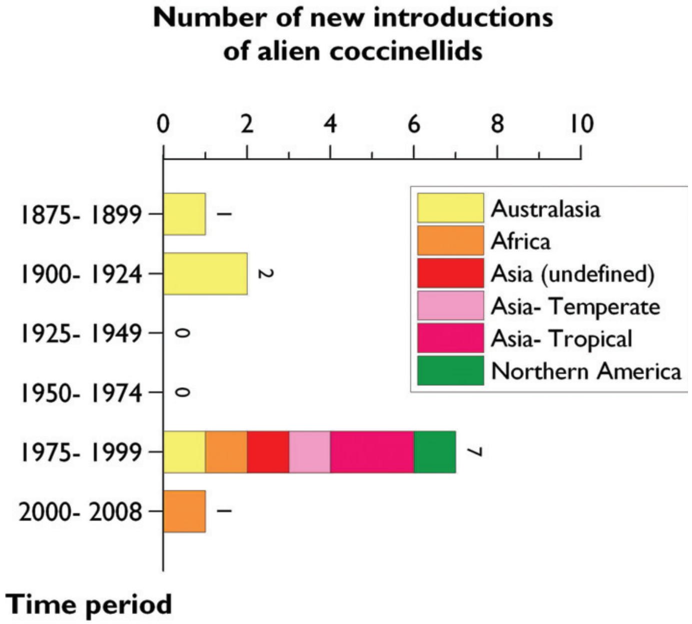

Figure 8.4.1. Temporal trends in the mean number of new records per year of coccinellid species alien *to* Europe from 1875 to 2008. The number above the bar indicates the total number of alien species newly recorded during the considered time period.

control purposes (Figures 8.4.1 and 8.4.2). In contrast, the coccinellid species selected to reinforce the activity of native natural enemies in temperate regions of Europe are from temperate regions of the globe for example, temperate Asia (*H. axyridis*) or North America (*Hippodamia convergens*).

8.4.5 Distribution of alien Coccinellids in Europe

The distribution of alien coccinellids in Europe mirrors the biogeographical distribution and patterns of introduction (Figure 8.4.3). Some species have dispersed widely; *H. axyridis* has spread rapidly from countries where it was deliberately introduced to many others across Europe. Furthermore, the commercial production of coccinellids by biological control companies and local producers led to a rapid increase in distribution thoughout the 1990's.

8.4.6 Use of alien coccinellids for biological control in Europe

The ecosystem service that predatory coccinellids provide in consuming pest insects has been recognised for over a century. The vedalia ladybird, *R. cardinalis*, is considered to have initiated modern biological pest control. It was released as a classical bio-

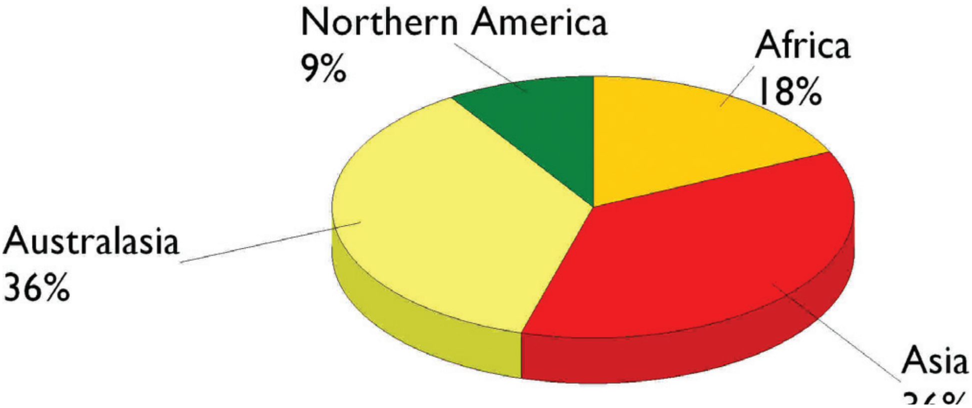

Figure 8.4.2. Origin of the 11 alien coccinellid species established in Europe.

logical control agent (native to Australia) in 1887 to control an alien cottony cushion scale (coccid), *I. purchasi*, which was threatening the citrus industry of California. The vedalia ladybird and the cottony cushion scale are still present in Californian citrus groves but the ecological balance between predator and prey ensures that the pest is no longer a problem (Caltagirone 1989, Majerus et al. 2006a).

The successful introduction of *R. cardinalis* for the control of *I. purchasi* resulted in considerable focus on Coccinellidae for importation programmes worldwide (Obrycki and Kring 1998). Over 40 species of coccinellid were introduced to North America following *R. cardinalis* during a period colloquially referred to as the "ladybird fantasy" (Caltagirone 1989, Dixon 2000). This worldwide phenomenon was mainly ineffectual; only four of over 40 species introduced to North America during this time established (Caltagirone 1989). In recent times there have been 155 attempts to control aphids and 613 to control coccids worldwide through the introduction of ladybirds (Dixon 2000). On a scale of success (complete, substantial, partial or no control) only one attempt to control aphids using coccinellids has been ranked as substantially successful and none have been completely successful (Dixon 2000). In contrast, 23 complete and 30 substantial successes have been achieved against coccids (Dixon 2000). In a few cases the introduced coccinellid species has had far-reaching, unacceptable impacts on biodiversity and so has been deemed an invasive species. *Harmonia axyridis*, harlequin ladybird, is the only such example in Europe (Brown et al. 2008a).

All of the 11 alien coccinellids in Europe have been intentionally released as biological control agents of pest insects. The first coccinellid to be introduced to Europe was *R. cardinalis* as a predator of *I. purchasi* in 1888 (Portugal), 1901 (Italy) and 1912 (Italy and France). This species was subsequently released through the mid and late 1900s to Italy, Portugal, Israel, France, Spain, Malta, Great Britain, Albania, Cyprus, Switzerland and the Ukraine. *Cryptolaemus montrouzieri*, native to Australia, was intentionally released to control mealybugs (Pseudococcidae), *Planococcus citri*, from 1908 in Italy. Subsequent releases were made in Spain (1926), Corsica (1970), France

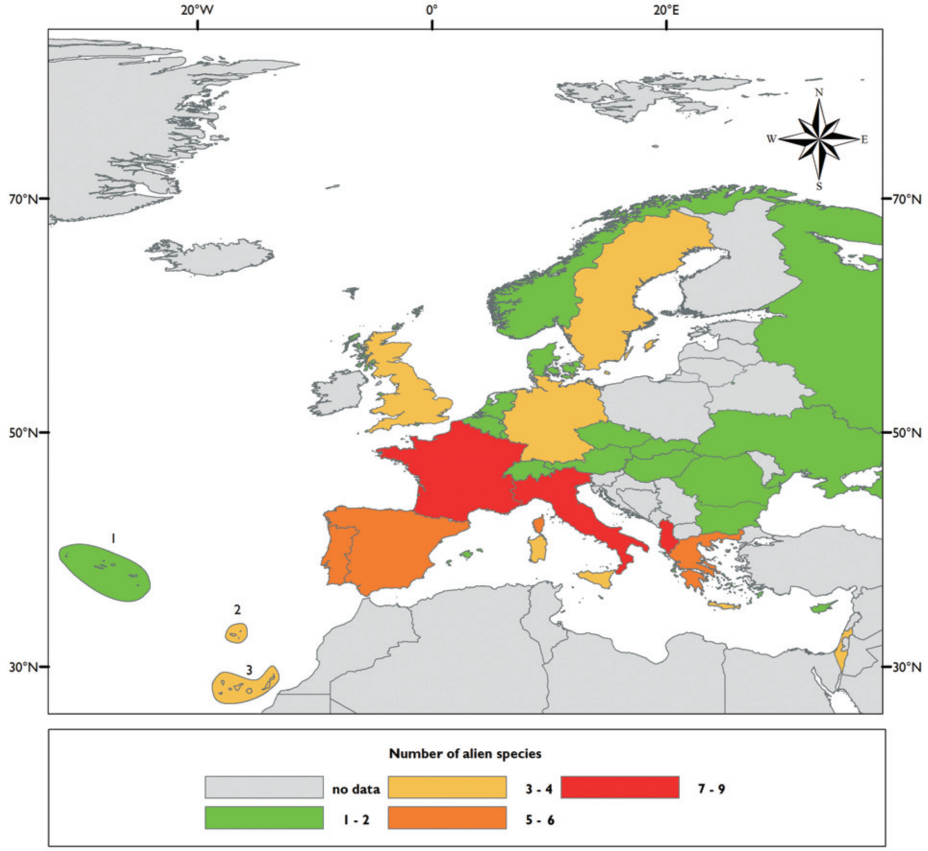

Figure 8.4.3. Colonisation of European countries and islands by coccinellids alien to Europe where known. Scale = total number of recorded alien coccinellids.

(1974), Portugal (1984) and Sweden (2001). This species is considered established in all the countries where it has been released other than Sweden (for which the status of this species is unknown). *Cryptolaemus montrouzieri* has been used extensively through augmentation (release of reared adults) and was the first coccinellid used to demonstrate an inoculative approach (whereby the aim is introduce a small number of individuals into a crop system with the expectation that they will reproduce and their offspring will continue to provide control of the target pest for an extended period of time). *Cryptolaemus montrouzieri* is easy and cheap to culture on mealybugs (Majerus 2004). *Rhyzobius lophanthae* is a species native to New Zealand which was introduced to Italy in 1908 for the control of Diaspididae (armoured scale insects). It has been released widely in European countries including: Portugal (1930 and 1984), Spain (1958), Sardinia (1973), France (1975), Greece (1977) and Germany (2000). This species has recently been reported as established in London, Great Britain (Natural History Museum, 2008).

Figure 8.4.4. Harlequin ladybeetle (*Harmonia axyridis*). Credit: Mark Bond

8.4.6.1 Control of Scale Insects

A number of coccinellid species have been used in historically significant and successful projects for the biological control of scale (Borges et al. 2006, Erler 2001, Katsoyannos 1997) including *R. cardinalis* and *R. lophanthae*. Other species introduced to Europe for control of scales include *Rhyzobius forestieri*, *Nephus reunioni*, *Chilocorus nigritus* and *Chilocorus kuwanae*.

Rhyzobius forestieri (native to Australia) has established in Italy, France, Greece and Albania. In the Cambos coastal plain of Greece this species is now considered the most abundant species of coccinellid within the coccidophagous guild (Katsoyannos 1997). *Nephus reunioni* (native to Africa) was intentionally released in a number of countries (Italy, Portugal, France, Greece, Albania and Spain) and is now considered to be established in Italy and Portugal. *Chilocorus nigritus* is native to the Indian sub-continent and South East Asia and is a candidate biological control agent for the control of species within the Coccoidea including three economically important families (Diaspididae, Pseudococcidae and Coccidae). It has a recent history, 1985 onwards, of introduction to a number of countries: Italy, Denmark, France, Germany, Netherlands, Great Britain and Albania. *Chilocorus kuwanae* is a biological control agent of scale insects and was introduced to Europe (Albania and Italy) from Asia in 1989.

8.4.6.2 Control of Aleyrodidae

The family Aleyrodidae comprises the commonly referred to whiteflies. Over fifty species of coccinellidae attack eggs and immature stages of whitefly pests (Obrycki and Kring 1998, Yigit et al. 2003). There is interesting variation in the preda-

Figure 8.4.5. Adults of *Cynegetis impunctata*. Credit: Gilles San Martin

tory behaviour of these polyphagous coccinellids; some are mobile, seeking out prey, and others are sedentary, and complete preimaginal development on one leaf (Obrycki and Kring 1998). In Europe one species, *Serangium parcesetosum*, has been introduced for the control of whitefly (*Bemisia tabaci*). *Serangium parcesetosum* was introduced from its native range of Asia and the Indian subcontinent to France including Corsica (Majka and McCorquodale 2006). A further species *Delphastus catalinae*, native to North America, has been introduced in glasshouses within Albania and Russia for the control of *Bemisia tabaci* and *Trialeurodes vaporariorum* (Kutuk and Yigit 2007, Legaspi et al. 2008). However, this species has not established in the wild. Studies on the thermal biology of *D. catalinae,* assessing the effects of temperature on development, voltinism and survival in the laboratory and field (non-indigenous range), indicate a strong correlation between survival in the laboratory at 5 °C and in the field in winter (Simmons and Legaspi 2004, Simmons and Legaspi 2007). *Delphastus catalinae* died out quickly in winter temperatures and this suggests that the probability of establishment is low in regions that experience low temperatures and scarcity of suitable food for part of the year (van Lenterenet et al. 2003). In the absence of studies on cold tolerance it is insufficient to assume that, on the basis of climate matching, winter would be an effective barrier to establishment of species originating from warmer climatic zones (van Lenteren et al. 2006). Risk assessments should also be sufficiently detailed to encompass strain specific parameters; the release of a non-diapausing strain versus a diapausing strain could result in very different impacts (van Lenteren et al. 2006). Furthermore, impacts through consumption of non-target hosts and dispersal require considerable attention (van Lenterenet et al. 2003). So, for example, although *D. catalinae* is not anticipated to survive winter temperatures in northern Europe, it is oligophagous

Figure 8.4.6. Adult of the phytophagous bryony ladybeetle, *Henosepilachna argus*. Credit: Mike Majerus.

and reported as an intra-guild predator of the aphelinid parasitoid *Encarsia sophia* (Zang and Liu 2007).

8.4.6.3 Control of Aphids

Hippodamia convergens and *H. axyridis* have both been released extensively throughout Europe for the control of aphids. *Hippodamia convergens* is native to America and several billion are collected annually from overwintering sites in California and sold throughout America. This practice has been shown to be highly ineffective because of adult dispersal (Dixon 2000, Roy and Majerus, unpubl.). Furthermore, removal of *H. convergens* is considered to have adverse effects on local populations and, in America, is responsible for the distribution of two ladybird parasites (the braconid wasp, *Dinocampus coccinellae* and the microsporidian, *Nosema hippodamiae*) (Saito and Bjornson 2006) and vectoring of plant pathogens (dogwood anthracnose fungus) (Bjornson 2008). This coccinellid has been released in Belgium, Sweden, Denmark, Albania and the Czech Republic in the 1990s and early 2000. It is unknown whether or not it is established.

The use of *H. axyridis* as an augmentative biological control agent (mass reared and released) has been widespread (Berkvens et al. 2008, Brown et al. 2008a). In 1982 it was introduced into France and has since been reared continuously over 100 generations on industrially produced eggs of the moth, *Ephestia kuehniella* (Brown et al. 2008a). It has since been introduced to a number of countries across Europe and also spread to others which had not intentionally released it (Table 8.4.3).

Figure 8.4.7. Larva of *Henosepilachna argus*. Credit: Gilles San Martin

8.4.7 Ecosystems and habitats invaded in Europe by alien Coccinellids

Coccinellid species can be classified as stenotopic or eurytopic (Hodek 1993, Iperti 1991). Microclimate is considered to be a particularly important feature of a coccinellid habitat. Many species of ladybird exhibit a preference for specific vegetation types or certain strata of the habitat. Coupled with this is the requirement for suitable food in sufficient abundance. Habitat preference varies seasonally as the microclimatic characteristics of a habitat change, which in turn influences the distribution of prey populations and the behaviour of coccinellids. Iperti (1999) documents the succession of aphid outbreaks in south eastern France; during a normal year aphids first appear on low plants and shrubs, they then progress to cultivated low plants and early deciduous trees and develop on cultivated trees and shrubs. However, climatic conditions vary annually and so it is difficult to predict the behaviour of coccinellids, particularly in a period of climate change.

There is a strong trend for alien coccinellids to occur in urban or cultivated habitats in Europe. Almost all species are most prevalent in recently cultivated agricultural, horticultural and domestic habitats, gardens and parks and greenhouses (EUNIS categories I I1, I2, J100; see appendix II). *Harmonia axyridis*, the most invasive of the alien coccinellids in Europe, follows this pattern although there have been a considerable number of records in Great Britain from natural habitats (Brown et al. 2008b). Indeed, *H. axyridis* is documented from both woodlands and forest habitats, small anthropogenic woodlands, parks and gardens, agricultural and horticultural habitats as well as from buildings in cities, towns and villages.

The abundance of native and alien coccinellid species in urban habitats and their tendency to aggregate in large numbers during autumn and winter enhances their visibility to people. This aggregation behaviour can be exploited by biological control practitioners through the collection and release of large numbers of beetles but species that exhibit this behaviour, such as *H. axyridis*, are increasingly seen as nuisance insects in domestic dwellings (Roy and Majerus 2006, Roy et al. 2008).

8.4.8 Ecological and economic impacts of alien coccinellids

The ecological and economic impacts of alien coccinellids are not well documented. Many authors have noted the low success rate of coccinellids as biological control agents of aphids (Dixon 2000, Iperti 1999, Majerus et al. 2006a). The success of coccinellids as biological control agents of coccids is higher than that of aphids but still relatively low at only 40 % of cases studied being designated as exerting complete or substantial control (Iperti 1999).

Rodolia cardinalis has been heralded as a success story for biological control (Caltagirone 1989). This species has been introduced into 33 countries to control *I. purchasi* and has yielded complete control in 26 countries (North America, Argentina, Peru, Chile, Portugal, Uruguay, Venezuela, France, Italy, Spain, Greece, Morocco, Tunisia, Turkey, Egypt, India, Japan and New Zealand); substantial control in four countries (Russia, Libya, the Bahamas, Ecuador) and partial control in two countries (Seychelles and Mauritius). A similar rate of success was achieved through the acclimatization of *C. montrouzieri* to control *Pseudococcus* spp. (Iperti 1999). Therefore, *R. cardinalis* and *C. montrouzieri* have contributed economic benefits through the ecosystem service they provide. Indeed, the initial cost of the *R. cardinalis* introduction programme in California 1888 was $1 500 with a return in just over a year of millions of dollars (Majerus 2004).

The lack of success of aphidophagous coccinellids has been attributed to asynchrony between the reproductive and development rates of the predatory coccinellids and their aphid prey (Dixon 2000). Furthermore, many aphidophagous coccinellids, in temperate climates, are univoltine whereas aphids are multivoltine. Coccidophagous coccinellids tend to stay in a localised area throughout their life cycle and, in contrast, aphidophagous coccinellids disperse widely (Iperti 1999).

Most intentional insect introductions do not cause ecological or economic problems, indeed of all the intentionally introduced insects to North America only 1.4 % have caused problems (van Lenteren et al. 2003). Indeed insect introductions are considered to be relatively safe: less than 1 % cause a population level effect in non-targets and only 3–5 % may have caused smaller scale effects (van Lenterenet et al. 2003). However, a number of coccinellids are documented as having non-target effects (van Lenterenet et al. 2003). *Cryptolaemus montrouzieri* is reported to lower the effectiveness of an introduced natural enemy (*Dactylopius opuntiae*) for weed control (Goeden and Louda 1976). The most infamous coccinellid introduction is undoubtedly *H. axyridis* (Majerus et al. 2006b, Roy and Majerus 2006, Roy et al. 2005, Roy and Wajnberg 2008).

Harmonia axyridis has been released as a classical biological control agent in North America since 1916. It has been commercially available in Europe since the 1980s and has many attributes that contribute to its economic viability, including its polyphagous nature. *Harmonia axyridis* preys on a wide variety of tree-dwelling homopteran insects, such as aphids, psyllids, coccids, adelgids and other insects (Koch et al. 2006). In North America, as well as offering effective control of target pests, such as aphids in pecans (Tedders and Schaefer 1994), *H. axyridis* is also providing control of pests in other systems such as *Aphis spiraecola* in apple orchards (Brown and Miller 1998) and several citrus pests (Michaud 2002). In both Asia and North America, *H. axyridis* has been reported to contribute to control of aphids on sweet corn, alfalfa, cotton, tobacco, winter wheat and soybean (Longo et al. 1994). The spread and increase of *H. axyridis* throughout Europe could, therefore, prove to be beneficial to ecosystem services through the reduction in aphid numbers below economically damaging levels and subsequent reduction in the use of chemical pesticides.

The polyphagous nature of *H. axyridis* means that negative impacts on non-target prey species would appear to be inevitable (Majerus 2006, Pell et al. 2008). However, there is very limited empirical evidence on this subject and studies considering the effects of *H. axyridis* on the population demography of non-target aphids, coccids and other prey species away from crop systems have not been conducted. *Harmonia axyridis* has been implicated as a potential predator of immature monarch butterflies, *Danaus plexippus*, an aposematic species that contains defensive chemicals (Koch et al. 2003). Laboratory studies have also indicated the potential for *H. axyridis* to engage in intra-guild predation (Pell et al. 2008, Roy et al. 2008, Ware and Majerus 2008). It is likely that many other species will be directly or indirectly affected by the arrival of *H. axyridis*. Indeed, intraguild predation is thought to be an important force in structuring aphidophagous ladybird guilds (Yasuda et al. 2004) and so *H. axyridis* has the potential to dramatically disrupt native guilds in Europe. *Harmonia axyridis* is a large, aggressive, polyphagous coccinellid (with a tendency for intraguild predation) that could impact on the abundance of native coccinellids and reduce their available niches (Legaspi et al. 2008).

The wide dietary range of *H. axyridis* coupled with its ability to disperse rapidly, forage widely and continuously breed gives this species the potential to significantly reduce European populations of coccids and aphids. This is, of course, considered beneficial in crop and horticultural systems, but not in other habitats where such direct competition for prey may result in a reduction in biodiversity and declines in native beneficial predators and parasitoids of aphids and coccids (Majerus 2006).

Majerus et al. (2008) noted that the negative effects of *H. axyridis* on other aphidophages are likely to be the result of a complex range of interactions, with *H. axyridis* in general having a competitive edge through resource competition, intraguild predation and a more plastic phenotype. A more rapid development rate, continual breeding ability and lack of diapause requirement, efficient chemical defence and relatively large size would provide *H. axyridis* with a significant reproductive advantage over many native British species. The pattern is anticipated to be widespread throughout Europe (Brown et al. 2008a).

8.4.10 Conclusions

Coccinellids have been introduced widely throughout Europe for the biological control of pest insects. Some of these species have established and for others the status is unknown. It is difficult to estimate the proportion of alien coccinellids in Europe for two reasons: there is not a definitive European check list for coccinellids and the status of some of the alien species is unknown. However, the proportion of alien coccinellids appears to be higher (approximately 5–10 %) than the proportion of aliens for other taxonomic groups (3.1 % alien Diptera). Only one species (*H. axyridis*) is considered to be invasive.

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References

Adriaens T, Branquart E, Maes D (2003) The Multicoloured Asian Ladybird *Harmonia axyridis* Pallas (Coleoptera: Coccinellidae), a threat for native aphid predators in Belgium? *Belgian Journal of Zoology* 133: 195–196.

Adriaens T, San Martin y Gomez G, Maes D (2008) Invasion history, habitat preferences and phenology of the invasive ladybird *Harmonia axyridis* in Belgium. *Biocontrol* 53: 69–88.

Audisio P, Canepari C (2009) Fauna Europaea - Coccinellidae. http://www.faunaeur.org/full_results.php?id=11062.

Belicek J (1976) Coccinellidae of Western Canada and Alaska with analyses of the transmontane zoogeographic relationship between the fauna of british Columbia and Alberta. *Questiones Entomology*: 283–409.

Berkvens N, Bonte J, Berkvens D, Tirry L, De Clercq P (2008) Pollen as an alternative food for *Harmonia axyridis*. *Biocontrol* 53: 201–210.

Berthiaume R, Hébert C, Cloutier C (2007) Comparative use of Mindarus abietinus (Homoptera: Aphididae) by two coccinellids (Coleoptera: Coccinellidae), the native Anatis mali and the exotic Harmonia axyridis, in a Christmas tree plantation. *Environmental Entomology* 36: 319–328.

Bjornson S (2008) Natural enemies of the convergent lady beetle, *Hippodamia convergens* Guerin-Meneville: Their inadvertent importation and potential significance for augmentative biological control. *Biological Control* 44: 305–311.

Booth RG (1998) A review of the species resembling *Chilocorus nigrita* (Coleoptera: Coccinellidae): potential agents for biological control. *Bulletin of Entomological Research* 88: 361–367.

Booth RG, Cross AE, Fowler SV, Shaw RH (1995) The biology and taxonomy of *Hyperaspis pantherina* (Coleoptera: Coccinellidae) and the classical biological control of its prey, *Orthezia insignis* (Homoptera: Ortheziidae). *Bulletin of Entomological Research* 85: 307–314.

Borges I, Soares AO, Hemptinne JL (2006) Abundance and spatial distribution of aphids and scales select for different life histories in their ladybird beetle predators. *Journal of Applied Entomology* 130: 356–359.

Brown MW, Miller SS (1998) Coccinellidae (Coleoptera) in apple orchards of eastern West Virginia and the impact of invasion by *Harmonia axyridis*. *Entomological News* 109: 143–151.

Brown PMJ, Adriaens T, Bathon H, Cuppen J, Goldarazena A, Hagg T, Kenis M, Klausnitzer BEM, Kovář I, Loomans AJ, Majerus MEN, Nedved O, Pedersen J, Rabitsch W, Roy HE, Ternois V, Zakharov I, Roy DB (2008a) *Harmonia axyridis* in Europe: spread and distribution of a non-native coccinellid. *Biocontrol* 53: 5–21.

Brown PMJ, Roy HE, Rothery P, Roy DB, Ware RL, Majerus MEN (2008b) *Harmonia axyridis* in Great Britain: analysis of the spread and distribution of a non-native coccinellid. *Biocontrol* 53: 55–67.

Caltagirone L E (1989) The history of the vedalia beetle importation to California and its impact on the development of biological control. *Annual Review of Entomology* 34: 1–16.

De Clercq P, Bonte M, Van Speybroeck K, Bolckmans K, Deforce K (2005) Development and reproduction of *Adalia bipunctata* (Coleoptera: Coccinellidae) on eggs of *Ephestia kuehniella* (Lepidoptera: Phycitidae) and pollen. *Pest Management Science* 61: 1129–1132.

Dixon A FG (2000) *Insect predator-prey dynamics: Ladybeetles and Biological Control*. Cambridge: Cambridge University Press. 257 pp.

Erler F, Tunc I (2001) A survey (1992–1996) of natural enemies of Diaspididae species in Antalya, *Turkey. Phytoparasitica* 29: 299–305.

Fowler S V (2004) Biological control of an exotic scale, *Orthezia insignis* Browne (Homoptera: Ortheziidae), saves the endemic gumwood tree, *Commidendrum robustum* (Roxb.) DC. (Asteraceae) on the island of St. Helena. *Biological Control* 29: 367–374.

Frank J H, McCoy ED (2007) The risk of classical biological control in Florida. Biological Control 41: 151–174.

Fürsch H (1990) Taxonomy of coccinellids, corrected version. *Coccinella* 2: 4–6.

Galecka B (1991) Distribution and role of coccinellids in an agricultural landscape. In: Polgar L, Chambers RJ, Dixon AFG, Hodek I (Eds) *Behaviour and Impact of Aphidophaga*. The Hague : SPB Academic Publishing, 137–141.

Goeden RD, Louda SM (1976) Biotic interference with insects imported for weed control. *Annual Review of Entomology* 21: 325–342.

Gurney B, Hussey NW (1970) Evaluation of some coccinellid species for biological control of aphids in protected cropping. *Annals of Applied Biology* 65: 451–458.

Hamid HA, Michelakis S (1994) The importance of *Cryptolaemus montrouzieri* Mulsant (Col.: Coccinellidae) in the control of the citrus mealy bug *Planococcus citri* (Risso) (Hom.: Coccoidea) under specific conditions. *Journal of Applied Entomology-Zeitschrift Fur Angewandte Entomologie* 118: 17–22.

Hill M, Baker R, Broad G, Chandler PJ, Copp GH, Ellis J, Jones D, Hoyland C, Laing I, Longshaw M, Moore N, Parrott D, Pearman D, Preston C, Smith RM, Waters R (2005) *Audit of non-native species in England*. Peterborough, UK: English Nature. 82 pp.

Hodek I (1993) Habitat and food specificity in aphidophagous predators. *Biocontrol Science and Technology* 3: 91–100.

Hodek I (1996) Food Relationships. In: Hodek I, Honek A (Eds) *Ecology of Coccinellidae*. The Hague: Kluwer Academic Publishers, 143–238.

Humble LM (1994) Recovery of additional exotic predators of balsam woolly adelgid, *Adelges piceae* (Ratzeburg) (Homoptera, Adelgidae), in British Columbia. *Canadian Entomologist* 126: 1101–1103.

Iperti G (1991) Abiotic and biotic factors influencing the distribution of the aphidophagous coccinellidae. In: Polgar L, Chambers RJ, Dixon AFG, Hodek I (Eds) *Behaviour and Impact of Aphidophaga*. The Hague: SPB Academic Publishing, 163–166.

Iperti G (1999) Biodiversity of predaceous coccinellidae in relation to bioindication and economic importance. *Agriculture Ecosystems & Environment* 74: 323–342.

Izhevsky SS, Orlinsky AD (1988) Life history of the importaed *Scymnus (Nephus) reunioni* (Col.: Coccinellidae) predator of mealybugs. *Entomophaga* 33: 101–114.

Katsoyannos P (1997) Status and importance of *Rhyzobius forestieri* (Col.: Coccinellidae) on citrus at Chios island, Greece, nine years after its introduction. *Entomophaga* 42: 387–392.

Koch RL, Hutchison WD, Venette RC, Heimpel GE (2003) Susceptibility of immature monarch butterfly, *Danaus plexippus* (Lepidoptera: Nymphalidae: Danainae), to predation by *Harmonia axyridis* (Coleoptera: Coccinellidae). *Biological Control* 28: 265–270.

Koch RL, Venette RC, Hutchison WD (2006) Invasions by *Harmonia axyridis* (Pallas) (Coleoptera: Coccinellidae) in the Western Hemisphere: Implications for South America. *Neotropical Entomology* 35: 421–434.

Kovář I (1996). Phylogeny. In: Hodek I, Honek A (Eds) *Ecology of Coccinellidae*. The Hague: Kluwer Academic Publishers, 19–32.

Kutuk H, Yigit A (2007) Life table of *Delphastus catalinae* (Horn) (Coleoptera: Coccinellidae) on cotton whitefly, *Bemisla tabaci* (Genn.) (Homoptera: Aleyrodidae) as prey. *Journal of Plant Diseases and Protection* 114: 20–25.

Legaspi JC, Legaspi BC, Simmons AM, Soumare M (2008) Life table analysis for immatures and female adults of the predatory beetle, *Delphastus catalinae*, feeding on whiteflies under three constant temperatures. *Journal of Insect Science* 8: 07.

Longo S, Mazzeo G, Russo A, Siscaro G (1994) *Aonidiella citrina* (Coquillet) a new pest of citrus in Italy. *Informatore Fitopatologico* 44: 19–25.

Majerus M, Strawson V, Roy HE (2006a) The potential impacts of the arrival of the harlequin ladybird, *Harmonia axyridis* (Pallas) (Coleoptera: Coccinellidae), in Britain. *Ecological Entomology* 31: 207–215.

Majerus MEN (1994). *Ladybirds*. Somerset: Harper Collins Publisher.

Majerus MEN (2006a) The impact of male-killing bacteria on the evolution of aphidophagous coccinellids. *European Journal of Entomology* 103: 1–7.

Majerus MEN, Roy HE, Brown PMJ, Ware RL (2006b) Guide to Ladybirds of the British Isles. Shrewsbury: Field Studies Council.

Majka CG, McCorquodale DB (2006) The Coccinellidae (Coleoptera) of the Maritime Provinces of Canada: new records, biogeographic notes, and conservation concerns. *Zootaxa* 1154: 49–68.

Malausa JC, Franco E, Brun P (1988) Establishment on the Cote-Dazur and in Corsica of *Serangium parcesetosum* (Col.: Coccinellidae), a predator of the citrus whitefly, *Dialeurodes citri* (Hom.: Aleyrodidae). *Entomophaga* 33: 517–519.

Michaud JP (2002) Invasion of the Florida citrus ecosystem by *Harmonia axyridis* (Coleoptera: Coccinellidae) and asymmetric competition with a native species, *Cycloneda sanguinea.* Environmental Entomology 31: 827–835.

Obrycki JJ, Kring TJ (1998) Predaceous Coccinellidae in biological control. *Annual Review of Entomology* 43: 295–321.

Pell JK, Baverstock J, Roy HE, Ware RL, Majerus MEN (2008) Intraguild predation involving *Harmonia axyridis*: a review of current knowledge and future perspectives. *Biocontrol* 53: 147–168.

Phoofolo MW, Giles KL, Elliott NC (2008) Larval life history responses to food deprivation in three species of predatory lady beetles (Coleoptera: Coccinellidae). *Environmental Entomology* 37: 315–322.

Ponsonby DJ, Copland MJW (2007a) Aspects of prey relations in the coccidophagous ladybird *Chilocorus nigritus* relevant to its use as a biological control agent of scale insects in temperate glasshouses. *Biocont*rol 52, 629–640.

Ponsonby DJ, Copland MJW (2007b) Influence of host density and population structure on egg production in the coccidophagous ladybird, *Chilocorus nigritus* F. (Coleoptera: Coccinellidae). *Agricultural and Forest Entomology* 9: 287–296.

Ricci C, Primavera A, Negri V (2006) Effects of low temperatures on *Chilocorus kuwanae* (Coleoptera: Coccinellidae) trophic activity. *European Journal of Entomology* 103: 547–551.

Roy HE, Majerus MEN (in press). *Coccinellids in a Changing World*. In Kindlmann P (Ed.) *Aphids in the changing world: Patterns and processes*. Dordrecht, The Netherlands: Kluwer Academic Publishers.

Roy HE, Majerus MEN (2006) *Harmonia axyridis*: A successful biocontrol agent or an invasive threat? In: Eilenberg J, Hokkanen HMT (Eds) *An ecological and societal approach to biological control*. Dordrecht, The Netherlands: Kluwer Academic Publishers, 295–309.

Roy HE, Brown PMJ, Rowland F, Majerus MEN (2005) Ecology of *Harmonia axyridis*. *British Wildlife* 16: 403–407.

Roy HE, Brown PMJ, Ware RL, Michie L-J, Beckmann B, Majerus MEN (2008) The harlequin ladybird marches on. *British Wildlife* 19: 182–186.

Roy HE, Wajnberg E (2008). From biological control to invasion: the ladybird *Harmonia axyridis* as a model species. *Biocontrol* 53: 1–4.

Saito T, Bjornson S (2006) Horizontal transmission of a microsporidium from the convergent lady beetle, *Hippodamia convergens* Guerin-Meneville (Coleoptera: Coccinellidae), to three coccinellid species of Nova Scotia. *Biological Control* 39: 427–433.

Simmons AM, Legaspi JC (2004) Survival and predation of *Delphastus catalinae* (Coleoptera: Coceinellidae), a predator of whiteflies (Homoptera: Aleyrodidae), after exposure to a range of constant temperatures. *Environmental Entomology* 33: 839–843.

Simmons AM, Legaspi JC (2007). Ability of *Delphastus catalinae* (Coleoptera: Coccinellidae), a predator of whiteflies (Homoptera: Aleyrodidae), to survive mild winters. *Journal of Entomological Science* 42: 163–173.

Smith SF, Krischik VA (2000) Effects of biorational pesticides on four coccinellid species (Coleoptera: Coccinellidae) having potential as biological control agents in interior landscapes. *Journal of Economic Entomology* 93: 732–736.

Tedders WL, Schaefer PW (1994) Release and establishment of *Harmonia axyridis* (Coleoptera: Coccinellidae) in the south-eastern United States. *Entomological News* 105: 228–243.

Thomas RJ, Majerus MEN, Brown PMJ, Roy HE (2009) A first record of *Cynegetis impunctata* (Coleoptera: Coccinellidae). *British Journal of Entomology and Natural History* 21

van Lenteren JC, Babendreier D, Bigler F, Burgio G, Hokkanen HMT, Kuske S, Loomans A JM, Menzler-Hokkanen I, van Rijn PCJ Thomas MB, Tommasini MG, Zeng QQ (2003). Environmental risk assessment of exotic natural enemies used in inundative biological control. *Biocontrol* 48: 3–38.

van Lenteren JC, Bale J, Bigler F, Hokkanen HMT, Loomans AJM (2006) Evaluating risks of releasing exotic biological control agents of arthropod pests. *Annual Review of Entomology* 51: 609–634.

Ware RL, Majerus MEN (2008) Intraguild predation of immature stages of British and Japanese coccinellids by the invasive ladybird *Harmonia axyridis*. *Biocontrol* 53: 169–188.

Yasuda H, Evans EW, Kajita Y, Urakawa K, Takizawa T (2004) Asymmetric larval interactions between introduced and indigenous ladybirds in North America. *Oecologia* 141: 722–731.

Yigit A, Canhilal R (2005) Establishment and dispersal of *Serangium parcesetosum* Sicard (Coleoptera, Coccinellidae), a predatory beetle of citrus whitefly, *Dialeurodes citri* Ashm. (Homoptera, Aleyrodidae) in the East Mediterranean region of Turkey. *Zeitschrift Fur Pflanzenkrankheiten Und Pflanzenschutz-Journal of Plant Diseases and Protection* 112: 268–275.

Yigit A, Canhilal R, Ekmekci U (2003). Seasonal population fluctuations of *Serangium parcesetosum* (Coleoptera: Coccinellidae), a predator of citrus whitefly, *Dialeurodes citri* (Homoptera: Aleyrodidae) in Turkey's eastern Mediterranean citrus groves. *Environmental Entomology* 32: 1105–1114.

Zang LS, Liu TX (2007) Intraguild interactions between an oligophagous predator, *Delphastus catalinae* (Coleoptera: Coccinellidae), and a parasitoid, *Encarsia sophia* (Hymenoptera: Aphelinidae), of *Bemisia tabaci* (Homoptera: Aleyrodidae). *Biological Control* 41: 142–150.

Table 8.4.1. List and main characteristics of the Coccinellidae species alien to Europe. Status: **A** Alien to Europe **C** cryptogenic species. Country codes abbreviations refer to ISO 3166 (see appendix I). Habitat abbreviations refer to EUNIS (see appendix II). Phylogeny after (2 0, 35). Last update 01/03/2010.

Subfamily *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Coccidulinae								
Rhyzobius forestieri (Mulsant, 1853)	A	Parasitic/ Predator	Australasia	1982, IT	AL, FR, GR, IT	I	Coccids (Scale insects)	Katsoyannos (1997)
Rhyzobius lophanthae (Blaisdell, 1892)	A	Parasitic/ Predator	Australasia	1908, IT	AL, DE, ES, ES-BAL, FR, FR-COR, GB, GR,GR-CRE, IT, IT-SAR, IT-SIC, IL, MT, PT, PT-AZO, PT-MAD,	I, J100	Coccids (Scale insects specifically Diaspididae)	Erler (2001)
Rodolia cardinalis (Mulsant, 1850)	A	Parasitic/ Predator	Australasia	1888, PT	AL, CH, CY, DE, ES, ES-BAL, ES-CAN, FR, FR-COR, GB, GR, GR-CRE, IL, IT, IT-SAR, IT-SIC, MT, PT, PT-AZO, PT-MAD, UA	I, J100	Coccids (Scale insects)	Caltagirone (1989), Frank and McCoy (2007)
Scymninae								
Hyperaspis pantherina Fürsch, 1975	A	Parasitic/ Predator	Africa	2002, PT-MAD	PT-MAD	U	*Orthezia insignis* (Scale insect)	Booth et al. (1995), Fowler (2004)
Cryptolaemus montrouzieri Mulsant, 1853	A	Parasitic/ Predator	Australasia	1908, IT	AL, ES, ES-CAN, FR, FR-COR, GR,GR-CRE, IL, IT, IT-SAR, IT-SIC, PT, RU, SE,	I, J100	Mealybugs	Hamid and Michelakis (1994), Smith and Krischik (2000)
Nephus reunioni Fürsch, 1974	A	Parasitic/ Predator	Africa	1983, FR	AL, ES, FR, GR, IT-SAR, PT	I	Coccids (Scale insects)	Izhevsky and Orlinsky (1988)
Chilocorinae								
Chilocorus kuwanae Silvestri, 1909	A	Parasitic/ Predator	Asia	1989, IT	AL, IT	I	Coccids (Scale insects)	Ponsonby and Copland (2007b), Ricci et al. (2006)
Chilocorus nigritus (Fabricius, 1798)	A	Parasitic/ Predator	Asia	1994, IT	AL, ,IT	I, J100	Coccids (Scale insects)	Booth (1998), Ponsonby and Copland (2007a), Ponsonby and Copland (2007b)

Subfamily *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Sticholotidinae								
Serangium parcesetosum Sicard, 1929	A	Parasitic/ Predator	Asia	1986, FR-COR	FR, FR-COR	I	Aleyrodidae	Yigit and Canhilal (2005), Yigit et al. (2003)
Coccinellinae								
Harmonia axyridis (Pallas, 1773)	A	Parasitic/ Predator	Asia	1991, BE	AL, AT, BE, BG, BY, CH, CZ, DE, DK, ES, ES-CAN, FR, FR-COR, GB, GR, GR-CRE, GR-ION, GR-SEG, HU, IL, IT, IT-SIC, , LI, LU, NL, NO, PT, RO, RU, SE, SK, UA	I	Polyphagous insect predator particularly aphids and coccids	Adriaens et al. (2003), Adriaens et al. (2008), Brown et al. (2008a), Brown et al. (2008b), Koch et al. (2003), Majerus (1994), Roy et al. (2005), Roy and Wajnberg (2008)
Hippodamia convergens Guerin-Meneville, 1842	A	Parasitic/ Predator	North America	1992, CZ	AL, BE, CZ, DK, SE	FA, J100	Aphids	Bjornson (2008), Phoofolo et al. (2008), Saito and Bjornson (2006)

Table 8.4.2. List and main characteristics of the Coccinellidae species alien within Europe. Country codes abbreviations refer to ISO 3166 (see appendix I). Habitat abbreviations refer to EUNIS (see appendix II). Phylogeny after Fürsch (1990), Koch et al. (2006). Last update 01/03/2010.

SubFamily *Species*	Regime	Native range	Invaded countries	Habitat*	Hosts	References
Scymninae						
Scymnus impexus Mulsant, 1850*	Parasitic/ Predator	West Palearctic	GB, SE	G, I2	*Dreyfusia piceae* on spruce and fir	Humble (1994), Majka and McCorquodale (2006)
Epilachninae						
Henosepilachna argus (Geoffroy, 1762)*	Phytophagous	West Palearctic	GB	E5, I2, FA	White bryony (*Bryonia dioica*)	Hill et al. (2005)

Table 8.4.3. Summary of release dates and records from wild populations of *Harmonia axyridis* across Europe. Adapted from Brown et al. (2008a). Updated: 01/03/2010

Country	Year of release (blank if not released)	Year of first record in the wild
Ukraine	1964	Unknown
Belarus	1968	Unknown
Portugal	1984	
France	1982	1991
Greece	1994	1998
Germany	1997	1999
Belgium	1997	2001
Netherlands	1996	2002
Spain	1995	2003
Switzerland	1996	2004
Luxembourg		2004
England and Channel Isl.		2004
Italy	1990s	2006
Czech Republic	2003	2006
Austria		2006
Denmark	2000s	2006
Wales		2006
Norway		2006
Poland		2007
Liechtenstein		2007
Sweden		2007
Northern Ireland		2007
Scotland		2007
Serbia		2008
Slovakia		2008
Hungary		2008
Bulgaria		2009
Romania		2009

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Coleoptera families other than Cerambycidae, Curculionidae *sensu lato*, Chrysomelidae *sensu lato* and Coccinelidae
Chapter 8.5

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Abstract

Here we consider 274 alien Coleoptera species belonging to 41 of the 137 beetle families in Europe (Cerambycidae, Curculionidae *sensu lato*, Chrysomelidae *sensu lato* and Coccinelidae are treated separately elsewhere). Among the families we consider as having invaded the European fauna, Acanthocnemidae and Ptilodactylidae represent new arrivals. Many species-rich families have surprisingly few aliens, whereas some relatively minor families such as Dermestidae, Nitidulidae and Anobiidae have a relatively high representation of alien species. Since the start of the 19th century, the number of coleopteran aliens introduced into Europe has continued to increase. Alien species colonizing Europe derive from a wide range of geographic regions as well as ecozones, but the most important source area is Asia. The countries with the largest number of alien species established are France, Germany and Italy. The majority have been introduced accidentally via international transport mechanisms. The most important route for importation is stored products and crops, followed by transport of wood, then horticultural and ornamental plants. Most alien species in these families are found within anthropogenic habitats in Europe. The introduction of invasive alien beetles in these families has had significant economic impacts, particularly as pests of stored foodstuffs, as well as serious ecological impacts. For example, the buprestid species *Agrilus planipennis*, recently recorded in Russia, is an important potential economic threat which may also impact the biodiversity associated with ash trees.

Keywords

Europe, beetles, Dermestidae, Nitidulidae, Anobiidae, alien species, invasive species, stored products, pests

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8.5.1. Introduction

Introductions of alien species in Europe started in ancient times (Genovesi and Shine 2003), but this phenomenon has grown rapidly during the two last centuries. This is considered largely to be a consequence of the globalization of trade (Smith et al. 2007). Among these introductions, Coleoptera dominate the alien terrestrial invertebrates in Europe, where the fauna consists of over 27,000 species in 137 families (Fauna Europaea Web Service). In addition to the alien species observed in the families Cerambycidae, Curculionidae (*sensu lato*), Chrysomelidae (*sensu lato*) and Coccinelidae, which were treated in the preceding chapters, 274 other beetles of exotic or cryptogenic origin have been established to date in Europe (Table 8.5.1). These alien species belong to 41 different families. Additionally, 237 species are considered to have been introduced through human activity from one region of Europe to another (Table 8.5.2). However, the cause of such movements are often difficult to ascertain, particularly where the original range is poorly known. Thus, the analyses detailed below will mostly consider the species alien *to* Europe.

8.5.2 Diversity of alien coleopteran species

The Coleoptera families treated here with the greatest number of species in Europe are Staphylinidae (rove beetles), Carabidae (ground beetles) and Tenebrionidae (darkling beetles) but these have proportionally few alien species (figure 8.5.1). These three families constitute an important component of the European ground fauna (Dajoz 2002). Conversely, the families with the most aliens in Europe and significant economic impact tend to be families with relatively few native species such as Dermestidae (carpet beetles), Nitidulidae (sap-feeding beetles) and Anobiidae (death-watch beetles). Two of the 41 families do not have any native species in Europe and they are new arrivals for the European fauna: Acanthocnemidae (little ash beetles) and Ptilodactylidae (toe-winged beetles). The following presentation of families follows the taxonomic classification of Fauna Europaea (Fauna Europaea Web Service) and of the Tree of Life Web Project (Maddison et al. 2007) (for Ptilodactylidae, not included in Fauna Europaea).

ADEPHAGA

The **Carabidae,** are widespread and known to colonize a great diversity of ecological niches (Denux et al. 2007, Holland 2002). They are typically predators (as larvae and adults), although some groups (e.g. Harpalinae) have evolved toward granivory (feeding on seeds). These life traits do not favour passive transportation by humans, and thus, only eight alien species have been established in Europe, accounting for approximately 0.2% of the European carabid fauna. Among these, *Somotrichus unifasciatus*, *Trechicus nigriceps* and *Plochionus pallens* have benefited from the global trade in food products to become cosmopolitan, being introduced with cargos of groundnuts, rice, broad beans,

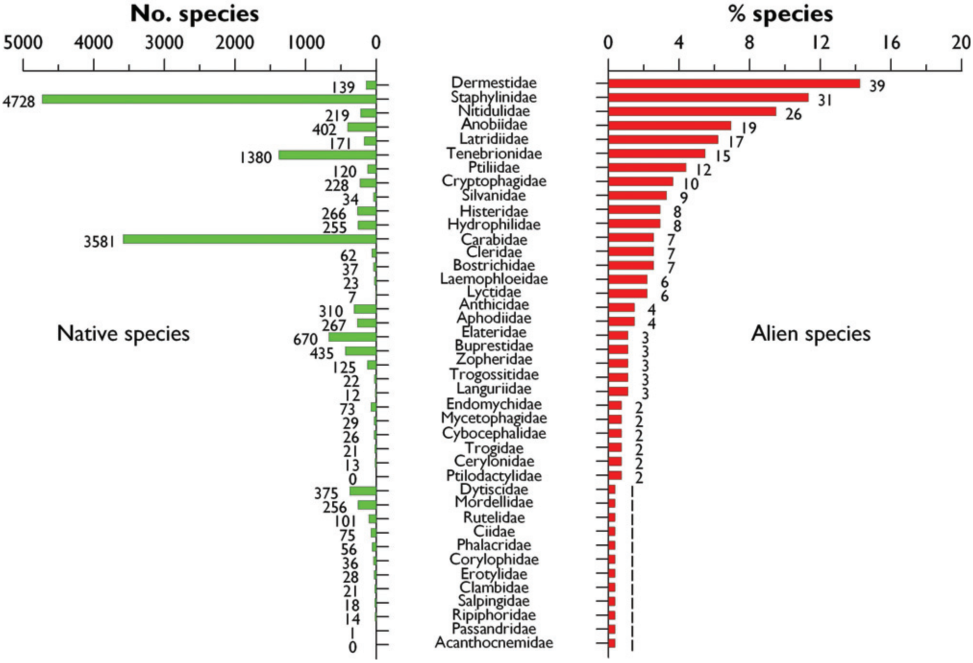

Figure 8.5.1. Relative importance of the Coleoptera families other than Cerambycidae, Curculionidae *sensu lato*, Chrysomelidae *sensu lato* and Coccinelidae families in the alien and native fauna in Europe. *Right* - Relative importance of the families in the alien entomofauna. Families are presented in a decreasing order based on the number of alien species. Species alien *to* Europe include cryptogenic species. The number over each bar indicates the number of alien species observed per family. *Left* - Species richness of the same families in the native European entomofauna. The number over each bar indicates the total number of species observed per family in Europe.

cocoa, etc. (Jeannel 1942, Weidner et al. 1984). Only one species is established throughout Europe: *Trechicus nigriceps* (recorded in 30 countries). This species seems to have been imported from the Eastern coast of Africa several centuries ago (Jeannel 1942).

The **Dytiscidae** (predaceous diving beetles) are all aquatic carnivores. Only one dytiscid beetle has been reported in our database (DAISIE). This large South American species, *Megadytes costalis*, has been recorded once in Great Britain, but there is no data on its establishment in the wild.

POLYPHAGA STAPHYLINIFORMIA

The **Hydrophilidae** (water scavenger beetles) are another family of aquatic beetles, easily distinguished from the Dytiscidae by the length of their maxillary palpi. One tribe, the Sphaeridiini, is exceptional due to its terrestrial, saprophagous and coprophagous habits. Many species share mammal dung with scarab beetles. Significantly, among eight hydrophilids reported as aliens in Europe, seven belong to the Sphaeridiini.

The **Histeridae** (clown beetles) are mainly predators, specializing on saprophagous, coprophagous or necrophagous prey. Eight species have been reported in the database, but little is known about their life traits, except for the widespread, cryptogenic *Carcinops pumilio*, which is common everywhere in natural and anthropized habitats.

The **Ptiliidae** (featherwinged beetles) are a very small family (120 species in Europe and 180 in the world) of which 12 alien species have been recorded in Europe. These are very tiny beetles, including the smallest of all, with a length of just 0.5 mm, whilst even the largest members of the family do not exceed 2 mm. Adults and larvae are usually found in rotting organic material in a wide range of habitats. Their small size and lifestyle means that they are easily dispersed via the movements of soil.

Staphylinidae is the most important group of Coleoptera in Europe and the second richest in the world (with over 46,000 species), but the number of alien species (31) in Europe is proportionally low, representing 0.7% of the whole of the Europeans staphylinid fauna. Many genera were not included in Fauna Europaea (Fauna Europaea Web Service), due to the lack of taxonomic expertise. Staphylinidae alien species found in Europe are essentially predatory (Coiffait 1972, Paulian 1988) and mainly species associated with compost, humus and decomposing matter (Cho 2008, Ødegaard and Tømmerås 2000, Tronquet 2006), such as *Bisnius parcus*, *Lithocharis nigriceps* and *Oxytelus migrator*. One predatory species, *Philonthus rectangulus*, has been reported from 36 countries/islands. Originating from temperate East Asia, it may have expanded westward naturally.

POLYPHAGA SCARABAEIFORMIA

The **Trogidae** (hide beetles) are a small family of beetles related to the scarabs. They feed on mammal skins and furs, or on bird feathers, either as late arriving necrophages on carrion, or as commensals of vertebrates in their nests. Two species from Australasia have been recorded in Spain in our database.

The **Aphodiidae** (dung beetle) are mainly small dung beetles, frequently included in the Scarabaeidae. Four species have been recorded as aliens, in one country only. Both *Saprosites* species introduced in Great Britain seem to be saproxylic beetles (Angus et al. 2003).

The **Rutelidae** (leaf chafers) are a family of brightly-coloured beetles, especially diverse in the tropics. Only one species of this family has been found in the Azores, the well-known Japanese beetle, *Popilia japonica*, which is considered as a severe pest in the United States, where it was introduced from Japan in 1912.

POLYPHAGA ELATERIFORMIA

The **Clambidae** (minute beetles) are very small beetles that have the capability to roll into a ball. One species is listed here, the Australian *Clambus simsoni*, a saprophagous species which seems to be rapidly expanding in western Europe.

The **Buprestidae** (metallic wood-boring or jewel beetles) are a well-known family of xylophagous beetles. In most cases, the larvae develop in living wood, and a few species became major pests in orchards or forests. Only three buprestid species have been reported as aliens in the database, each observed in only one country.

The **Ptilodactylidae**, the "toed-winged beetles", are a group of elateriform Coleoptera, which was formely treated as part of the Dascilloidea and included in Byrrhoidea (Maddison et al. 2007). Little is known of the biology of adults (Aberlenc and Allemand 1997). The habit of soil-leaf litter dwelling of both the adults and larvae facilitates their distribution with potted plants (Mann 2006).

The **Elateridae** (click beetles) are a large family of beetles with quite diverse life history traits. Some species have soil-living larvae, either predators or rhizophages, with reported agricultural pests in the latter category. Other species are saproxylic (predators or saprophages), some of which are very specialized, and have high conservation value. Three species are reported as aliens here, occuring in one country each. The life history traits of these species remain unknown.

POLYPHAGA BOSTRICHIFORMIA

The European **Dermestidae** comprise only 139 species (less than 1% of the European Coleoptera fauna) yet they are the largest contributor to the database, with 40 species reported as aliens. Many species are synanthropic and associated with animal remains, leathers and skins, dried meats, woollens and furs (Delobel and Tran 1993), such as *Dermestes vorax*, *D. frischi*, *D. maculatus*, *D. lardarius* and *Anthrenus flavidus*. Some species eat stored seeds such as *Trogoderma granarium.* The protraction of the number of larval stages and longevity in suboptimal nutritive media (Delobel and Tran 1993), as well as the relevance of the food product trade, explain partly how the damaging pests of this family have easily conquered new territories.

The **Lyctidae** (true powder-post beetles) are a very small family (13 species in Europe) closely related to the Bostrichidae. All species are wood-borers, specializing on hardwoods. They usually attack dry wood that is less than five years old, and may become important pests of structural wood or furniture. As inhabitants of raw or manufactured wood products, they are easily transported. Six species have been reported as aliens in Europe, but only one, *Lyctus brunneus*, has been established throughout the continent for more than 150 years.

The **Bostrichidae** (horned powder-post beetles) are a small family (37 native species in Europe). The native species are saproxylophages, whereas the aliens are either wood-borers or grain-feeders (apparently, some species show both feeding habits) (Lesne 1901). Seven species have been reported as aliens, and have been found in many countries. The wood-borers may cause important damage to manufactured objects, but the stored-product feeders (*Dinoderus* spp., *Rhyzopertha dominica*) are the most economically harmful. Among these, the lesser grain borer, *Rhyzopertha dominica*, has been observed in 34 countries/islands.

The **Anobiidae** have 19 alien species compared to 402 native species in Europe. About 11 species are associated with stored food products and include devastating pests such as *Lasioderma sericorne* which attacks a wide variety of dried products of animal or vegetable origin (Espanol 1992, Weidner et al. 1984). Several species attack soft woody matter: wood in the case of *Ernobius mollis*, but also books in the case of *Nicobium castaneum*, which can cause irrepairable damage. Many cryptogenic anobiid species are established in Europe for centuries, and may be found in many countries.

POLYPHAGA CUCUJIFORMIA

The **Nitidulidae** have 26 aliens compared with 219 native species in Europe. A third of these have occurred as far west as Macaronesia, but the other species have expanded their range in many countries of mainland Europe. As the majority of species are pollen-eaters, phytophagous, mycetophagous or predatory, they have a particular agronomic importance, damaging crops and stored food products. Among these, the 13 aliens species of the genus *Carpophilus* cause damage to dried fruits (Weidner et al. 1984).

The **Cybocephalidae** are a very small family, frequently subsumed within Nitidulidae. Cybocephaline beetles are well known predators of armoured scale insects (Coccoidea: Diaspididae) throughout tropical, sub-tropical and temperate regions of the world (Kirejtshuk et al. 1997).They are minute beetles, very convex and able to roll into a ball, as for Clambidae.

The **Silvanidae** (silvanid flat bark beetles) are a small family (34 native species in Europe) of flat beetles, formerly included in the Cucujidae. These insects were originally mycetophages, living under the bark of trees, but the feeding habits of many species have adapted to grain and fruit feeding, so that they have become synanthropic pests of stored products (Ratti 2007). Nine species are listed in the database, among which three are cryptogenic, long-established species occuring in several countries, such as the sawtoothed grain beetle, *Oryzaephilus surinamensis*.

The **Laemophloeidae** (lined flat bark beetles) are a small family of flat beetles with 23 native species in Europe, which was formerly included in the Cucujidae. They are closely related to the Silvanidae, and show the same life history traits. Six species, belonging to the genus *Cryptolestes*, are reported as aliens in Europe. They have established successfully in many countries.

The **Phalacridae** (shining flower beetles) are a small family of minute, rounded beetles. One North American species of *Phalacrus* has been recorded in the Azores, whose biological traits remain unknown (many species are micro-mycetophages).

The **Cryptophagidae** (silken fungus beetles) are an important family of mycetophagous insects with 228 native species in Europe, living in various habitats. Ten species have been reported as aliens in Europe, which are now established in many countries (the Cryptophagidae have the widest species range). The majority of these species (*Cryptophagus* spp.) are cryptogenic, feeding on fungal spores or decaying vegetal material, sometimes on stored products.

The **Languriidae** (lizard beetles) are a small family (12 native species in Europe) of phytophagous or saprophagous beetles. Three alien species are considered here, with a rather low dispersal rate. Nevertheless, *Cryptophilus integer* and *Pharaxonotha kirschii* are reported as pests of stored products.

The **Erotylidae** (pleasing fungus beetles) are a small family of mycetophagous beetles, with many species in saproxylic habitats. One Japanese species, *Dacne picta*, has possibly been introduced in Central Europe.

The **Cerylonidae** (minute bark beetles) are a small family of saproxylic beetles. They just appear here because a well-known pest of stored grain, *Murmidius ovalis*, is now included in this family (formerly Murmidiidae). This is a cosmopolitan species probably originating from tropical Asia.

The **Endomychidae** (handsome fungus beetles) are a small family of mycetophagous beetles (Shockley 2009, Shockley et al. 2009b), closely related to the Coccinellidae. Two very small species (*Holoparamecus* spp.) are cryptogenic and may be found in many countries worldwide.

The **Corylophidae** (minute hooded beetles) are another small family of micromycetophagous beetles, which occur in a variety of habitats. One species, *Orthoperus aequalis*, from Australia, has now established in 10 countries within Europe.

The **Latridiidae** (minute hooded beetles) are also a small family with 171 native species in Europe and 17 aliens which are essentially mycetophagous and associated with stored food products, such as *Dianerella filum* or *Cartodere nodifer*. These species are also plaster beetles which occupy wet places in the plastered walls of houses (Bouget and Vincent 2008). However, these latridiids do not appear to have an economic impact (Delobel and Tran 1993) and merely indicate bad food storage conditions.

The **Trogositidae** (bark-gnawing beetles) are a small family of saproxylic insects, living as saprophages or predators of other insects under the bark of trees. The three species reported here are predators of cosmopolitan pests of stored products.

The **Cleridae** (checkered beetles) are a conspicuous family of brightly coloured insects. Nearby all species are predators of other insects. Seven species are reported as aliens in the database, some of them (*Necrobia* spp.) established in Europe for a long time. These are either predators of xylophagous beetles or predators of stored product insects, and thus likely to be transported everywhere with their prey. We include here in the Cleridae the small family Thanerocleridae, which shows life traits similar to the typical Cleridae, with one introduced species, *Thaneroclerus buqueti*.

The **Acanthocnemidae**, have only one alien species: *Acanthocnemus nigricans* which is attracted by forest fires (Schmitz et al. 2002). The recent worldwide expansion of this species is due to the commercial export of Australian wood (Kreiss et al. 2005).

The **Mycetophagidae** (hairy fungus beetles) are a family of saproxylic insects, feeding on tree fungi. Two species, specialized on fungi growing on rotten vegetal material, are reported in the database. *Typhaea stercorea* is a well-known cryptogenic species, whereas *Litargus balteatus* is an American species found only recently in Europe

The **Ciidae** (minute tree-fungus beetles) are another family of saproxylic insects feeding on tree fungi. Only one species (out of 76 occurring in Europe) is reported here as alien, *Xylographus bostrichoides*. This small insect probably originates from Asia and has to date been found in 19 European countries.

The **Mordellidae** (tumbling flower beetles) are a large family (256 native species in Europe) of flower-dwelling insects, with endophytic larvae. Only one species, *Mordellistena cattleyana*, is considered as an alien in Europe. This is a neotropical insect whose larvae develop inside tissues of ornamental orchids (Costa Lima 1955). This behaviour may have enabled its importation through the horticultural trade, since it has been found in Germany and the Netherlands.

The **Ripiphoridae**, formerly spelled Rhipiphoridae (wedge-shaped beetles), are a small family of strange parasitic insects. Their larvae develop in other insect orders, namely Hymenoptera, Orthoptera or Dictyoptera. One species, *Ripidius pectinicornis*, has sometimes been found in harbours, along with its host cockroaches (mainly *Blatta orientalis*).

The **Zopheridae** (ironclad beetles) were previously included in the Colydiidae. This is a family of saproxylic, bark-living insects with 125 native species in Europe. The three species reported as aliens in Europe are probably predators of other saproxylic insects. They are established in one country only, or a small number of countries in the case of *Pycnomerus inexpectus*, a species found in tropical greenhouses.

The **Tenebrionidae** is mainly composed of saprophagous species. Many species are xerophiles or thermophiles, which explains their predominance in areas with hot climate and their low representation in more temperate zones (Dajoz 2002). About 15 tenebrionid alien species are present in Europe (1.1% of European tenebrionid fauna). The majority of these species are associated with spoiled or wet cereals (Weidner et al. 1984). They include very damaging pests, such as species of *Tribolium*, which enter cracks in wet or already damaged seeds, and *Alphitobius* spp., which feed on mildewed food products.

The **Salpingidae** (narrow-waisted bark beetles) are a small family of saproxylic beetles with 18 native species in Europe. One species only is mentioned here, *Aglenus brunneus*, formerly included in the Colydiidae (Zopheridae). It is a very small, blind insect, often found in stables or poultry houses, where it feeds on animal waste (Dajoz 1977).

The **Anthicidae** (antlike flower beetles) are small beetles resembling ground beetles. Four species are considered as aliens, among 310 native species living in Europe. These insects typically feed on rotten vegetal material, which has been heated through fermentation. These life history traits probably enable a wide tolerance to cold temperatures, and some species are cosmopolitan, found everywhere in the world, from tropical to boreal climates, e.g. *Omonadus floralis*, recorded in 40 countries.

8.5.3 Temporal trends

Some Coleoptera species were introduced to Europe a very long time ago. Fossils of alien species have even been found in archeological sites, such as the blind flightless beetle *Aglenus brunneus* in Iceland (Buckland et al. 2009) and *Amara aulica* (alien but native in Europe), which arrived in the Faroe islands with the Viking settlers

(Brandt 2006). But the first date of introduction of a new species into a country is often difficult to establish. A species could have been present for years without its presence being noticed immediately. Particularly relevant here are small or inconspicuous species lacking agronomic or economic impact (e.g. Ptiliidae), and members of neglected or hard to identify taxonomic groups (e.g. Cryptophagidae and Staphylinidae).

The precise date of the first record is available for 201 species (i.e. 73.1% of aliens). The first statistical data derives from the beginning of the 19th century with the introduction of the nitidulid *Carpophilus hemipterus* in 1800 by the historical opening of trade routes (Audisio 1993). Then comes the trogossitid *Tenebroides mauritanicus* in 1803, and the anobiid *Nicobium castaneum* in 1807. The endomychid *Holoparamecus depressus* arrived in 1843 and the anobiid *Lasioderma sericorne* in 1848. These detritivores are all associated with stored food products or wood.

We observed an accelerating increase in the number of new records per year (figure 8.5.2), from 0.1 p.a. between 1800–1849 to 3.5 p.a. during 2000–2007, with an intermediate level of 1.3 p.a. during the period 1900–1924. During this last period, 33 new alien species were recorded, including 14 alone for the year 1900. This unexpected increase coincides with the industrial revolution of the first developing European countries (Cosseron and Faverjon 1991) (Great Britain, Belgium, France, and Germany) and with the increase in imports ensuing from it.

8.5.4 Biogeographic patterns

8.5.4.1 Origin of alien species

Alien species come from all continents except Antarctica (figure 8.5.3) (arthropods most represented on this continent are Collembola and mites rather than beetles) (Schulte et al. 2008). The considerable periods of environmental stress in Antarctic (Benoit et al. 2009) limit the diversity of insects, even though a very few beetles do occur there (Vernon et al. 1999), such as the ground-beetles *Amblysogenium pacificum* and *A. minimum*. These factors explain easily the absence of invasives coming from Antarctic.

About 82 aliens have origins currently considered cryptogenic. These are cosmopolitan species or distributed mainly in on one or more ecozones, with a tendency to become cosmopolitan. This is particularly the case with the cryptophagid *Cryptophagus cellaris*, a holarctic species which has become practically cosmopolitan following international commercial exchanges (Delobel and Tran 1993).

Asia is the most important source of aliens, with 58 species established in Europe (21%), comprising Dermestidae (13 spp.), Staphylinidae (8 spp.), Nitidulidae (6 spp.), Anthicidae (4 spp.) and Carabidae (3 spp.). These families are generally associated with stored products, crops, decomposing matter such as compost, and to a lesser extent with wood. The 16 other families number one or two species of aliens each.

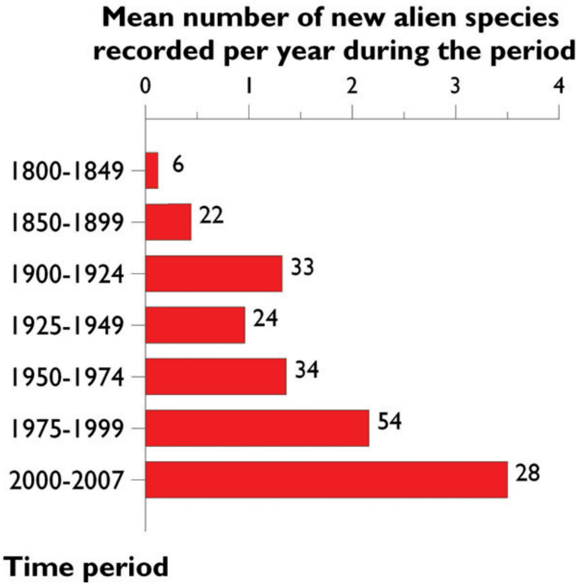

Figure 8.5.2. Temporal changes in the mean number of new records per year of alien Coleoptera species of families other than Cerambycidae, Curculionidae *sensu lato*, Chrysomelidae *sensu lato* and Coccinelidae, from 1800 to 2007. The number over each bar indicates the absolute number of species newly recorded per time period.

About 35 aliens come from Africa and these comprise Nitidulidae (5 spp.), Carabidae (3 spp.), Histeridae (3 spp.), Hydrophilidae (3 spp.) and Tenebrionidae (3 spp.). Nitidulidae and Tenebrionidae have been transported through stored food products. The mode of introduction is unknown for Carabidae and Hydrophilidae. There are also 14 other families having one or two alien species, which are partly associated with stored food products and wood.

The 55 aliens coming from the American continent (20% of the all alien species to Europe), include 24 species from North America and 31 species from Central and South America. From North America, the principal families are Dermestidae (7 spp.), Nitidulidae (6 spp.) and Tenebrionidae (4 spp.). Four species of Staphylinidae and four species of Ptiliidae derive from Central and South America. As for Asia and Africa, the neoarctic and neotropic aliens are mainly associated with foodstuffs and cultures. About 16 other families coming from America with one or two alien species have also been recorded in Europe.

Relatively few aliens originate from Australia. The 25 species of Australian origin include Latridiidae (4 spp.), Ptiliidae (4 spp.) and Staphylinidae (3 spp.). These species have no economic impact. The 12 other families include one or two alien species each, among which are species of the stored food products (*Ptinus ocellus*, *Anthrenus oceanicus*, *Brachypeplus mauli*) or living under the tree bark (*Ptinella cavelli* and *P. errabunda*).

The aliens with a specifically tropical origin (Pantropical) are the least presented in Europe with 20 species, that is to say 7% of all exotic species to Europe. The families

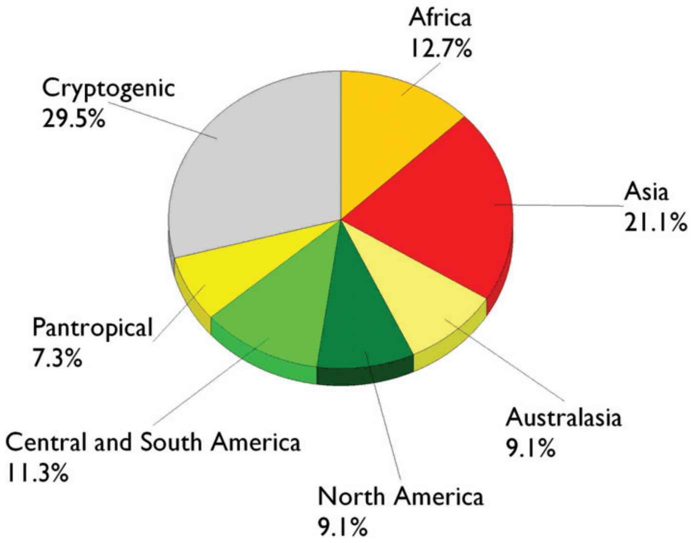

Figure 8.5.3. Origin of the Coleoptera species alien *to* Europe of families other than Cerambycidae, Curculionidae *sensu lato*, Chrysomelidae *sensu lato* and Coccinelidae

with the most species are Anobiidae (3 spp.), Bostrichidae (3 spp.) and Tenebrionidae (3 spp.). The eight other families have only one or two species each. These tropical aliens are associated with stored food products and fruits.

During different time slices, the origin of alien species has increasingly diversified (figure 8.5.4). The number of ecozones represented has increased from three (Africa, Asia, Pantropical) during 1800–1849 to six since 1950–1974 (Africa, Asia, Australasia, Central and South America, North America, Pantropical). The geographic source has also varied temporally although Asia has always been both an important and early region of origin. This situation can be explained by the opening of the trade route between Europe and India by the Cape of Good Hope at the end of the 15th century (which was also the sole sea route before the opening of the Suez Canal in 1869) and the strong Western influence which followed, the opium wars and the East India Companies, which revolutionized methods and the extent of the trade with Asia.

We highlight especially two ambiguous periods for biological invasions: 1850–1899 and 1925–1949. During the first period, no new record of an alien from Africa was recorded in Europe. The same goes for the second period with a fall of the number of new arrivals detected from South America (nine in 1900–1924 and only two in 1925–1949). These phenomena may coincide with the Great Depression, the result of the economic crisis of 1929 (Cosseron and Faverjon 1991, Gravereau and Trauman 2001), which affected both the level of protectionism on trade routes and the overall volume of international economic exchange between Europe and its colonies. The consequence for South America, Asia and Africa was "the crisis of dessert products", coinciding with the fall of the purchasing power in Europe and North America. Thus in Brazil for example, in an attempt to control the market, coffee was burned in engines (Launay 1999).

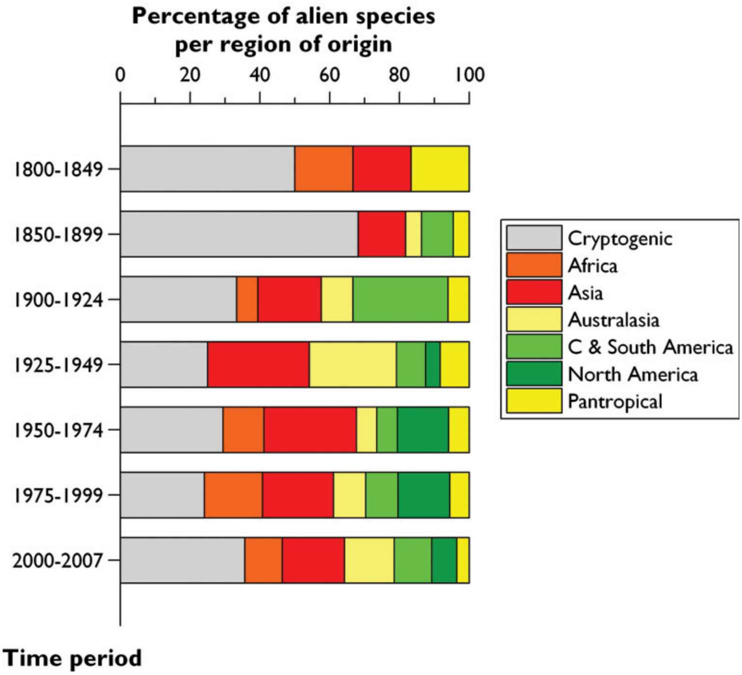

Figure 8.5.4. Temporal changes in the origin of the Coleoptera species alien *to* Europe of families other than Cerambycidae, Curculionidae *sensu lato*, Chrysomelidae *sensu lato* and Coccinelidae

The late arrival of aliens to Europe from North America is remarkable (first record in 1935) and probably corresponds to weak exports of foodstuffs towards Europe (except cereals). For forest biotopes especially, the North American component of species is small and of limited economic impact in Europe (Dajoz 2007).

8.5.4.2 Distribution of alien species within Europe and their range expansion

The majority of European countries have been directly affected by alien species (figure 8.5.5), but there is a very great mismatch in the number of species present in one country versus another.

The archipelago of Svalbard, with an insect fauna of a meagre 230 species (Coulson 2007), seems free from aliens. As in the case of Antarctica, the strong environmental contraints (harsh temperatures, shortened seasons and strong winds) have evidently limited the colonization of insects (Hulle et al. 2008) and geographical isolation has posed a barrier. For Macedonia there is a lack of readily accessible data (Tomov 2009), which has prevented us updating the situation there.

The countries/islands most affected by aliens are France (126), Germany (107), Italy (101), Austria (98), Great Britain (97), Switzerland (91), the archipelago of Azores (92), Denmark (89) and the Czech Republic (84).

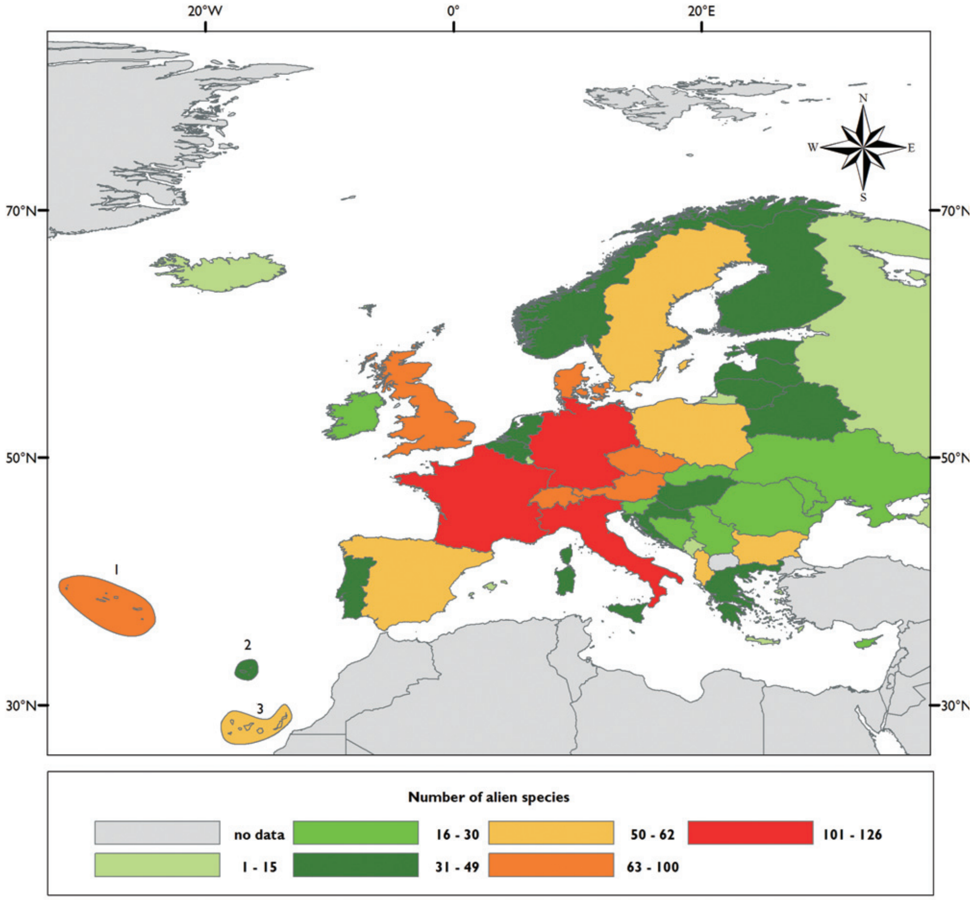

Figure 8.5.5. Comparative colonization of continental European countries and islands by by the Coleoptera species alien *to* Europe of families other than Cerambycidae, Curculionidae *sensu lato*, Chrysomelidae *sensu lato* and Coccinelidae. Archipelago: **1** Azores **2** Madeira **3** Canary islands.

The number of aliens per country is not significantly correlated with Global Domestic Product per capita (International Monetary Fund), latitude, nor longitude of the centroid of the country. In contrast, the number of aliens per country is significantly correlated with import (Spearman-Rho 0.650, P-value < 0.001) from 2003 to 2008 (The World Factbook) and also more weakly with area (Spearman-Rho 0.432, P-value < 0.01).

In spite of its geographical isolation (1500km from Europe, 1450km from Africa and 3900km from North America) and its small area, the archipelago of Azores has a large number of aliens. Since their historical discovery, the geographic position of the Azores has made the islands a strategic harbour for transatlantic ships, resulting in the introduction overall of several hundreds of taxa (Haggar 1988, Heleno 2008). Twenty-four alien species have been recorded exclusively in the Azores archipelago.

Indeed, alien native species in Europe have colonized islands more than other continental countries. The archipelago of Azores is the most affected with 126 alien species to Europe, followed by Great Britain (with 58 aliens), Faroe Islands (32 aliens) and Canary Islands (32 aliens). Perhaps surprisingly, Austria is the most important continental country affect by alien native to Europe, with 13 species.

8.5.5 Main pathways to Europe

The most important pathways for accidental invasions of exotic species to Europe are those closely bound to international transport, whereas the most important processes relating to deliberate introductions are the biological control of agricultural pests and the pollination of crops (Ruiz and Carlton 2003). Rapidly developing international trade and the reduction of travel times by air to less than two days, have meant that a living insect can be transported almost any part of the world (Mouchet et al. 1995).

Only three species have been introduced intentionally in Europe, two for biological control. The first is the cybocephalid beetle *Cybocephalus nipponicus*, originating in South Korea (Evans et al. 2005) and introduced into Italy for the control of cochineals bugs (Diaspididae) (Lupi 2002). The second species is *Ripidius pectinicornis* (Ripiphoridae), a parasitoid of the german cockroach *Blattella germanica* (Falin 2001) which was released from culture and is now present in several European countries (Bétis 1912). The third species is the tenebrionid *Zophobas morio* which has been used for bird and especially lizard food (Thomas 1995).

About 98.9% of aliens have been introduced accidently in Europe. The exact pathway of introduction is difficult to establish. The introduction vector is unknown for 123 aliens out of the total of 275. Theses aliens are essentially detritiphagous, saproxylophagous or predatory species.

The first clearly identified means of importation is via stored products and crops (approximately 120 aliens, or 40%). This can be explained by the importance of the international stored products trade (cereals, fruits and vegetables) and the primary position of Coleoptera as pests of stored products (Delobel and Tran 1993). About 20 Coleoptera have been implicated directly in the transport of woods. Some species have been found in wood derivatives such as *Dinoderus minutus*, a bostrichid introduced with furniture and bamboo-work (Lesne 1901). Few species have been identified as transported with horticultural or ornamental products, despite the increase of economic importance of ornamental pot plants (Lawson 1996), in sharp contrast for example to the situation in Lepidoptera (see Chapter 11). However, the level may be underestimated for this route, as some Coleoptera tend to occur in compost and may pass unnoticed via the pot plant trade.

The extruded starch products used as impact protection for fragile packing can even be a food source for stored grains pests (Fraga et al. 2009) as for *Cryptolestes ferrugineus*, *Lasioderma serricorne* and *Tribolium castaneum*. Thus starch-packings could become a new vector of introductions in the future.

8.5.6 Most invaded ecosystems and habitats

The anthropogenic habitats most strongly colonized by coleopteran alien species (figure 8.5.6), are buildings (50%), cultivated lands (20%) and forest habitats (10%). The large proportion of species associated with foodstuffs explains this relation. Conversely, the weak colonization of pseudo-natural habitats can be explained by the near-absence of phytophagous, and more particularly phyllophagous species among the coleopteran families treated here. This result contrasts with the situation for other groups of predominantly phytophagous insects (Cerambycidae, Chrysomelidae, Lepidoptera: Chapter 8.1, 8.3, 11).

In spite of the popularity of exotic species for the aquatic animal and plant trade (Leppäkoski et al. 2002) and the fact that migrating waterfowl can transport aquatic invertebrates or their eggs (Figuerola et al. 2003), surprisingly no water beetle has been introduced into Europe, except for the dytiscid *Megadytes costalis* (again contrasting with the situation for Lepidoptera, the aquatic Pyraloidea: Chapter 11). This low importance of the aquatic route in Coleoptera is also observed in the United States, where only 2.2% of the invasive arthropods are aquatics (Pimentel et al. 2005).

8.5.7 Ecological and economics impacts

Most alien species do not become invasive in their new locations (Genovesi and Shine 2003). It is often difficult to predict whether a new introduction will actually become established (Streito and Martinez 2008). However, the subset of alien species that are invasive may have significant environmental, economic and public health impacts and threaten the wholesale homogenisation of ecosystems (Sefrova 2005).

Invasive alien species are now considered to be the second greatest cause of global biodiversity loss after direct habitat destruction (Simberloff 2001) and have adverse environmental, economic and social impacts from the local level upwards.

The invasion of most Coleoptera treated here bears a direct relation to human presence (synanthropic species). Their impact is essentially with stored foodstuffs which they can extensively damage (Sefrova 2005). Coleoptera damaging stored food products on a global economic scale are very few (Delobel and Tran 1993), but include several species of aliens in Europe, among which are *Cryptolestes ferrugineus*, *C. pusillus*, *Lasioderma serricorne*, *Oryzaephilus surinamensis*, *Rhyzopertha dominica*, *Tribolium castaneum*, *T. confusum* and *Trogoderma granarium*. The impact of insect pests in a given situation can widely fluctuate depending on various parameters, in particular on production levels and the commercial value of those products infested both in time and in a geo-economic context. However, these synanthropic species are not known to have a direct effect on biodiversity.

The situation for agronomic and forest species can be different. The buprestid *Agrilus planipennis,* recently recorded in European Russia, is a very good example. This xylophagous East Asian species is presently causing significant damage to ash trees (*Fraxinus* spp.) in North America (Baranchikov et al. 2008). *A. planipennis* has killed

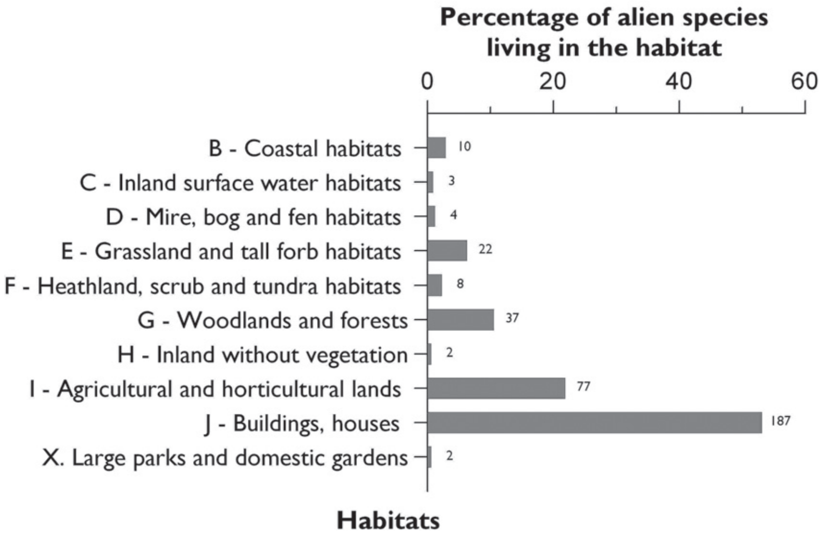

Figure 8.5.6. Main European habitats colonized by the Coleoptera species alien *to* Europe of families other than Cerambycidae, Curculionidae *sensu lato*, Chrysomelidae *sensu lato* and Coccinelidae. The number over each bar indicates the absolute number of alien coleopterans recorded per habitat. Note that a species may have colonized several habitats.

over 15 million forest and ornamental trees in several US States in less than 10 years (Poland and McCullough 2006). It is alarming that European ash trees are not more resistant than those of North America (Baranchikov et al. 2008). *Agrilus planipennis* could become a serious pest in Europe with a dramatic economy impact as well as potentially for biodiversity associated with *Fraxinus*.

Many species are associated with compost and even while their economical impact may be negligible (as mainly predators or detritivores), ecological disruption may still occur. This appears to be the case with the Staphylinid *Lithocharis ochracea*. This native beetle has declined, supplanted by the alien species *L. nigriceps* (Ødegaard and Tømmerås 2000, Tronquet 2006).

Even if the eradication of invasive species seems possible in Europe and in particular for mammals (Genovesi 2005), the possibility of eradication of invasive Coleoptera appears much more remote.

8.5.8 Conclusion

On of the most striking consequences of globalization is the increase in the problem of invasive species (Perrings et al. 2005). The volume of international trade and travel is now so great, and the modes of entry so varied, that not all consignments or routes of entry can be screened (Levine and D'Antonio 2003). Three categories are particularly important to highlight for the coleopteran alien species treated here: synantropic

Figure 8.5.7. Habitus of some Coleoptera species alien *to* Europe. **a** *Ernobius mollis* **b** *Tribolium castaneum* **c** *Oryzaephilus surinamensis* **d** *Alphitobius diaperinus* **e** *Cryptolestes duplicatus* **f** *Dermestes lardarius* **g** *Gnathocerus cornutus* **h** *Rhizopertha dominica* **i** *Necrobia ruficollis* **j** *Trechicus nigriceps* **k** *Lyctus brunneus* **l** *Gibbium psylloides* (Credit: Pierre Zagatti).

habitats with essentially stored products, compost (probably that associated with ornamental plants), and forest or wood-derived products.

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References

Aberlenc HP, Allemand R (1997) Acclimation en France de *Ptilodactyla exotica*, espèces à moeurs anthropophiles (Coleoptera, Ptilodactylidae). *Bulletin de la Société entomologique de France* 102: 93–102.

Abood F, Murphy RJ (2006) World distribution of *Minthea rugicollis* (Coleoptera: Lyctidae). *Journal of Tropical Forest Science* 18 (4): 250–254.

Allemand R (2008) Anobiidae nouveaux ou méconnus de la faune de France (3e note) (Coleoptera). *Bulletin de la Société entomologique de France* 113 (3): 397–402.

Alonso-Zarazaga MA, Sánchez-Ruiz M, and Sánchez-Ruiz A (2003) Une nueva familia de Coleoptera para Espana: Acanthocnemidae. *Bol. S.E.A.* 32: 179–180.

Anderson R (1997) Northern Ireland species inventories. Rove beetles (Coleoptera: Staphylinidae). Environment and Heritage Service. http://www.ehsni.gov.uk/pubs/publications/Staph.pdf

Anderson R, McFerran D, Cameron A (2000) The Ground Beetles of Northern Ireland (Coleoptera, Carabidae). Atlas of the northern Ireland Flora and Fauna, Volume 1. Ulster Museum, U.K., Belfast. 256 pp.

Angus RB, Wilson CJ, Maté JF, Hammond PM, Mann DJ (2003) *Saprosites mendax* (Blackburn) and *S. natalensis* (Peringuey) (Scarabaeoidea, Aphodiidae), two species introduced into Britain. *Proceedings of the Second Pan-European Conference on Saproxylic Beetles*, 2003, 72–76.

Arndt E (2006) Niche occupation by invasive ground-dwelling predator species in Canarian laurel forests. *Biological Invasions* 8: 893–902.

Audisio P (1993) Coleoptera Nitidulidae - Kateretidae. Fauna d'Italia, vol. 32. Calderini, Italia, Bologna. 971 pp.

Baranchikov Y, Mozolevskaya E, Yurchenko G, Kenis M (2008) Occurrence of the emerald ash borer, *Agrilus planipennis* in Russia and its potential impact on European forestry. *OEPP/EPPO Bulletin* 38: 233–238.

Baraud J (1985) Coléoptères Scarabaeoidea: faune du Nord de l'Afrique, du Maroc au Sinaï. Lechevalier, France, Paris. 651 pp.

Baraud J (1992) Faune de France: France et régions limitrophes . 78 . Coléoptères Scarabaeoidea d'Europe. Fédération française des sociétés de sciences naturelles and Société linnéenne de Lyon, France, Lyon. 856 pp.

Barsevskis A, Bicevskis M, Valainis U, Savenkovs N, Cibulskis R, Kalnins M, Strode N (2004) Faunistic records of the beetles (Hexapoda: Coleoptera) in Latvia. 1. *Acta Biol. Univ. Daugavp.* 4 (2): 93–106.

Batten R (1976) De Nederlandse soorten van de keverfamilie Mordellidae. *Zoologische Bijdragen* 19: 3–37.

Beal RS, Kadej M (2008) Description of the Larva of *Sefrania Bleusei* Pic and assignment of *Sefrania Sabulorum* (Beal) to the New Genus *Araphonotos* Beal and Kadej (Coleoptera: Dermestidae). *Entomological News* 119: 245–250.

Bellés X (1985) Habitats and food habits of the Gibbiinae (Coleoptera: Ptinidae). *Bull. Inst. Cat. Hist. Nat.* 50: 263–267.

Bellés X, Halstead DGH (1985) Identification and geographical distribution of *Gibbium aequinoctiale* Boieldieu and *Gibbium psylloides* (Czenpinski) (Coleoptera: Ptinidae). *Journal of Stored Products Research* 21: 151–155.

Bengtson SA (1981) Terrestrial invertebrates of the Faroa Islands: III. Beeltes (Coleoptera): check-list, distribution, and habitats. *Fauna norv. Ser. B.* 28: 52–82.

Benoit JB, Elnitsky MA, Schulte GG, Lee RE, Denlinger DL (2009) Antarctic collembolans use chemical signals to promote aggregation and egg laying. *Journal of Insect Behavior* 22: 121–133.

Bercedo P (1997) El género *Omorgus* Erichson, 1847 en la Peninsula Ibérica (Coleoptera, Scarabaeoidea: Trogidae). *Bol. S.E.A.* 17: 29–31.

Bercedo P, Arnaiz L, Coello P, Baena M (2005) *Ozognathus cornutus* (LeConte, 1859) new anobiid for the Iberian fauna (Coleoptera: Anobiidae). *Boletin Sociedad Entomologica Aragonesa* 37: 213–214.

Bercedo P, Becerra RG, Arnaiz L (2008) El género *Calymmaderus* Solier, 1849 nuevo para Canarias y descripcion de una nueva especie (Coleoptera: Ptinidae: Dorcatominae). *Boletin Sociedad Entomologica Aragonesa* 42: 33–35.

Bétis L (1912) Faune entomologique Armoricaine, Coléoptères Rhipiphoridés. Imprimerie Oberthur, France, Rennes. 40 pp.

Borges PAV (1990) A checklist of the Coleoptera from the Azores with some systematic and biogeographic comments. *Bol. Mus. Mun. Funchal* 42 (220): 87–136.

Borges PAV, Vieira V, Dinis F, Jarroca S (2005) List of Arthropods (Arthropoda). *In* Borges et al. (eds.): *A list of the terrestrial fauna (Mollusc and Arthropoda) and flora (Bryophyta, Pteridophyta and Spermatophyta) from the Azores*. Angra do Heroísmo Horta, Ponta Delgada, 163–221.

Bouget C, Moncoutier B (2003) Contribution à la connaissance des Rhizophaginae de France (Coleoptera, Cucujoidea, Monotomidae). *Bulletin de la Société entomologique de France* 108 (3): 287–306.

Bouget C, Vincent R (2008) Les Latridiidae de la faune de France continentale et de Corse: mise à jour de la clé des genres et du catalogue des espèces (Coleoptera, Cucujoidea). *Bulletin de la Société entomologique de France* 113: 101–120.

Boukal DS, Boukal M, Fikacek M, Hajek J, Klecka J, Skalicky S, Stastny J, Trávnicek D (2007) Catalogue of water beetles of the Czech Republic (Coleoptera: Sphaeriusidae, Gyrinidae, Haliplidae, Noteridae, Hygrobiidae, Dytiscidae, Helophoridae, Georissidae, Hydrochidae, Spercheidae, Hydrophilidae, Hydraenidae, Scirtidae, Elmidae, Dryopidae, Limnichidae, Heteroceridae, Psephenidae). *Klapalekiana* 43 (Suppl.): 1–289.

Bowestead S (1999) A revision of the Corylophidae (Coleoptera) of the west Palaearctic region. Muséum d'histoire naturelle Genève, Suisse, Genève. 203 pp.

Brandt D (2006) More stamps and Story of the Faroe Islands. Postverk Føroya (The Faroese Postal Administration). Postverk Føroya (The Faroese Postal Administration), Denmark, Tórshavn. 360 pp.

Buckland PC, Panagiotakopulu E, and Sveinbjarnardottir G (2009) A failed invader in the North Atlantic, the case of *Aglenus brunneus* Gyll. (Col., Colydiidae), a blind flightless beetle from Iceland. *Biological Invasions* 11: 1239–1245.

Bunalski M (1999) Die Blatthornkäfer Mitteleuropas (Coleoptera: Scarabaeoidea): Bestimmung, Verbreitung, Ökologie. František Slamka, Slovakia, Bratislava. 80 pp.

Callot H (2003) *Cryptophilus obliteratus* Reitter, 1878, espèce nouvelle pour la faune de France (Coleoptera, Languriidae). *Bulletin de la Société entomologique de Mulhouse* 59 (1): 5–6.

Callot HJ (1993) Sur quelques staphylins capturés dans la Bas-Rhin et peut-être nouveaux pour la Faune de France: *Philonthus spinipes* Sharp., *Philonthus scribae* Fauvel, *Ontholestes haroldi* Eppelsheim, *Aleochara irmgardis* Vogt. *Bul. Soc. ent. Mulhouse* Janvier-Mars: 13–15.

Camerini G (2009) Factors affecting *Lymantria dispar* mortality in a willow wood in northern Italy. *Bulletin of Insectology* 62 (1): 21–25.

Cho YB (2008) Korean species of the genus *Bisnius* Stephens (Coleoptera: Staphylinidae). *Entomological Research* 38: 90–92.

Cobos A (1986) Fauna ibérica de Coleópteros Buprestidae. Consejo Superior de Investigaciones Científicas, Spain, Madrid. 364 pp.

Coiffait H (1972) Coléoptères Staphylinidae de la région paléarctique occidentale 1. Généralités, sous-famille Xantholinae - Leptotyphinae. *Supplément à la Nouvelle Revue d'Entomologie* 4: 1–593.

Cosseron S, Faverjon P (1991) L'Europe de 1815 à nos jours. Une histoire et une chronologie commentée. La Manufacture, France, Besançon. 641 pp.

Costa Lima AM (1955) Insetos do Brasil. 9° Tomo, Capitulo XXIX: Coleopteros, 3a Parte. *Escola Nacional de Agronomia, Rio de Janeiro* 11 (9): 1–289.

Coulson SJ (2007) Terrestrial and freshwater invertebrate fauna of the High Arctic archipelago of Svalbard. *Zootaxa* 1448: 41–68.

Cuppen J (2003) *Carpelimus zealandicus*, een nieuwe kortschildkever voor Nederland (Coleoptera: Staphylinidae). *Nederlandse Faunistische Mededelingen* 19: 35–40.

Curtis J (1836) British entomology; being illustrations and descriptions of the Genera of Insects found in Great Britain and Ireland. Vol XIII. pl. 578–625. Printed by Richard Taylor.

DAISIE: European Invasive Alien Species Gateway. http://www.europe-aliens.org.

Dajoz R (1977) Coléoptères Colydiidae et Anommatidae paléarctiques. Faune de France et du Bassin méditerranéen. Masson, France, Paris. 280 pp.

Dajoz R (2002) Les coléoptères carabidés et ténébrionidés: écologie et biologie. Tec et Doc, France, Paris. 522 pp.

Dajoz R (2007) Les insectes et la forêt. Rôle et diversité des insectes dans le milieu forestier. 2e édition. Tec & Doc, France, Paris. 648 pp.

Darlington PJ (1964) Australian carabid bettles XIV. Perigona. *Psyche* 71: 125–129.

De Laclos E, and Büche B (2009) La Vrillette sans peine: quatrième note (Coleoptera Anobiidae). *L'Entomologiste* 65 (4): 207–213.

Degiovanni A, Pezzi G (2007) *Anthicus catalanus* Bonadona, 1953 nuovo per l'Italia reperti di altre specie (Insecta Coleoptera Anthicidae). *Quaderno di Studi e Notizie di Storia Natuale della Romagna* 24: 69–77.

Delobel A, Tran M (1993) Les Coléoptères des denrées entreposées dans les régions chaudes. CTA/ORSTOM, France, Paris. 424 pp.

Denux O, Augustin S, Berthelot A (2007) Biodiversité des Carabidae dans les peupleraies picardes (Coleoptera). *L'Entomologiste* 63: 243–256.

Du Chatenet G (2000) Coléoptères Phytophages d'Europe. Tome 1. NAP, France, Vitry-sur-Seine. 360 pp.

Duff AG (2008) Checklist of beetles of the British Isles. A.G. Duff, United Kingdom, Somerset, Wells. 164 pp.

Enckell PH, Bengtson SA, Wiman B (1987) Serf and Waif Colonization - Distribution and Dispersal of Invertebrate Species in Faroe-Island Settlement Areas. *Journal of Biogeography* 14 (1): 89–104.

Espanol F (1979) Géneros de Dorcatominae de la fauna europea (Col. Anobiidae). Nota 92. *Misc. Zool. Barcelona* 5: 33–42.

Espanol F (1992) Coleoptera, Anobiidae. Fauna Iberica. Vol. 2. Museo Nacional de Ciencias Naturales, CSIC, Spain, Madrid. 195 pp.

Evans GA, Dessart P, Glenn H (2005) Two new species of *Aphanogmus* (Hymenoptera: Ceraphronidae) of economic importance reared from *Cybocephalus nipponicus* (Coleoptera: Cybocephalidae). *Zootaxa* 1018: 47–54.

Falcoz L (1929) Tableaux analytiques des Coléoptères de la faune franco-rhénane (France, Hollande, Belgique, Région rhénane, Valais). Vol. III: Famille 33: Cryptophagidae. Imprimerie des Miscellanea entomologica, France, Narbonne.197 pp.

Falin ZH (2001) Notes on the Occurrence of *Ripidius pectinicornis* Thunberg (Coleoptera: Rhipiphoridae) in the Continental United States and Hawaii. *The Coleopterists Bulletin* 55: 194–197.

Fauna Europaea Web Service: Fauna Europaea version 1.1. http://www.faunaeur.org.

Ferrer J (2004) Espèces de *Cynaeus* Leconte 1851, introduites en Europe du Nord. (Coleoptera, Tenebrionidae, Ulomini). *Nouvelle Revue d'Entomologie (N.S.)* 21 (2): 103–104.

Ferrer J, Andersson B (2002) Species of *Cynaeus* found in Sweden and Finland, with a note of the identity between *Cynaeus depresus* (Horn 1870) and *Cynaeus opacus* (Champion 1886) syn. conf. (Coleoptera, Tenebrionidae, Diaperini). *Entomofauna, Zeitschrift für Entomologie* 23 (12): 145–148.

Ferrer J, Martinez Fernandez JC (2008) *Blaps mortisaga* (L.) o la leyenda de la muerte, una especie introducida en Europa boreal y occidental (Coleoptera, Tenebrionidae). *Boln. Asoc. esp. Ent.* 32 (3–4): 245–261.

Figuerola J, Green AJ, Santamaria L (2003) Passive internal transport of aquatic organisms by waterfowl in Donana, south-west Spain. *Global Ecology and Biogeography* 12: 427–436.

Fikacek M, Boukal M (2004) *Pachysternum capense*, a new genus and species for Europe, and updated key to genera and subgenera of European Sphaeridiinae (Coleoptera: Hydrophilidae). *Klapalekiana* 40: 1–12.

Fraga FB, Alencar IDCC, Tavares MT (2009) Insect pests dissemination by extruded starch packages. *Neotropical Entomology* 38: 548–549.

Franz JM (1958) Studies on *Laricobius erichsonii* Rosenh (Coleoptera: Derodontidae), a predator on Chermesids. Part 1, Distribution, life-history and ecology. *Entomophaga* 3 (2): 109–164.

Freude H, Harde KW, Lohse GA (1964) Die Käfer Mitteleuropas, Band 4: Staphylinidae I (Micropeplinae bis Tachyporinae). Goecke & Evers, Germany, Krefeld. 264 pp.

Freude H, Harde KW, Lohse GA (1967) Die Käfer Mitteleuropas, Band 7: Clavicornia. Goecke & Evers, Germany, Krefeld. 310 pp.

Freude H, Harde KW, Lohse GA (1969) Die Käfer Mitteleuropas, Band 8: Teredilia, Heteromera, Lamellicornia. Goecke & Evers, Germany, Krefeld. 388 pp.

Freude H, Harde KW, Lohse GA (1971) Die Käfer Mitteleuropas, Band 3: Adephaga 2, Palpicornia, Histeroidea, Staphylinoidea 1. Goecke & Evers, Germany, Krefeld. 365 pp.

Freude H, Harde KW, Lohse GA (1974) Die Käfer Mitteleuropas, Band 5: Staphylinidae 2 (Hypocyphtinae und Aleocharinae), Pselaphidae. Goecke & Evers, Germany, Krefeld. 381 pp.

Freude H, Harde KW, Lohse GA (1979) Die Käfer Mitteleuropas, Band 6: Diversicornia. Goecke & Evers, Germany, Krefeld. 367 pp.

Freude H, Harde KW, Lohse GA (1989) Die Käfer Mitteleuropas: 1. Supplementband mit Katalogteil. Bd. 12, 346 S. Goecke & Evers, Germany, Krefeld. 245 pp.

Gamarra P, Outerelo R (2005) Catalogo Iberobalear de los Aleocharinae (Coleoptera: Staphylinidae). *Boletin Sociedad Entomologica Aragonesa* 37: 1–81.

Gamarra P, Outerelo R (2009) Catalogo Iberobalear de los Micropeplinae y Proteininae (Coleoptera: Staphylinidae). *Boletin Sociedad Entomologica Aragonesa* 45: 207–211.

Genovesi P (2005) Eradications of invasive alien species in Europe: a review. *Biological Invasions* 7: 127–133.

Genovesi P, Shine C (2003) European Strategy on Invasive Alien Species. Council of Europe, Strasbourg, t-pvs (2003) 7 rev. 50 pp.

Glavendekic M, Mihajlovic L, Petanovic R (2005) Introduction and spread of invasive mites and insects in Serbia and Montenegro. *Plant protection and plant health in Europe: introduction and spread of invasive species*, held at Humboldt University, Germany, Berlin, 9–11 June 2005, 229–230.

Gomy Y (2006) Contribution à l'établissement des catalogues régionaux: Histeroidea (Coleoptera). V. *L'Entomologiste* 62 (3–4): 101–115.

Gomy Y (2008) Contribution à l'établissement des catalogues régionaux: Coleoptera Histeridae VII. *L'Entomologiste* 64 (6): 325–347.

Gomy Y (2009) Contribution à l'établissement des catalogues régionaux: Coleoptera Histeridae VII. *L'Entomologiste* 65 (6): 313–328.

Gravereau J, Trauman J (2001) Crises financières. Economica, France, Paris. 459 pp.

Haggar JP (1988) The structure, composition and status of the cloud forests of Pico Island in the Azores. *Biological Conservation* 46: 7–22.

Haines CP, Rees DP (1989) Guide pratique des types d'insectes et d'acariens qui s'attaquent au poisson traité. FAO Document technique sur les pêches - 303. Organisation des Nations Unies pour l'alimentation et l'agriculture, Italia, Rome. 33 pp.

Halperin J, Geis KU (1999) Lyctidae (Coleoptera) of Israel, their damage and its prevention. *Phytoparasitica* 27 (4) 257–262.

Hava J (2003) World catalogue of the Dermestidae (Coleoptera). Studie a zprávy Okresního muzea Praha-východ, Supplementum 1, Czech Republic, Praha. 196 pp.

Hava J: A Catalogue of World Dermestidae. http://www.dermestidae.wz.cz.

Heleno RH (2008) The impact of alien plants on native biota in the Azores: a food web approach. *PhD thesis. School of Biological Sciences, University of Bristol, England*. 179 pp.

Hemp C, Dettner K (2003) Description of larvae of the genus *Formicomus* laferte, and data on the life cycles of *Omonadus floralis* (Linne) and *Notoxus monoceros* (Linne) (Coleoptera: Anthicidae). *Coleopterists Bulletin* 57: 361–368.

Hermann A, Baena M (2004) New records of Dermestidae (Coleoptera) for Spain and Europe. *Boln. S.E.A.* 34 (2004): 211–213.

Holland JM (2002) The agroecology of carabid beetles. Intercept Limited, UK, Andover. 356 pp.

Hulle M, Bonhomme J, Maurice D, and Simon JC (2008) Is the life cycle of high arctic aphids adapted to climate change? *Polar Biology* 31: 1037–1042.

Hurka K (1996) Carabidae of the Czech and Slovak Republics. Kabourek, Czech Republic, Zlin. 565 pp.

Iablokoff-Khnzorian SM (1975) Etude sur les Erotylidae (Coleoptera) palearctiques. *Acta Zoologica Cracoviensia* 20 (8).

Imperial Institute of Entomology (1930) The Review of applied entomology. Series A, Agricultural. The Imperial Institute of Entomology, England, London. 895 pp.

International Monetary Fund: World Economic Outlook database. http://www.imf.org/external/pubs/ft/weo/2009/02/weodata/index.aspx [accessed October 2009].

Jeannel R (1942) Coléoptères Carabiques, II. Collection Faune de France. Lechevalier, France, Paris. 600 pp.

Kadej M (2005) Data on the occurence of some species of Dermestidae (Coleoptera) in Poland. *Wiadomosci Entomologiczne* 24 (1): 21–31.

Kirejtshuk AG, James DG, Heffer R (1997) Description and biology of a new species of *Cybocephalus* Erichson (Coleoptera: Nitidulidae), a predator of Australian citrus whitefly. *Australian Journal of Entomology* 36: 81–86.

Korge H (2005) Rote Liste und Gesamtartenliste der Kurzflügelkäfer (Coleoptera: Staphylinidae) von Berlin. In Der Landerbeauftragte für Naturschutz und Landschaftspflege / Senatsverwaltung für Stadtentwicklung (Hrsg.): Rote Listen der gefährdeten Pflanzen und Tiere von Berlin. CD-ROM.

Kreiss E-J, Schmitz A, and Schmitz H (2005) Morphology of the prothoracic discs and associated sensilla of *Acanthocnemus nigricans* (Coleoptera, Acanthocnemidae). *Arthropod Structure & Development* 34: 419–428.

Kuschel G (1990) Beetles in a suburban environment: a New Zealand case study. The identity and status of Coleoptera in the natural and modified habitats of Lynfield, Auckland (1974–1989). DSIO Plant Protection Report no. 3. New Zealand Department of Scientific and Industrial Research, New Zealand, Auckland. 118 pp.

Laibner S (2000) Elateridae of the Czech and Slovak Republics. Kabourek, Czech Republic, Zlin. 292 pp.

Launay M (1999) Versailles, une paix baclée ? Le XXème siècle est mal parti. Complexe, France, Paris. 188 pp.

Lawson RH (1996) Economic importance and trends in ornamental horticulture. *Ninth international symposium on virus diseases of ornamental plants*, Israel, Herzliya, 17–22 March, 1996. 226–237.

Leppäkoski E, Gollasch S, and Olenin S (2002) Invasive Aquatic Species of Europe Distribution, Impacts and Management. Kluwer Academic, Nederland, Dordrecht. 583 pp.

Leseigneur L (1972) Coléoptères Elateridae de la faune de France continentale et de Corse. *Bulletin mensuel de la Société linnéenne de Lyon*, vol. 41, suppl. 1–380.

Lesne P (1901) Synopsis des Bostrychides paléarctiques. *L'Abeille* 30: 73–136.

Lesne P (1904) Supplément au Synopsis des Bostrychidae paléarctiques. *L'Abeille* 30: 153–168.

Levine JM, and D'Antonio CM (2003) Forecasting biological invasions with increasing international trade. *Conservation Biology* 17: 322–326.

Libungan L, Gíslason GM, and Þórðarson T (2008) Varmasmiður – stærsta bjalla á Íslandi (English summary: The ground beetle Carabus nemoralis – biggest beetle in Iceland). *Náttúrufræðingurinn* 77: 15–18.

Lima AMdC (1955) Insetos do Brasil. 9° Tomo, Capitulo XXIX. Coleopteros, 3a Parte. Escola Nacional de Agronomia, Série didatica, Brazil, Rio de Janeiro. 289 pp.

Luff M (1998) Provisional atlas of the ground beetles (Coleoptera, Carabidae) of Britain. Biological Records Centre, England, Huntingdon. 194 pp.

Luff ML (2007) The Carabidae (ground beetles) of Britain and Ireland (Second Edition). Handbooks for the identification of British Insects. Vol 4 Part 2. Royal Entomological Society, England, Shrewsbury. 247 pp.

Luka H, Nagel P, Feldmann B, Luka A, Gonseth Y (2009) Checkliste der Kurzflügelkäfer der Schweiz (Coleoptera: Staphylinidae ohne Pselaphinae). *Mitteilungen der Schweizerischen Entomogischen Gesellschaft* 82: 61–100.

Lupi D (2002) *Cybocephalus nipponicus* Endrody-Younga (Coleoptera Cybocephalidae) on *Diaspis echinocacti* (Bouche) in Liguria. *Bollettino di Zoologia Agraria e di Bachicoltura* 34: 463–466.

Machado A (1976) Introduction to a faunal study of the Canary Islands' Laurisilva, with special reference to the ground-beetles (Coleoptera, Caraboidea). In: Kunkel G (Ed) *Biogeography and Ecology in the Canary Islands*. The Hague, Junk, Netherlands. 347–411.

Machado A, Oromi P (2000) Elenco de los Coleopteros de las islas Canarias. Catalogue of the Coleoptera of the Canary islands. Instituto de Estudios Canarios, Spain, Tenerife, La Laguna. 306 pp.

Maddison DR, Schulz KS, Maddison WP (2007) The Tree of Life Web Project. *Zootaxa* 1668: 19–40.

Mann DJ (2006) *Ptilodactyla exotica* Chapin, 1927 (Coleoptera: Ptilodactylidae: Ptilodactylinae) established breeding under glass in Britain, with a brief discussion on the family Ptilodactylidae. *Entomologist's Monthly Magazine* 142: 67–79.

Mannerkoski I, Ferrer J (1992) *Cynaeus opacus* Champion, a new tenebrionid beetle in Finland (Coleoptera, Tenebrionidae). *Entomologica Fennica* 31 (8): 95–97.

Martinez M, Cocquempot C (1985) Sur la présence en France de *Reesa vespulae*, espèce indésirable (Coleoptera Dermestidae). *L'Entomologiste* 41 (1): 21–25.

Mazur S (1989) Note synonymique sur les genres *Pactolinus* MOTSCHULSKY, *Pachylister* LEWIS et *Macrolister* LEWIS (Col. Histeridae). *Nouv. Revue Ent. (N.S.)* 6 (1): 84.

Mendonça E, and Borges PAV (2009) Distribution of the Exotic Arthropods from the Azores. Portugal, Univ. Azores, Angra do Heroísmo. 87 pp.

Mifsud D, Audisio P (2008) The Kateretidae and Nitidulidae of the Maltesse Archipelago (Coleoptera). *Bulletin of the entomological society of Malta* 2008 (1): 15–37.

Mitter H, Schuh R (2008) *Catogenus rufus* (F.) - neu für Europa! (Coleoptera: Passandridae). *Koleopterologische Rundschau* 78: 329–332.

Moncoutier B (2001) Les "Clavicornes" de la faune de France (première partie). *Le Coléoptèriste* 43: 187–207.

Moncoutier B (2002) Les «Clavicornes» de la faune de France (deuxième partie). *Le Coléoptèriste* 5: 7–33.

Monzo C, Vanaclocha P, Outerelo R, Ruiz-Tapiador I, Tortosa D, Pina T, Castanera P, Urbaneja A (2005) Catalogación de especies de las familias Carabidae, Cicindelidae y Staphylinidae en el suelo de los cítricos de la provincia de Valencia, España. *Bol. San. Veg. Plagas* 31: 483–492.

Mouchet J, Giacomini T, Julvez J (1995) Spreading of disease vectors and pests throughout the world by man. *Cahiers d'Etudes et de Recherches Francophones/Sante* 5: 293–298.

Neculiseanu ZZ, and Matalin AV (2000) A catalogue of the ground-beetles of the Republic of Moldova (Insecta, Coleoptera, Carabidae). Pensoft, Bulgaria, Sofia. 164 pp.

Newton A: Staphylinini Species Catalog Draft. http://www.staphylinini.org/staphylinini/Products.html.

Ødegaard F, Tømmeras B (2000) Compost heaps - refuges and stepping-stones for alien arthropod species in northern Europe. *Diversity and Distributions* 6: 45–59.

Ortuno V, Toribio M (2005) Carabidae de la Peninsula Iberica y Baleares. Vol. 1. Trechinae, Bembidiini. Argania, Spain, Barcelona. 455 pp.

Paulian R (1988) Biologie des Coléoptères. Lechevalier, France, Paris. 719 pp.

Paulian R, Baraud J (1982) Lucanoidea et Scarabaeoidea. Lechevalier, France, Paris. 477 pp.

Peck SB (2009) The beetles of Barbados, West Indies (Insecta: Coleoptera): diversity, distribution and faunal structure. *Insecta Mundi* 73: 1–51.

Perrault GG (1981) Le genre *Lesitus* (Foehlig) (Col. Carabidae) III - le sous-genre *Nebrileistus* (Banninger). *Bulletin de la Société linnéenne de Lyon* 50 (7): 22–226.

Perrault GG (1984) New record of *Notobia (Anisotarsus) cupripennis* (Germar) (Coleoptera: Carabidae: Harpalini). *The Coleopterists Bulletin* 38 (4): 334.

Perrings C, Dehnen-Schmutz K, Touza J, Williamson M (2005) How to manage biological invasions under globalization. *Trends in Ecology & Evolution* 20: 212–215.

Pimentel D, Zuniga R, Morrison D (2005) Update on the environmental and economic costs associated with alien-invasive species in the United States. *Ecological Economics* 52: 273–288.

Poland TM, McCullough DG (2006) Emerald ash borer: Invasion of the urban forest and the threat to North America's ash resource. *Journal of Forestry* 104: 118–124.

Pollock DA, Ivie MA (1996) Anthicidae (Coleoptera) of the Virgin Islands. *Florida Entomologist* 79: 230–240.

Ratti E (2007) Silvanid beetles in Italy (Coleoptera Cucujoidea Silvanidae). *Bollettino del Museo Civico di Storia Naturale di Venezia* 58: 83–137.

Ratti E: Coleotteri alieni in Italia. http://www.msn.ve.it [accessed 25.05.2007].

Reemer M (2003) Invasieve Arthropoda in Nederland: een eerste inventarisatie. European Invertebrate Survey, Nederland, Leiden. 63 pp.

Reibnitz J, Schawaller W (2006) *Cynaeus angustus* (Leconte, 1851) (Coleoptera: Tenebrionidae), eine neue Adventivart in Mitteleuropa ? *Mitt. ent. V. Stuttgart* 41: 153–154.

Rogé J (2003) Prolifération de *Lispinus impressicollis* (Motschulsky, 1857) et de *Symbiotes gibberosus* (Lucas, 1846), hôtes d'un biotope particulier, dans le département de l'Aude (11) (Coleoptera, Staphylinidae et Endomychidae). *L'Entomologiste* 59 (3): 65–66.

Rücker WH (1995) *Cartodere australica* (Belon) und *Cartodere norvegica* (Strand) (Coleoptera: Latridiidae). *Mitt. internat. entomol. Ver.* 20: 59–61.

Ruiz GM, and Carlton JT (2003) Invasive species: vectors and management strategies. *In* Invasive species: vectors and management strategies. Island Press, USA, Washington. 518 pp.

Ruta R, Konwerski S, Fkrolik R, Lason A, Milkowski M (2006) New records of dermestid beetles (Coleoptera: Dermestidae) in Poland. Part 2. Megatominae. *Wiadomosci Entomologiczne* 25 (1): 21–28.

Ruta R, Konwerski S, Kadej M, Herrmann A, Lason A (2004) Three species of dermestid beetles (Coleoptera: Dermestidae) new to the Polish fauna with remarks on dermestids introduced to Poland. *Polskie Pismo Entomologiczne* 73: 307–314.

Ryndevich SK (2004) Review of species of the genus *Cercyon* Leach, 1817 of Russia and adjacent regions. I. Subgenus *Cercyon* (*s.str.*) Leach, 1817. *Cercyon lateralis*-group (Coleoptera: Hydrophilidae). *Annales Universitatis Mariae Curie-Sklodowska* 59: 1–13.

Santamaria JM, Gayoso A, Otero JC (1996) Los Laemophloeidae Ganglbauer, 1899 (Coleoptera) iberobaleares. Lista de especies y datos corologicos. *Boln. Asoc. esp. Ent.* 20 (3–4): 107–114.

Schaefer L (1949) Les Buprestides de France: tableaux analytiques des Coléoptères de la faune franco-rhénane, France, Rhénanie, Belgique, Hollande, Valais, Corse. Famille LVI. E. Le Moult, France, Paris . 511 pp.

Scheerpeltz O (1972) Studien an den paläarktischen Arten der Gattung *Myrmecopora* Saulcy (Col. Staphylinidae). *Koleopterologische Rundschau* 50: 93–109.

Schmitz H, Schmitz A, Trenner S, Bleckmann H (2002) A new type of insect infrared organ of low thermal mass. *Naturwissenschaften* 89: 226–229.

Schuh R, Mifsud D (2000) The cylindrical bark beetles of Malta (Insecta: Coleoptera: Zopheridae, Colydiinae). *Ann. Naturhist. Mus. Wien* 102B: 259–267.

Schulte GG, Elnitsky MA, Benoit JB, Denlinger DL, Lee RE (2008) Extremely large aggregations of collembolan eggs on Humble Island, Antarctica: a response to early seasonal warming? *Polar Biology* 31: 889–892.

Sefrova H (2005) Introduced and invasive insect species in the Czech Republic and their economic and ecological impact (Insecta). *Acta Univ. Agric. Silvic. Mendel. Brun.* 53 (17): 151–158.

Šefrova H, Lastuvka Z (2005) Catologue of alien animal species in the Czech Republic. *Acta Univ. Agric. Silvic. Mendel. Brun.* 53 (18): 151–170.

Serrano J, Lencina JL, Andujar A (2003) Distribution patterns of Iberian Carabidae (Insecta, Coleoptera). *Graellsia* 59 (2–3): 129–153.

Sharp D (1882–1887) Biologia centrali-americana. Insecta. Coleoptera. Vol. I. Part 2. Published for the editors by R.H. Porter, England, London. 824 pp.

Shockley FW (2009) Endomychidae. Handsome fungus beetles. http://tolweb.org/Endomychidae/9169/2009.03.31 [accessed 31.03.2009] In: The Tree of Life Web Project, http://tolweb.org/.

Shockley FW, Tomaszewska KW, McHugh JV (2009a) An annotated checklist of the handsome fungus beetles of the world (Coleoptera: Cucujoidea: Endomychidae). *Zootaxa* 1–113.

Shockley FW, Tomaszewska KW, and McHugh JV (2009b) Review of the natural history of the handsome fungus beetles (Coleoptera: Cucujoidea: Endomychidae). *Insecta Mundi* 72: 1–24.

Simberloff D (2001) Biological invasions - how are they affecting us, and what can we do about them? *Western North American Naturalist* 61: 308–315.

Smith RM, Baker RHA, Malumphy CP, Hockland S, Hammon RP, Ostoja-Starzewski JC, Collins DW (2007) Recent non-native invertebrate plant pest establishments in Great Britain: origins, pathways, and trends. *Agricultural and Forest Entomology* 9: 307–326.

Soldati F (2007) Fauna of France and Corsica, Coleoptera Tenebrionidae (Alleculinae excluded). Systematic Catalogue and Atlas. *Mémoires de la Société Linnéenne de Bordeaux* 6: 1–186.

Sörensson M, Johnson C (2004) The first European records of the pantropical genus *Bambara* Vuillet, and a review of the immigrant featherwing beetles in Europe (Coleoptera: Ptiliidae). *Koleopterologische Rundschau* 74: 287–302.

Stoch F: Checklist of the species of the italian fauna. Version 2.0. http://www.checklist.faunaitalia.it [accessed 03.12.2003].

Streito JC, Martinez M (2008) Entomological actualities: new introduced pests insects (period January 2000 at June 2005). *7eme Conference Internationale sur les Ravageurs en Agriculture*, France, Montpellier, 26–27 octobre, 2008, unpaginated.

Tamisier J-P (2004) *Clambus simsoni* Blackburn, un petit coléoptère australien en pleine expansion en France (Coleoptera, Clambidae). *Bull. Société linnéenne de Bordeaux* 32 (1): 41–45.

Telnov D (1996) Sixty three new and rare species of Coleoptera in the fauna of Latvia. *Latvijas entomologs* 35: 36–43.

The World Factbook: Central Intelligence Agency, 2009. https://www.cia.gov/library/publications/the-world-factbook/index.html.

Théry A (1942) Coléoptères Buprestides. Lechevalier, France, Paris. 221 pp.

Thomas MC (1995) Invertebrate Pets and the Florida Department of Agriculture and Consumer Services. *Florida Entomologist* 78: 39–44.

Tomov R (2009) Non-indigenous insects and their threat to biodiversity and economy in Albania, Bulgaria and Republic of Macedonia. Pensoft, Bulgaria, Sofia. 112 pp.

Trautner J, Geigenmuller K (1987) Tiger beetles, ground beetles. Illustrated key to the Cicindelidae and Carabidae of Europe. TRIOPS Verlag, Margraf Distributor. Germany, Gaimersheim. 488 pp.

Tronquet M (2006) Catalogue iconographique des coléoptères des Pyrénées-Orientales. Association roussillonnaise d'entomologie, France, Perpignan. 78 pp.

Turin H, Penev L, Casale A (2003) The Genus *Carabus* in Europe. A synthesis. Pensoft, Sofia, Bulgaria. 511 pp.

Valemberg J (1997) Catalogue descriptif, biologique et synonymique de la faune Paléarctique des coléoptères Carabidae Latreille, 1806. Tome 1 Corpus. Mémoire de la Société Entomologique du Nord de la France, France, Villeneuve d'Ascq. 659 pp.

Vernon P, Caron F, Davies L (1999) Annual activity of two endemic beetles (Carabidae) at the edge between fell-field and moorland on a sub-Antarctic island. European *Journal of Soil Biology* 35: 39–43.

Vieira V, Borges P, Karsholt O, Wunderlich J (2003) The Arthropoda fauna of Corvo island (Azores): new records and updated list of species. *Vieraea* 31: 145–156.

Vincent R (1999) Une nouvelle fois un *Aridius* (Coléoptère Latridien) va-t-il envahir l'Europe ? (*Cartodere (Aridius) delamarei* Dajoz, 1962). *L'Entomologiste* 55 (2): 53–55.

Vorst O (2009) *Cercyon castaneipennis* sp. n., an overlooked species from Europe (Coleoptera: Hydrophilidae). *Zootaxa* 2054: 59–68.

Vorst O, Van Ee G, Huijbregts H, Van Nieuwenhuijzen A (2007) On some smaller Latvian Coleoptera. *Latvijas entomologs* 44: 15–25.

Weidner H, Rack G, Friedrichsen D (1984) Tables de détermination des principaux ravageurs des denrées entreposées dans les pays chauds. GTZ, Germany, schborn. 157 pp.

Wittenberg R, Kenis M, Blick T, Hanggi A, Gassmann A, Weber E (2006) Invasive alien species in Switzerland: an inventory of alien species and their threat to biodiversity and economy in Switzerland. Federal Office for the Environment (FOEN), Switzerland, Bern. 155 pp.

Yélamos T (1992) Data on Afrotropical Histendae (Coleoptera), with description of *Hister sindarae* n. sp. Misc. Zool. Barcelona 16: 37–43.

Zahradnik P, Mifsud D (2005) *Ozognathus cornutus* (LeConte) - new record for the Palaearctic Region (Coleoptera: Anobiidae). *Studies and reports of District Museum Prague-East, Taxonomical Series* 1(1–2): 141–143.

Table 9.5.1. List and characteristics of the Coleoptera species alien *to* Europe of families other than Cerambycidae, Curculionidae *sensu lato*, Chrysomelidae *sensu lato* and Coccinelidae. Status: **A** Alien *to* Europe **C** Cryptogenic. Country codes abbreviations refer to ISO 3166 (see Appendix I). Habitat abbreviations refer to EUNIS (see Appendix II).

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Acanthocnemidae								
Acanthocnemus nigricans (Hope 1845)	A	phytophagous	Australasia	1922, FR-COR	CY, FR, FR-COR, DE, IT, IT-SAR, IT-SIC, PT, ES	I2	timber, wood	Alonso-Zarazaga et al. (2003), (Kreiss et al. (2005)
Anobiidae								
Calymmaderus oblongus (Gorham, 1883)	A	phytophagous	Tropical, subtropical	Unknown	PT-AZO	J1	stored products	Bercedo et al. (2008), Borges et al. (2005), Espanol (1979), Mendonça and Borges (2009)
Epauloecus unicolor (Piller and Mitterpacher)	C	detritivorous	Cryptogenic	1861, DE	AT, BE, BA, BG, HR, CZ, DK, EE, FI, FR, FR-COR, DE, HU, IS, IE, IT, LV, LT, LU, MD, NL, NO, PL, PT, PT-AZO, RO, RU, RS, SK, SI, ES, SE, CH, UA, GB	J1	barns, cowsheds, animal burrows	Tomov (2009), Wittenberg et al. (2006)
Ernobius mollis (Linnaeus, 1758)	C	phytophagous	Cryptogenic	Unknown	PT-AZO	J, G	soft wood, sawmills, books	Borges et al. (2005), Espanol (1992), Mendonça and Borges (2009)
*Gibbium aequinoctia*le Boieldieu, 1854	A	detritivorous	Tropical, subtropical	Unknown	MT	J1	stored products	Bellés and Halstead (1985)
Gibbium psylloides (Czempinski, 1778)	C	detritivorous	Cryptogenic	1900, CZ	AL, AT, BE, BA, BG, HR, CY, CZ, DK, EE, FI, FR, FR-COR, DE, GR, HU, IE, IT, IT-SAR, IT-SIC, MT, MD, NL, PL, PT, PT-MAD, RO, RU, RS, SK, ES, ES-BAL, SE, CH, UA, GB	J1	houses, hotels, stored products	Bellés (1985), Bellés and Halstead (1985), Duff (2008), Freude et al. (1969), Šefrova and Lastuvka (2005), Wittenberg et al. (2006)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Lasioderma sericorne Fabricius, 1792	A	phyto-phagous	Tropical, subtropical	1848, PT	AL, AT, BG, CZ, DK, EE, HU, IT, IT-SAR, IT-SIC, LV, MT, PT, RS, CH	J1	tobacco, stored products	Borges et al. (2005), Espanol (1992), Freude et al. (1969), Glavendekic et al. (2005), Šefrova and Lastuvka (2005), Wittenberg et al. (2006)
Mezium affine Boieldieu 1856	C	detriti-vorous	Crypto-genic	Unknown	AT, DK, DE, PT-AZO, PT-MAD, ES, ES-CAN, SE	J	mills, stored products, bird nests	Bellés (1985), Freude et al. (1969)
Mezium americanum Laporte de Castelnau, 1840	A	detriti-vorous	North America	Unknown	IT, IT-SAR, MT, PT-AZO	J	stored products	Bellés (1985), Borges et al. (2005)
Nicobium castaneum (Olivier, 1790)	C	phyto-phagous	Crypto-genic	1807, PT	AT, BA, HR, CY, CZ, FR, FR-COR, DE, GR, IT, IT-SAR, IT-SIC, MT, PL, PT, PT-AZO, PT-MAD, RO, SI, ES, ES-BAL, ES-CAN, CH, UA	J	soft wood furniture, old books	Espanol (1992), Freude et al. (1969), Mendonça and Borges (2009), Šefrova and Lastuvka (2005)
Ozognathus cornutus (LeConte, 1859)	A	detriti-vorous	North America	2005, ES	MT, RO, ES	J	dead wood	Allemand (2008), Bercedo et al. (2005), Zahradnik and Mifsud (2005)
Pseudeurostus hilleri (Reitter 1877)	A	detriti-vorous	Asia-Temperate	1993, DE	DK, DE	J	likely scavenger and inhabitant of residues, potential minor pest of feed mills and warehouses	
Ptilineurus marmoratus (Reitter, 1877)	A	phyto-phagous	Asia	1999, FR	FR, SE	G	trees	Imperial Institute of Entomology (1930)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Ptinus bicinctus Sturm 1837	C	detritivorous	Cryptogenic	1856, FR	AT, BY, BE, BA, BG, HR, CZ, DK, EE, FI, FR, FR-COR, DE, HU, IT, IT-SAR, LV, NL, NO, PL, RO, RU, RS, SK, SI, ES, SE, CH, UA	J1	stored products	Freude et al. (1969)
Ptinus clavipes Panzer, 1792	C	detritivorous	Cryptogenic	Unknown	EE, LV, MT, ES-CAN, GB	J1	stored products, fur	Duff (2008), Freude et al. (1969), Machado and Oromi (2000)
Ptinus fur (Linnaeus 1758)	C	detritivorous	Cryptogenic	1940, BG	AL, AD, AT, BY, BE, BA, BG, HR, CY, CZ, DK, EE, FÖ, FI, FR, FR-COR, DE, GR, HU, IS, IE, IT, IT-SAR, IT-SIC, LV, LI, LT, LU, MT, MD, NL, NO, PL, PT, PT-AZO, PT-MAD, RO, RU, RS, SK, SI, ES, ES-BAL, ES-CAN, SE, CH, UA, GB	J1, J6	waste, dried vegetals	Bengtson (1981), Borges et al. (2005), Duff (2008), Mendonça and Borges (2009), Tomov (2009)
Ptinus latro Fabricius, 1775	C	detritivorous	Cryptogenic	1850, CZ	AL, AT, BY, BE, BA, BG, HR, CY, CZ, DK, EE, FI, FR, FR-COR, DE, GR, GR-CRE, HU, IE, IT, IT-SAR, IT-SIC, LV, LI, LT, LU, MT, MD, NL, NO, PL, PT, PT-AZO, PT-MAD, RO, RS, SK, SI, ES, ES-CAN, SE, CH, UA, GB	J	old wood, synanthropic	Borges et al. (2005), Freude et al. (1969), Šefrova and Lastuvka (2005), Tomov (2009)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Ptinus tectus Boieldieu 1856	A	detriti-vorous	Australasia	1916, DE	AT, BY, BE, BA, BG, HR, CY, CZ, DK, EE, FÖ, FI, FR, DE, GR, HU, IE, IT, LV, LT, LU, MD, NL, NO, PL, PT, PT-AZO, RU, RS, SK, SI, ES, SE, CH, UA, GB	J1	stored products	Allemand (2008), Bengtson (1981), Duff (2008), Wittenberg et al. (2006)
Tricorynus tabaci (Guérin-Méneville, 1850)	A	phyto-phagous	C & S America	1965, CZ	HR, CZ, DK, FR, DE, IT	J	seeds, stored products; crataegus in native fields	Freude et al. (1969), Šefrova and Lastuvka (2005)
Trigonogenius globulus Solier, 1849	A	detriti-vorous	C & S America	1939, CZ	CZ, DK, GB	J	dried animal products, insects, herbarium, stored products	Duff (2008), Ratti. Coleotteri alieni in Italia., Šefrova and Lastuvka (2005)
Anthicidae								
Anthicus crinitus La Ferte-Senectere, 1849	A	unknown	Asia	Unknown	CY, GR, GR-SEG, MT, PT-MAD	J	anthropophilous, larva scavenger	Pollock and Ivie (1996)
Anthicus czernohorskyi Pic, 1912	A	unknown	Asia	1982, IT	IT	U		Degiovanni and Pezzi (2007)
Omonadus floralis (Linnaeus 1758)	A	detriti-vorous	Asia-Tropical	1951, HR, BG	AL, AT, BA, BG, HR, CY, CZ, DK, EE, FI, FR, FR-COR, DE, GR, GR-CRE, GR-ION, GR-SEG, HU, IE, IT, IT-SAR, IT-SIC, LV, LI, LT, MT, NL, NO, PL, PT, PT-AZO, PT-MAD, RO, RU, SK, ES, ES-BAL, ES-CAN, SE, CH	J6	vegetal decay, detritiphage, mycophage, adult predator	Freude et al. (1969), Hemp and Dettner (2003), Machado and Oromi (2000), Mendonça and Borges (2009), Tomov (2009)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Stricticomus tobias (De Marseul 1879)	A	detriti-vorous	Asia	1944, IT	AT, BY, BE, CZ, DK, EE, FR, FR-COR, DE, HU, IT, IT-SAR, IT-SIC, LV, LT, MT, MD, NL, PT, PT-MAD, SK, ES, ES-CAN, SE, CH, GB	I, J1	rotten vegetal tissues	Duff (2008), Freude et al. (1969), Machado and Oromi (2000), Telnov (1996), Wittenberg et al. (2006)
Aphodiidae								
Aphodius gracilis Boheman, 1857	A	detriti-vorous	Africa	Unknown	PT-AZO	E	dung	Baraud (1985)
Saprosites mendax Blackburn, 1892	A	detriti-vorous	Australasia	1921, GB	GB	I2	rotting wood; in borings of *Dorcus* and *Sinodendron* beetles	Baraud (1992), Duff (2008), Paulian and Baraud (1982)
Saprosites natalensis (Peringuey, 1901)	A	detriti-vorous	Africa	1982, GB	GB	I2	rotting wood	Duff (2008)
Tesarius caelatus (Laconte, 1857)	A	detriti-vorous	North America	1976, GB	GB	U		Baraud (1992), Duff (2008)
Bostrichidae								
Apate monachus Fabricius, 1775	A	phyto-phagous	Tropical, subtropical	Unknown	FR, FR-COR, IT-SAR, IT-SIC, ES	G3, I2	polyphagous stem borer, fruit trees, Acacia	Freude et al. (1969), Lesne (1901)
Bostrychoplites cornutus (Olivier 1790)	A	phyto-phagous	Africa	Unknown	DK, DE, IT, ES, SE	J	timber (ethnic carved wooden bowls and ornaments)	Freude et al. (1969), Ratti. Coleotteri alieni in Italia.)
Dinoderus bifoveolatus (Wollaston, 1858)	A	phyto-phagous	Tropical, subtropical	Unknown	AT, BE, HR, DK, DE, NL, PT-MAD, SK, ES, SE, CH, GB	J	bamboo borer (N); dried cassava chips and stored products	Duff (2008), Freude et al. (1969), Lesne (1901)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Dinoderus minutus (Fabricius, 1775)	A	phyto-phagous	Tropical, subtropical	1965, CZ	AL, BE, CZ, DK, FR, DE, GR, IT, IT-SAR, IT-SIC, NL, PL, SK, SE, GB	J,I2	bamboo, manioc (Cassava), stored products (intro)	Duff (2008), Freude et al. (1969), Lesne (1901),Lesne (1904), Šefrova and Lastuvka (2005)
Rhyzopertha dominica (Fabricius, 1792)	A	phyto-phagous	Asia-Tropical	1900, CZ	AL, AT, BY, BE, BG, HR, CY, CZ, DK, EE, FI, FR, FR-COR, DE, GR, GR-SEG, IE, IT, IT-SAR, IT-SIC, LV, MT, NL, PL, PT, PT-AZO, RO, SK, ES, ES-BAL, ES-CAN, SE, CH, GB	J1	stored products, mainly cereals	Borges et al. (2005), Cobos (1986), Duff (2008), Freude et al. (1969), Lesne (1901), Lesne (1904), Machado and Oromi (2000), Mendonça and Borges (2009), Šefrova and Lastuvka (2005), Tomov (2009), Wittenberg et al. (2006)
Sinoxylon senegalense Karsch, 1831	A	phyto-phagous	Africa	Unknown	DE	J	*Acacia* wood borer (N); imported construction wood	Lesne (1901)
Heterobostrychus hamatipennis (Lesne, 1895)	A	phyto-phagous	Asia	2005, BE	BE	J	xylophagous, Salix, osier goods	Lesne (1901)
Buprestidae								
Agrilus planipennis Fairmaire, 1888	*A*	phyto-phagous	Asia	2003	RU	I2	*Fraxinus*	Baranchikov et al. (2008)
Buprestis decora Fabricius, 1775	A	phyto-phagous	North America	Unknown	ES-CAN	I2		Cobos (1986), Machado and Oromi (2000)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Chrysobothris dorsata (Fabricius, 1787)	A	phyto-phagous	Africa	1986, ES	ES	F5, I		Ratti. Coleotteri alieni in Italia.)
Carabidae								
Laemostenus complanatus (Dejean, 1828)	A	parasitic/ predator	Africa	Unknown	FR, FR-COR, IE, PT-AZO, ES-CAN, GB	B, J, H1	littoral in ports, cellars caves	Anderson et al. (2000), Arndt (2006), Borges et al. (2005), Duff (2008), Jeannel (1942), Luff (1998), Luff (2007), Machado (1976), Machado and Oromi (2000), Mendonça and Borges (2009), Perrault (1981), Perrault (1984)
Leistus nubivagus Wollaston, 1864	A	parasitic/ predator	Africa	Unknown	ES-CAN	U		Machado (1976), Machado and Oromi (2000), Perrault (1981)
Notiobia cupripennis (Germar, 1824)	A	phyto-phagous	C & S America	Unknown	ES-CAN	I2	seeds of Amaranthus	Machado and Oromi (2000), Perrault (1984)
Plochionus pallens (Fabricius, 1775)	A	parasitic/ predator	C & S America	2000, NL	DK, FR, DE, HU, IT, NL	J	in ports, transported with peanuts, raisin storages	Trautner and Geigenmuller (1987), Valemberg (1997)
Pterostichus caspius (Ménétriés, 1832)	A	parasitic/ predator	Asia-Temperate	1980, CZ	BG, CZ	U	Predator in various environments, pyrophilous	Hurka (1996), (Šefrova and Lastuvka (2005), Valemberg (1997)
Somotrichus unifasciatus (Dejean, 1831)	A	parasitic/ predator	Africa	Unknown	FR, IT	J	predator of beetles in stored products, avian droppings	Jeannel (1942), (Valemberg (1997)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Trechicus nigriceps (Dejean, 1831)	A	parasitic/ predator	Asia-Tropical	1902, DE	AT, BE, BA, BG, HR, CZ, DK, FI, FR, DE, HU, IT, LV, LI, LU, MD, NL, NO, PL, PT-AZO, PT-MAD, RS, SK, SI, ES, ES-CAN, SE, CH, UA, GB	I1, I2, J1, J6	compost, predator, gardens; also in peanuts	Borges et al. (2005), Darlington (1964), Duff (2008), Hurka (1996), Luff (2007), Machado and Oromi (2000), Mendonça and Borges (2009), Neculiseanu and Matalin (2000), Serrano et al. (2003), Tomov (2009), Trautner and Geigenmuller (1987), Valemberg (1997), Wittenberg et al. (2006)
Cerylonidae								
Murmidius ovalis (Beck 1817)	A	detritivorous	Asia	Unknown	AL, AT, DK, FR, DE, HU, IT, PL, CH, GB	J1	stored products (few damage-ports)	Duff (2008), Wittenberg et al. (2006), Moncoutier (2002)
Philothermus montandoni Aube, 1843	A	detritivorous	Tropical, subtropical	Unknown	FR, IT	X11	botanical garden	Stoch: Checklist of the species of the italian fauna)
Ciidae								
Xylographus bostrychoides (Dufour 1843)	A	detritivorous	Asia?	Unknown	AT, BY, BA, BG, HR, CZ, DK, FR, FR-COR, GR, HU, IT, IT-SAR, IT-SIC, PL, RO, SK, ES, UA	I	feeds on fungi	Tomov (2009)
Clambidae								
Clambus simsoni Blackburn 1902	A	detritivorous	Australasia	1987, SE	AT, FR, DE, NL, SE, GB	G	forest, firewood, compost; mycophagous	Duff (2008), Tamisier (2004)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Cleridae								
Necrobia ruficollis (Fabricius 1775)	C	parasitic/ predator	Crypto-genic	1976, LT	AT, DK, EE, FI, HU, LT, NO, PT-AZO, SE, CH	J1, J6	predator on old bones, decaying animals	Borges et al. (2005), Du Chatenet (2000), Freude et al. (1979), Mendonça and Borges (2009), Wittenberg et al. (2006)
Necrobia rufipes (De Geer 1775)	A	parasitic/ predator	Tropical, subtropical	1935, LT	AT, BG, DK, EE, FI, DE, LT, NO, PT, PT-AZO, SE, CH	J1, J6	predator, necrophage, seeds with oil content (copra, soya), dried fish	Borges et al. (2005), Du Chatenet (2000), Freude et al. (1979), Haines and Rees (1989), Tomov (2009), Wittenberg et al. (2006)
Necrobia violacea (Linnaeus 1758)	C	parasitic/ predator	Crypto-genic	1976, LT	AT, DK, FI, HU, LT, NO, SE, CH	J1, J6	old bones, prey dry carrion	Freude et al. (1979), Wittenberg et al. (2006)
Opetiopalpus scutellaris (Panzer 1797)	A	parasitic/ predator	Africa	Unknown	AT, EE, FR, DE, ES	J	old timber houses	Du Chatenet (2000), Freude et al. (1979)
Paratillus carus (Newman, 1840)	A	parasitic/ predator	Australasia	1933, GB	FR, GB	G,I2	predator on Lyctiidae	Du Chatenet (2000), Duff (2008)
Tarsostenus univittatus (Rossi, 1792)	C	parasitic/ predator	Crypto-genic	1990, CZ	AT, CZ, CH	J	predator on Bostrychidae, Anobiidae	Du Chatenet (2000), Freude et al. (1979), Šefrova and Lastuvka (2005), Wittenberg et al. (2006)
Thaneroclerus buqueti (Lefebvre, 1835)	A	parasitic/ predator	Asia	1963, CZ	CZ, DE, IT, PL	J	predator on insects on tobacco, rice (*Lasioderma*, *Areaocerus*)	Du Chatenet (2000), Freude et al. (1979), Šefrova and Lastuvka (2005)
Corylophidae								
Orthoperus aequalis Sharp 1885	A	detriti-vorous	Australasia	Unknown	HR, FR, FR-COR, IT, PT-AZO, PT-MAD, ES, ES-CAN, CH, GB	G, I2		Borges et al. (2005), Bowestead (1999), Duff (2008), Machado and Oromi (2000), Ratti. Coleotteri alieni in Italia.)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Cryptophagidae								
Atomaria lewisi Reitter, 1877	A	detritivorous	Asia	1937, GB	AL, AT, BY, BE, HR, CZ, DK, EE, FI, DE, IT, LV, LT, MD, NO, PL, PT-AZO, SK, SE, CH, UA, GB	I2, J1, G	mycophage; compost, In decaying plant material	Duff (2008), Freude et al. (1967), Ødegaard and Tømmerås (2000), Šefrova and Lastuvka (2005), Wittenberg et al. (2006)
Caenoscelis subdeplanata C.Brisout de Barneville, 1882	A	detritivorous	North America	1950, GB	BY, HR, CZ, EE, FI, FR, FR-COR, DE, IT, LV, LT, LU, MT, MD, NL, NO, PL, PT-MAD, RU, SI, ES, ES-CAN, SE, CH, UA, GB	G, X11, I2, FB	mycophage; forests In decaying wood and plant material	Duff (2008), Falcoz (1929), Freude et al. (1967), Ratti. Coleotteri alieni in Italia., Tomov (2009), Wittenberg et al. (2006)
Cryptophagus acutangulus Gyllenhall, 1828	C	detritivorous	Cryptogenic	1956, BG	AL, AT, BY, BE, BA, BG, CZ, DK, EE, FI, FR, DE, IT, LV, LT, PL, RO, RS, SK, SI, SE, CH, UA, GB	J	attic, mills	Falcoz (1929), Freude et al. (1967), Tomov (2009)
Cryptophagus affinis Sturm 1845	C	detritivorous	Cryptogenic	1956, BG	AL, BG, CZ, FR, GR, IT, IT-SIC, LV, MT, PT-AZO, PT-MAD, RO, ES-CAN, GB	J	fungi, dry fruits	Borges et al. (2005), Duff (2008), Falcoz (1929), Freude et al. (1967), Machado and Oromi (2000), Mendonça and Borges (2009), Tomov (2009)
Cryptophagus cellaris (Scopoli, 1763)	C	detritivorous	Cryptogenic	1939, PT	AL, AT, BY, BE, BA, BG, HR, CZ, DK, FI, FR, DE, GR, HU, IT, IT-SIC, LV, MT, MD, NL, NO, PL, PT, PT-AZO, PT-MAD, RO, SK, SI, ES-CAN, SE, CH, UA, GB	J	mycophagous, stored products, herbariums, insects	Borges et al. (2005), Duff (2008), Falcoz (1929), Freude et al. (1967), Machado and Oromi (2000), Moncoutier (2002), Tomov (2009)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Cryptophagus fallax Balfour-Browne, 1953	C	detritivorous	Cryptogenic	1900, CZ	AL, AT, BY, BE, BA, BG, CZ, DK, EE, FI, FR, DE, IE, IT, IT-SIC, LV, LT, MT, NL, PL, RO, RS, SK, SI, SE, CH, UA, GB	J1	stored products	Duff (2008), Freude et al. (1967), Šefrova and Lastuvka (2005), Tomov (2009)
Cryptophagus pilosus Gyllenhal 1828	C	detritivorous	Cryptogenic	1956, BG	BY, BG, FÖ, FR, LV, PT-AZO, PT-MAD	J1	attic	Bengtson (1981), Borges et al. (2005), Enckell et al. (1987), Falcoz (1929), Freude et al. (1967), Mendonça and Borges (2009), Tomov (2009)
Cryptophagus subfumatus Kraatz, 1856	C	detritivorous	Cryptogenic	1956, BG	AD, AT, BY, BE, BA, BG, CZ, DK, EE, FI, FR, FR-COR, DE, IT, IT-SAR, LV, LT, MD, NL, NO, PL, PT-AZO, PT-MAD, SK, SI, ES-CAN, SE, CH, UA, GB	J1	dry fruits, nuts	Duff (2008), Falcoz (1929), Freude et al. (1967), Tomov (2009)
Curelius japonicus (Reitter, 1877)	C	detritivorous	Cryptogenic	1997, IT	DE, IT, MT, ES, ES-CAN	U	probably a fungus feeder	Peck (2009)
Henoticus californicus (Mannhereim 1843)	A	detritivorous	North America	Unknown	BY, BE, DK, FR, DE, NL, SE, GB	J1	stored products	Duff (2008), Falcoz (1929), Freude et al. (1967), Ratti. Coleotteri alieni in Italia.)
Cybocephalidae								
Aglyptinus agathidioides Blair 1930	A	parasitic/ predator	Africa	1912, GB	ES-CAN, GB	G, F,I2, J	potters bar	Duff (2008), Machado and Oromi (2000)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Cybocephalus nipponicus Endrody-Younga, 1971	A	parasitic/ predator	Asia-Temperate	2002, IT	IT	J100	predator of scales	Evans et al. (2005), Lupi (2002), Ratti. Coleotteri alieni in Italia.)
Dermestidae								
Anthrenocerus australis (Hope, 1843)	A	detritivorous	Australasia	1933, GB	FR, NL, GB	J1	clothes	Duff (2008), Freude et al. (1979), Hava (2003), Hava. A Catalogue of World Dermestidae., Reemer (2003)
Anthrenus caucasicus Reitter, 1881	A	detritivorous	Asia	1941, LV	AT, LV, PL	J1, I2, E	larva scavenger; adult on flowers	Freude et al. (1979), Hava. A Catalogue of World Dermestidae., Ruta et al. (2004)
Anthrenus flavidus Solsky, 1876	A	detritivorous	Asia	1935, PL	DE, PL	J1, E	wood, paper, leather and woven fabrics in collections in museums	Freude et al. (1979), Hava. A Catalogue of World Dermestidae.)
Anthrenus flavipes LeConte, 1854	C	detritivorous	Cryptogenic	1955, PL	BG, CZ, DK, IT-SAR, IT-SIC, PL, CH, GB	J1, G	domestic, feeds on furnitures, fabrics, etc., adult pollinophage; larva necrophagous (faeces, cadavers, pine processionnary nests)	Duff (2008), Freude et al. (1979), Hava (2003), Hava. A Catalogue of World Dermestidae., Ratti. Coleotteri alieni in Italia., Šefrova and Lastuvka (2005), Tomov (2009), Wittenberg et al. (2006)
Anthrenus oceanicus Fauvel, 1903	A	detritivorous	Australasia	2004, CZ	CZ, MT	J1, E	stored products	Hava (2003), Hava. A Catalogue of World Dermestidae., Šefrova and Lastuvka (2005)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Attagenus diversepubescens Pic, 1936	A	detritivorous	C & S America	Unknown	DE	J	stored products	Hava (2003)
Attagenus fasciatus (Thunberg, 1795)	C	detritivorous	Cryptogenic	1927, DE	BG, DE, IT, MT, GB	J1, J6	necrophagous, in vegetal	Duff (2008), Freude et al. (1979), Hava (2003), Ratti. Coleotteri alieni in Italia., Tomov (2009)
Attagenus gobicola Frivaldszky, 1892	A	detritivorous	Asia-Temperate	Unknown	SE	J	stored products	Hava (2003)
Attagenus lynx (Mulsant & Rey, 1868)	A	detritivorous	Asia-Temperate	Unknown	PL	J	stored products	Hava (2003)
Attagenus smirnovi Zhantiev, 1973	C	detritivorous	Cryptogenic	1973, RU	BY, CZ, DK, LV, NO, PL, RU, CH, GB	J1	pest of animal-origin material (skin, furs, wool) but also buildings, entomological collections	Barsevskis et al. (2004), Duff (2008), Hava (2003), Ruta et al. (2004), Šefrova and Lastuvka (2005)
Attegenus unicolor Brahm 1791	C	detritivorous	Cryptogenic	1978, GB	BG, CZ, DK, LV, PL, CH, GB	J1, J6, E	domestic, feeds mainly on fabrics, adult pollinophage; larva necrophagous and cereals	Borges et al. (2005), Duff (2008), Freude et al. (1979), Hava (2003), Hermann and Baena (2004), Kadej (2005), Tomov (2009), Wittenberg et al. (2006)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Dermestes ater De Geer 1774	C	detritivorous	Cryptogenic	1868, GB	AT, BG, EE, FR, DE, LT, MT, PL, PT-AZO, ES-CAN, CH, GB	J1, J6	necrophagous	Duff (2008), Freude et al. (1979), Haines and Rees (1989), Hava (2003), Machado and Oromi (2000), Šefrova and Lastuvka (2005), Wittenberg et al. (2006)
Dermestes bicolor Fabricius, 1781	A	detritivorous	Asia-temperate	Unknown	ES-CAN	J	stored products	Freude et al. (1979), Hava (2003), Machado and Oromi (2000)
Dermestes carnivorus Fabricius, 1775	A	detritivorous	C & S America	1919, PL	BE, FR, IE, PL, GB	J1, J6, G	necrophagous in houses, bird nests, dead fish	Freude et al. (1979), Haines and Rees (1989), Hava. A Catalogue of World Dermestidae.)
Dermestes coronatus Steven 1808	A	detritivorous	Asia	Unknown	PL	E	grasslands	Hava (2003)
Dermestes frischi Kugelann, 1792	C	detritivorous	Cryptogenic	1862, GB	BG, DK, EE, FR, IE, LV, LT, PT-AZO, GB	J1, J6	domestic	Borges et al. (2005), Duff (2008), Freude et al. (1979), Haines and Rees (1989), Hava (2003), Hava. A Catalogue of World Dermestidae., Mendonça and Borges (2009), Tomov (2009)
Dermestes lardarius (Linnaeus, 1758)	C	detritivorous	Cryptogenic	1880, BG	BG, DK, EE, FR, HU, LT	J1, J6	necrophagous but in vegetal matters (peanuts, corn), eggs predation	Camerini (2009), Freude et al. (1979), Haines and Rees (1989), Hava (2003), Hava. A Catalogue of World Dermestidae., Tomov (2009)
Dermestes leechi Kalík, 1952	A	detritivorous	Asia	Unknown	ES, GB	J	crushed bones	Duff (2008), Hava (2003), Hava. A Catalogue of World Dermestidae.)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Dermestes maculatus De Geer, 1774	C	detriti-vorous	Crypto-genic	1871, PL	AL, AT, BG, FR, IE, LT, MT, PL, PT, PT-AZO, CH, GB	J1, J6	domestic, on animal products, fabrics, necrophagous but in vegetal matter(corn kernels)	Borges et al. (2005), Duff (2008), Freude et al. (1979), Haines and Rees (1989), 88180, Wittenberg et al. (2006)
Dermestes peruvianus Laporte de Castelnau, 1840	A	detriti-vorous	C & S America	1919, PL	AT, CZ, FR, DE, IT, PL, ES-CAN, CH, GB	J1, J6, G	domestic, on animal products, fabrics;, necrophagous but in vegetal matter (corn kernels)	Freude et al. (1979), Haines and Rees (1989), Hava (2003), Machado and Oromi (2000), Šefrova and Lastuvka (2005)
Dermestes vorax Motschulsky, 1860	A	detriti-vorous	Asia-Temperate	Unknown	IT	J	detrivorous	Freude et al. (1979), Hava (2003)
Novelsis horni (Jayne, 1882)	A	detriti-vorous	C & S America	Unknown	NL	J		Hava (2003), Hava. A Catalogue of World Dermestidae.)
Orphinus fulvipes Guerin-Meneville 1838	A	detriti-vorous	Tropical, subtropical	Unknown	FR, GB	J	stored products	Duff (2008), Freude et al. (1979), Hava (2003)
Phradonoma tricolor (Arrow, 1915b:431)	A	detriti-vorous	Asia-Tropical	Unknown	DK, NL	J		Hava (2003), Hava. A Catalogue of World Dermestidae.)
Reesa vespulae (Milliron, 1939)	A	detriti-vorous	North America	1977, GB	CZ, DK, EE, FR, DE, IT, LV, NO, SE, CH, GB	J1	domestic places and in museum collections	Duff (2008), Freude et al. (1979), Hava (2003), Martinez and Cocquempot (1985), Ratti. Coleotteri alieni in Italia., Šefrova and Lastuvka (2005), Wittenberg et al. (2006)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Sefrania bleusei Pic 1899	A	detritivorous	Africa	1998, PL	FR, PL	J1, J6	fish bones, window sills, entomological collections	Beal and Kadej (2008), Hava (2003), Hava. A Catalogue of World Dermestidae., Ruta et al. (2004)
Telopes heydeni Reitter 1875	A	detritivorous	Africa	Unknown	FR	J1		Freude et al. (1979), Hava (2003)
Thaumaglossa rufocapillata Redtenbacher, 1867	A	parasitic/predator	Asia, Africa	Unknown	DE, NL	U	egg cases of mantids	Freude et al. (1979), Hava (2003)
Thorictodes heydeni Reitter, 1875	C	detritivorous	Cryptogenic	1958, IT	IT	J1	stored seeds, peanuts	Ratti. Coleotteri alieni in Italia., Freude et al. (1979), Hava (2003)
Thylodrias contractus Motschulsky, 1839	A	detritivorous	Asia-Temperate	1935, IT	FR, IT, GB	J1	animal materials	Duff (2008), Šefrova and Lastuvka (2005), Freude et al. (1979), Hava (2003)
Trogoderma angustum (Solier, 1849)	A	detritivorous	C & S America	1921, PL	AT, CZ, DK, DE, LV, LT, PL, SE, CH	J1	domestic situations and in museum collections	Barsevskis et al. (2004), Freude et al. (1979), Hava (2003), Ruta et al. (2006), Šefrova and Lastuvka (2005), Wittenberg et al. (2006)
Trogoderma glabrum (Herbst, 1783)	C	detritivorous	Cryptogenic	1904, BG	AT, BG, DK, FR, LV, LT, CH, GB	J1	domestic situations and in nests of solitary wasps	Duff (2008), Freude et al. (1979), Hava (2003), Tomov (2009), Wittenberg et al. (2006)
Trogoderma granarium Everts, 1898	A	detritivorous	Asia	1895, GB	AL, AT, BG, CZ, DK, DE, HU, IE, IT, IT-SAR, IT-SIC, PL, CH, GB	J1	stored products, especially cereals	Duff (2008), Freude et al. (1979), Hava (2003), Šefrova and Lastuvka (2005), Tomov (2009), Wittenberg et al. (2006)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Trogoderma inclusum LeConte, 1854	A	detritivorous	North America	1956, GB	AL, IT, PL, GB	J1	psychophage, stored products	Duff (2008), Hava (2003), Hermann and Baena (2004), Ratti. Coleotteri alieni in Italia.)
Trogoderma insulare Chevrolat, 1863	A	detritivorous	C & S America	Unknown	FR	J	stored products	Hava (2003)
Trogoderma longisetosum Chao & Lee, 1966	A	detritivorous	Asia	2005, CZ	AL, CZ	J1	stored products	Hava (2003), Hava. A Catalogue of World Dermestidae., Šefrova and Lastuvka (2005)
Trogoderma megatomoides Reitter, 1881	A	detritivorous	C & S America	1900, CZ	AL, AT, CZ, FR, IT, NL, SE	J1	insects in collection	Freude et al. (1979), Hava (2003), Ratti. Coleotteri alieni in Italia., Šefrova and Lastuvka (2005)
Trogoderma variabile Ballion, 1878	A	detritivorous	Asia	1978, GB	CZ, FI, IT, LV, SE, GB	J1	wheat, any dry vegetal and animal stored products in warehouse; major pest	Duff (2008), Hava (2003), Hava. A Catalogue of World Dermestidae., Šefrova and Lastuvka (2005), Ratti. Coleotteri alieni in Italia.)
Trogoderma versicolor (Creutzer, 1799)	C	detritivorous	Cryptogenic	Unknown	AT	J	eggs predation	Camerini (2009), Freude et al. (1979)
Dytiscidae								
Megadytes costalis Fabricius, 1775	A	parasitic/ predator	C & S America	Unknown	GB	U	predator	Duff (2008)
Elateridae								
Cardiophorus taylori Cobos, 1970	A	phytophagous	Africa	1952, DE	DE	U	unknown	
Conoderus posticus (Eschscholtz)	A	phytophagous	C & S America	Unknown	PT-AZO	U	*Chrysanthemoides monilifera*	Borges (1990), Borges et al. (2005), Mendonça and Borges (2009)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Panspaeus guttatus Sharp, 1877	A	phyto-phagous	Australasia	1981, GB	GB	U	unknown	Duff (2008), Freude et al. (1979)
Endomychidae								
Holoparamecus caularum Aube, 1843	C	detriti-vorous	Crypto-genic	1937, FR, FR-COR	AT, BG, FR, FR-COR, DE, CH	I, J, J6	on fungus, on decaying plant material, attic	Borges et al. (2005), Moncoutier (2002), Shockley et al. (2009a), Tomov (2009)
Holoparamecus depressus Curtis, 1833	C	detriti-vorous	Crypto-genic	1843, FR	DK, FR	J, J6	flour, dry fruits, medicinal plants, decayed wood	Curtis (1836), Shockley et al. (2009a)
Erotylidae								
Dacne picta Crotch, 1873	A	detriti-vorous	Asia	1954, FR-COR	AL, CZ, FR, FR-COR, IT, PL, ES	J	shitake mushrooms	Iablokoff-Khnzorian (1975), Šefrova and Lastuvka (2005)
Histeridae								
Carcinops pumilio (Erichson, 1834)	C	parasitic/ predator	Crypto-genic	1995, LT	AT, BG, DE, LV, LT, PT-AZO, CH	E	cadavers, faeces, *Dracunculus*	Borges (1990), Borges et al. (2005), Freude et al. (1971), Mendonça and Borges (2009), Tomov (2009), Wittenberg et al. (2006)
Carcinops troglodytes (Paykull, 1811)	A	parasitic/ predator	C & S America	Unknown	PT-AZO	J	predator on *Tribolium*, *Sitophilus* in manioc, poultry fly predator	Borges et al. (2005)
Chalcionellus decemstriatus Reichardt, 1932	A	parasitic/ predator	Africa	Unknown	FR	E	feces, cadavers	Freude et al. (1971), Gomy (2006), Gomy (2008), Gomy (2009)
Diplostix mayeti (Marseul, 1870)	A	parasitic/ predator	Africa	Unknown	FR	I2	predator under bark and pods, peanuts, manioc	Delobel and Tran (1993), Yélamos (1992)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Hister bipunctatus Paykull, 1811	A	parasitic/ predator	Africa	1974, FR	CY, FR, ES	E	dung	
Hypocaccus brasiliensis (Paykull, 1811)	C	parasitic/ predator	Crypto-genic	Unknown	IT, PT-AZO	B1	cadavers, faeces, sandy soil	Mendonça and Borges (2009)
Paromalus luderti Marseul, 1862	A	detriti-vorous	C & S America	Unknown	FR, ES, ES-CAN	I	decaying *Opuntia* in native range; straw and manure in invaded area	Gomy (2008), Machado and Oromi (2000)
Saprinus lugens Erichson, 1834	A	detriti-vorous	North America, C & S America	1984, IT	HR, FR, IT, IT-SAR, IT-SIC, PT, ES	H	cadavers, faeces	Ratti. Coleotteri alieni in Italia.)
Hydrophilidae								
Cercyon inquinatus Wollaston, 1854	A	unknown	Africa	Unknown	AT, HR, CZ, IT, PT-AZO, ES-CAN	U	decomposing seaweed, rotting fruits, cave guano	Borges et al. (2005), Boukal et al. (2007), Machado and Oromi (2000), Ryndevich (2004)
Cercyon laminatus Sharp, 1873	A	parasitic/ predator	Asia-Temperate	1950, CZ, IT	AL, AT, BE, CZ, DK, EE, FI, FR, DE, IT, LT, NL, ES, SE, CH, GB	E3, F9, I	compost, predator, In various humid environments; wet grasslands	Duff (2008), Freude et al. (1971), Ødegaard and Tømmerås (2000), Ratti. Coleotteri alieni in Italia., Wittenberg et al. (2006)
Cercyon nigriceps (Marsham, 1802)	A	parasitic/ predator	Asia?	Unknown	CZ, PT-AZO	U		Borges et al. (2005), Boukal et al. (2007), Freude et al. (1971), Mendonça and Borges (2009), Ryndevich (2004)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Cryptopleurum subtile Sharp, 1884	A	parasitic/ predator	Asia-Temperate	1950, IT	AL, AT, BE, CZ, DK, FI, FR, DE, HU, IT, NL, NO, SE, CH, GB	E3, F9, I	compost, predator, In various humid environments	Duff (2008), Freude et al. (1971), Ødegaard and Tømmerås (2000), Šefrova and Lastuvka (2005), Wittenberg et al. (2006)
Dactylosternum abdominale (Fabricius, 1792)	A	parasitic/ predator	Africa	Unknown	HR, CY, FR, DE, GR, IT, PT-AZO, PT-MAD, ES, ES-CAN	C1+C2	thermophilic, standing water with plants; egg predator on banana weevil in Kenya	Borges et al. (2005), Machado and Oromi (2000), Mendonça and Borges (2009)
Oosternum sharpi Hansen, 1999	A	unknown	North America	Unknown	PT-AZO	C1, D	in standing water	Borges et al. (2005), Mendonça and Borges (2009), Peck (2009)
Pachysternum capense (Mulsant, 1894)	A	unknown	Africa	Unknown	GR, IT, ES-CAN	C1, D	in standing water	Boukal et al. (2007), Fikacek and Boukal (2004), Machado and Oromi (2000), Ratti. Coleotteri alieni in Italia.)
Pelosoma lafertei Mulsant, 1844	A	unknown	C & S America	1929, IT	FR, IT	D1-D4 ? J?	plant held waters, or phytotelmata	Fikacek and Boukal (2004), Sharp (1882–1887)
Laemophloeidae								
Cryptolestes duplicatus (Waltl 1834)	C	detriti-vorous	Crypto-genic	1990, FR	AT, BY, CZ, DK, FR, DE, HU, PL	J1, G1	under oak bark, stored products	Santamaria et al. (1996)
Cryptolestes ferrugineus (Stephens, 1831)	C	detriti-vorous, parasitic/ predator	Crypto-genic	1875, CZ	AT, BY, BE, BG, HR, CZ, DK, FI, FR, DE, GR, HU, IT-SIC, LV, LT, MT, PL, PT, PT-AZO, PT-MAD, RS, ES, SE, CH, UA, GB	J1, G	stored products, under bark	Borges et al. (2005), Duff (2008), Mendonça and Borges (2009), Santamaria et al. (1996), Šefrova and Lastuvka (2005), Tomov (2009), Wittenberg et al. (2006)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Cryptolestes pusilloides (Steel & Howe, 1952)	C	detritivorous	Cryptogenic	1978, IT	AT, BE, HR, CZ, DK, FI, FR, DE, GR, HU, IT, IT-SIC, MT, PL, PT, PT-MAD, RS, ES, SE, UA, GB	J	stored products, psychophage/mills	Duff (2008), Ratti. Coleotteri alieni in Italia., Santamaria et al. (1996)
Cryptolestes pusillus (Schönherr, 1817)	A	detritivorous	Tropical, subtropical	1875, CZ	AL, AT, BY, BG, CZ, DK, FR, DE, IT, IT-SAR, MT, PT-AZO	J	synanthropic, grain, damage	Borges et al. (2005), Moncoutier (2002), Santamaria et al. (1996), Šefrova and Lastuvka (2005), Tomov (2009)
Cryptolestes spartii (Curtis, 1834)	C	detritivorous	Cryptogenic	1991, FR	AL, EE, FR, FR-COR, DE, PT-AZO, ES, ES-CAN, CH	J1, F	corn flour; dry wood (Sarothamnus)	Santamaria et al. (1996), Wittenberg et al. (2006)
Cryptolestes turcicus (Grouvelle, 1876)	C	detritivorous	Cryptogenic	1904, FR	AL, AT, BE, HR, CZ, DK, FI, FR, DE, GR, HU, IT, IT-SAR, IT-SIC, PL, PT, PT-AZO, PT-MAD, RS, ES, SE, CH, UA, GB	J1	dry fruits, grain, wheat, synanthropic	Borges et al. (2005), Duff (2008), Santamaria et al. (1996), Šefrova and Lastuvka (2005), Wittenberg et al. (2006)
Languriidae								
Cryptophilus integer (Heer, 1841)	C	detritivorous	Cryptogenic	Unknown	AT, MT, PT-AZO, CH	J1	stored products; mycophagous, Vigna	Borges et al. (2005), Mendonça and Borges (2009), Wittenberg et al. (2006)
Cryptophilus obliteratus Reitter,1874	A	detritivorous	Asia	1982, DE	AT, DK, FR, DE	I	hay	Callot (2003)
Pharaxonotha kirschii Reitter, 1875	C	detritivorous	Cryptogenic	1900, CZ	CZ	J1	psychophage, grain, floour	Šefrova and Lastuvka (2005)
Latridiidae								
Adistemia watsoni (Wollaston, 1871)	C	detritivorous	Cryptogenic	1959, CZ	CZ, FR, DE, CH, GB	J1, I	*Tamarindus* seeds, dry fruits, Feeds on fungus, found in herbariium	Bouget and Vincent (2008), Duff (2008), Freude et al. (1967), Šefrova and Lastuvka (2005), Wittenberg et al. (2006)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Cartodere bifasciata (Reitter, 1877)	A	detritivorous	Australasia	2000, DE	AT, BE, CZ, DK, FR, DE, NL, PT-MAD, SE, CH, GB	G, I2	mycophagous, under bark	Bouget and Vincent (2008), Duff (2008), Reemer (2003)
Cartodere delamarei (Dajoz, 1960)	A	detritivorous	C & S America	1976, FR	FR	I, J6	mycophagous, vegetal decay	Bouget and Vincent (2008), Vincent (1999)
Cartodere nodifer (Westwood, 1839)	A	detritivorous	Australasia	1850, DE	AL, AT, BY, BE, BA, BG, HR, CY, CZ, DK, EE, FI, FR, FR-COR, DE, GR, GR-CRE, HU, IS, IE, IT, IT-SAR, IT-SIC, LV, LI, LT, LU, MT, MD, NL, NO, PL, PT, PT-AZO, PT-MAD, RO, RU, RS, SK, SI, ES, ES-BAL, ES-CAN, SE, CH, UA, GB	I, J6	mycophagous, compost, attic, hay	Borges et al. (2005), Bouget and Vincent (2008), Duff (2008), Machado and Oromi (2000), Mendonça and Borges (2009), Tomov (2009)
Cartodere constricta (Gyllenhal, 1827)	C	detritivorous	Cryptogenic	1889, GB	BY, FR, LV, NO, SE, GB	J1, J6	mycophagous, compost, dry fruits, remains, dust	Bouget and Vincent (2008), Duff (2008), Telnov (1996)
Corticaria elongata(Gyllenhal 1827)	C	detritivorous	Cryptogenic	1889, GB	AT, BY, BE, BA, BG, HR, CZ, DK, EE, FI, FR, FR-COR, DE, GR, HU, IT, IT-SAR, IT-SIC, LV, LT, LU, MD, ME, NL, NO, PL, PT, PT-AZO, RO, RS, SK, ES, SE, CH, UA, GB	G, I, J	forest humus, rotten fruits, hay, firewood	Borges et al. (2005), Bouget and Vincent (2008), Duff (2008), Freude et al. (1967), Mendonça and Borges (2009), Moncoutier (2002), Telnov (1996), Tomov (2009)
Corticaria fenestralis Linneaus, 1758)	C	detritivorous	Cryptogenic	1908, FR	AT, BY, BG, FR, DE, CH	G, I, J	vegetal refuses, hotels, houses, pine bark	Bouget and Vincent (2008), Duff (2008)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Corticaria fulva (Comolli, 1837)	C	detritivorous	Cryptogenic	1874, FR	AT, BY, BG, FR, DE, PT-AZO, CH	I, J6	Fungi on cacao, spices, cereals, decaying plant material	Borges et al. (2005), Bouget and Vincent (2008), Duff (2008), Freude et al. (1967), Mendonça and Borges (2009), Tomov (2009), Wittenberg et al. (2006)
Corticaria pubescens (Gyllenhal, 1827)	C	detritivorous	Cryptogenic	1897, GB	AT, BY, FR, DE, HU, LT, CH	I, J6	tobacco, medicinal plants, on fungus, on decaying plant material	Bouget and Vincent (2008), Freude et al. (1967), Wittenberg et al. (2006)
Corticaria serrata (Paykull 1798)	C	detritivorous	Cryptogenic	1997, LT	AT, BY, BG, DE, LT, PT-AZO, CH	I, J1, J6	on fungus, on decaying plant material, corn, barley	Borges et al. (2005), Bouget and Vincent (2008), Freude et al. (1967), Mendonça and Borges (2009), Tomov (2009), Wittenberg et al. (2006)
Dienerella argus (Reitter, 1884)	C	detritivorous	Cryptogenic	1907, GB	FR, LV, GB	G	mycophagous, mosses, old trees	Bouget and Vincent (2008), Duff (2008), Moncoutier (2002), Telnov (1996)
Dienerella costulata (Reitter, 1877)	C	detritivorous	Cryptogenic	1900, CZ	CZ, DK, FR	J	foodstuffs, roots, cellars, appartments	Bouget and Vincent (2008), Šefrova and Lastuvka (2005)
Dienerella filum (Aubé, 1850)	C	detritivorous	Cryptogenic	1850, FR	AT, BE, BG, CZ, FR, DE, IE, LV, MT, SE, CH, GB	I, J	cereals, herbaria, yeast, on fungus, on decaying plant material	Bouget and Vincent (2008), Duff (2008), Freude et al. (1967), Moncoutier (2002), Šefrova and Lastuvka (2005), Tomov (2009)
Lathridius australicus Belon, 1887	A	detritivorous	Australasia	Unknown	PT-AZO	U	unknown	Duff (2008), Freude et al. (1967), Mendonça and Borges (2009)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Latridius minutus (Linnaeus, 1767)	C	detriti-vorous	Crypto-genic	1852, FR	AT, BY, BG, FÖ, FR, FR-COR, DE, LV, LT, PT-AZO, CH, GB	I, J	cereals/ mills, cellars, attic, on fungus, on decaying plant material	Bengtson (1981), Borges et al. (2005), Bouget and Vincent (2008), Duff (2008), Enckell et al. (1987), Freude et al. (1967), Moncoutier (2002), Tomov (2009), Wittenberg et al. (2006)
Metophthalmus serripennis Broun 1914	A	detriti-vorous	Australasia	1928, DE	DE, GB	J	fungi on straw, warehouses; dead leaves	Duff (2008)
Migneauxia orientalis Reitter, 1877	C	detriti-vorous	Crypto-genic	1993, DE	AT, DK, FR, DE, PL, CH	I, J	rice, on fungus, on decaying plant material	Bouget and Vincent (2008), Wittenberg et al. (2006)
Lyctidae								
Lyctus africanus Lesne, 1907	A	phyto-phagous	Africa	Unknown	AT, FR, CH	J1	ginger roots; sapwood in field	Freude et al. (1969), Ratti. Coleotteri alieni in Italia., Wittenberg et al. (2006)
Lyctus brunneus (Stephens, 1830)	A	phyto-phagous	Asia	1850, FR	AL, AT, BY, BG, CZ, DK, FR, DE, GR, IT, IT-SAR, LV, MT, PT, RS, CH	J1	manioc; sapwood	Borges et al. (2005), Freude et al. (1969), Glavendekic et al. (2005), Mendonça and Borges (2009), Šefrova and Lastuvka (2005), Wittenberg et al. (2006)
Lyctus cavicollis J. L. LeConte, 1805	A	phyto-phagous	North America	1996, DE	AT, FR, DE, CH	J1	wood in houses	Ratti. Coleotteri alieni in Italia., Wittenberg et al. (2006)
Lyctus planicollis J. L. LeConte, 1858	A	phyto-phagous	North America	1935, FI	AT, FI, FR	J1	*Quercus*, *Fraxinus* (N), wood post in houses	Freude et al. (1969), Ratti. Coleotteri alieni in Italia.)
Lyctus sinensis Lesne, 1911	A	phyto-phagous	Asia	Unknown	GB	J1	timber yards, rarely in the wild	Duff (2008)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Minthea rugicollis (Walker, 1858)	A	phytophagous	Tropical, subtropical	Unknown	IT	J1	timber-feeding beetle; attack wide-pored hardwood, broadleaf or coniferous trees and timber with starch levels of greater than 3% (*Afzelia*, *Artocarpus*, *Avicennia*, *Bombax*, *Helicia*, *Koompassia*, *Shorea*)	Abood and Murphy (2006), Halperin and Geis (1999)
Mordellidae								
Mordellistena cattleyana Champion, 1913	A	phytophagous	C & S America	1921, NL	DE, LV, NL	J100	*Cattleya*, *Vandia*, warm greenhouses. On flowers of *Angelica silvestris* in pine forest.	Batten (1976), Lima (1955), Telnov (1996)
Mycetophagidae								
Litargus balteatus Leconte, 1856	A	detritivorous	North America	1983, CZ	AT, CZ, FR, IT, PT-AZO, CH	I, J6	on fungus, on decaying plant material, Maize, dried grapes, stored products	Borges et al. (2005), Ratti. Coleotteri alieni in Italia., Šefrova and Lastuvka (2005), Wittenberg et al. (2006)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Typhaea stercorea (Linnaeus, 1758)	C	detritivorous	Cryptogenic	1955, BG	AT, BG, FR, DE, IT, IT-SAR, IT-SIC, LT, MT, PT-AZO, CH	I, J, J6	on fungus, on decaying plant material, waste, decay; mills, attic	Borges et al. (2005), Freude et al. (1967), Mendonça and Borges (2009), Tomov (2009), Wittenberg et al. (2006)
Nitidulidae								
Brachypeplus deyrollei Murray, 1864	A	detritivorous	Africa	1999, FR	FR	I	decaying fruits	Ratti. Coleotteri alieni in Italia., Mifsud and Audisio (2008), Moncoutier (2001)
Brachypeplus mauli Gardner & Classey, 1962	A	detritivorous	Australasia	2005, PT-AZO	PT-AZO, PT-MAD	J1	stored products; under bark	Audisio (1993), Borges (1990), Borges et al. (2005), Mendonça and Borges (2009)
Carpophilus bifenestratus Murray, 1864	A	phytophagous, detritivorous	Africa	1993, FR, FR-COR	AL, BA, BG, HR, CY, FR, FR-COR, GR, IT, IT-SAR, IT-SIC, MT, ME, PT-MAD, RS, SI, ES, ES-BAL, ES-CAN	I, J6	rotten fruits	Mifsud and Audisio (2008)
Carpophilus dimidiatus (Fabricius, 1792)	A	phytophagous, detritivorous	C & S America	1900, CZ	AL, AT, BG, CZ, DK, EE, FR, FR-COR, IT, IT-SAR, IT-SIC, MT, PL, PT-AZO, ES, CH	I, J1	stored products, corn in fields	Audisio (1993), Borges et al. (2005), Mendonça and Borges (2009), Mifsud and Audisio (2008), Moncoutier (2001), Šefrova and Lastuvka (2005), Tomov (2009)
Carpophilus freemani Dobson, 1956	A	phytophagous, detritivorous	Tropical, subtropical	1976, IT	AL, DK, FR-COR, GR, IT, IT-SAR, IT-SIC, PT-AZO, ES	I, J1	dry fruits, maize in field	Audisio (1993), Borges (1990)
Carpophilus fumatus Boheman, 1851	A	phytophagous, detritivorous	Africa	1977, IT	AL, IT, IT-SIC, PT, PT-AZO	J1	*Tamarindus* seeds, dry fruits, granaries	Audisio (1993), Mendonça and Borges (2009), Ratti. Coleotteri alieni in Italia., Vieira et al. (2003)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Carpophilus hemipterus (Linnaeus, 1758)	A	phytophagous, detritivorous	Asia-Tropical	1800, IT	AL, AT, BY, BG, CZ, FR, FR-COR, DE, IT, IT-SAR, IT-SIC, LT, MT, PL, PT-AZO, ES, CH	I, J1	decaying grapes, dry fruits, cereals in granaries, fruits on ground, mushrooms	Audisio (1993), Borges et al. (2005), Mendonça and Borges (2009), Mifsud and Audisio (2008), Šefrova and Lastuvka (2005), Tomov (2009), Wittenberg et al. (2006)
Carpophilus ligneus Murray, 1864	A	phytophagous, detritivorous	C & S America	1981, ES-CAN	HR, FR, DE, GR, ES-CAN	J1	maize, dry fruits, granaries	Audisio (1993), Machado and Oromi (2000)
Carpophilus marginellus Motschulsky, 1858	A	phytophagous, detritivorous	Asia-Tropical	1938, GB	AT, BY, BE, BG, CZ, DK, FI, FR, FR-COR, DE, GR, IT, IT-SAR, IT-SIC, MT, NL, NO, PL, PT-AZO, PT-MAD, ES, ES-CAN, SE, CH, GB	J1	mainly domestic; cereals, compost, saprophagous	Audisio (1993), Borges et al. (2005), Duff (2008), Machado and Oromi (2000), Mendonça and Borges (2009), Ødegaard and Tømmerås (2000), Reemer (2003), Šefrova and Lastuvka (2005), Tomov (2009), Wittenberg et al. (2006)
Carpophilus mutilatus Erichson, 1843	A	phytophagous, detritivorous	C & S America	1900, CZ	AT, BG, CZ, DK, FR, FR-COR, IT, IT-SAR, IT-SIC, LT, MT, PT-AZO	J1, I	dry fruits	Audisio (1993), Borges et al. (2005), Mendonça and Borges (2009), Mifsud and Audisio (2008), Šefrova and Lastuvka (2005), Tomov (2009)
Carpophilus nepos Murray, 1864	A	phytophagous, detritivorous	Tropical, subtropical	Unknown	AL, BA, BG, HR, CY, FR, FR-COR, GR, GR-CRE, GR-ION, GR-NEG, GR-SEG, IT-SAR, IT-SIC, MT, PT, PT-AZO, RO, RU, SI, ES, ES-BAL, ES-CAN, UA	J1, I	dry fruits, outdoors in mediterranean; houses in central europe	Borges et al. (2005), Machado and Oromi (2000), Mendonça and Borges (2009), Mifsud and Audisio (2008), Tomov (2009)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Carpophilus obsoletus Erichson, 1843	A	phytophagous, detritivorous	Asia-Tropical	1895, GR-CRE	CY, CZ, DK, FR, FR-COR, GR, GR-CRE, IT, IT-SAR, IT-SIC, MT, PT, ES,	J1, I	rotten fruits outdoors, granaries (maize, corn)	Audisio (1993), Mifsud and Audisio (2008), Šefrova and Lastuvka (2005)
Carpophilus pilosellus Motschulsky, 1858	A	phytophagous, detritivorous	Asia-Tropical	1983, CZ	AT, HR, CZ, FR, IT, IT-SAR, IT-SIC, PT-AZO, RS, SI	J1, I	dry fruits, fruits on ground, poultry dung	Audisio (1993)
Carpophilus succisus Erichson, 1843	A	phytophagous, detritivorous	C & S America	2005, PT-AZO	PT-AZO	J1	maize	Borges et al. (2005)
Carpophilus zeaphilus Dobson, 1969	A	phytophagous, detritivorous	Africa	1985, PT, ES	AL, FR, IT, IT-SIC, PT, ES	J1, I	maize	Audisio (1993), Ratti. Coleotteri alieni in Italia.)
Epuraea luteola Erichson, 1843	A	detritivorous	C & S America	1970, ES-CAN, PT-MAD	AL, FR, IT, IT-SAR, IT-SIC, MT, MD, PT-MAD, ES-CAN	G, I	fruits (*Prunus*), mushrooms	Audisio (1993), Machado and Oromi (2000), Mifsud and Audisio (2008), Ratti. Coleotteri alieni in Italia., Tomov (2009)
Epuraea ocularis Fairmaire, 1849	A	detritivorous	Asia-Tropical	1900, IT	AL, AT, FR, DE, IT, IT-SIC, MD, ES, ES-CAN, CH	J	mycophagous; manioc, dry fruits	Machado and Oromi (2000), Mifsud and Audisio (2008), Ratti. Coleotteri alieni in Italia.)
Glischrochilus fasciatus (Olivier, 1790)	A	phytophagous, parasitic/predator	North America	1977, DE	DE, CH	I	bark beetle predator, vegetables, fruits	Audisio (1993)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Glischrochilus quadrisignatus (Say, 1835)	A	phytophagous, parasitic/ predator	North America	1950, DE	AL, AT, BY, BA, BG, HR, CZ, FR, DE, GR, HU, IT, LI, LT, MD, ME, PL, RO, RU, RS, SK, SI, SE, CH, UA, GB	I	bark beetle predator, vegetables, fruits	Audisio (1993), Glavendekic et al. (2005), Mendonça and Borges (2009), Ratti. Coleotteri alieni in Italia., Reemer (2003), Šefrova and Lastuvka (2005), Tomov (2009), Wittenberg et al. (2006)
Meligethes ruficornis (Marsham, 1802)	C	phytophagous	Cryptogenic	Unknown	MT, GB	G,I2	*Ballota nigra* pollen	Audisio (1993), Duff (2008), Mifsud and Audisio (2008)
Nitidula carnaria (Schaller, 1783)	C	detritivorous	Cryptogenic	2005, PT-AZO	MT, PT-AZO	J1		Audisio (1993), Borges et al. (2005), Mendonça and Borges (2009), Mifsud and Audisio (2008)
Omosita colon (Linnaeus, 1758)	C	detritivorous	Cryptogenic	2005, PT-AZO	PT-AZO	E, G, I, J	old bones left on the soil surface	Audisio (1993), Borges et al. (2005), Mendonça and Borges (2009)
Omosita discoidea (Fabricius, 1775)	C	detritivorous	Cryptogenic	2005, PT-AZO	PT-AZO	E, G, I, J	cadavers, carrion	Audisio (1993), Borges et al. (2005), Mendonça and Borges (2009)
Phenolia tibialis (Boheman, 1851)	A	detritivorous	Africa	2005, PT-AZO	PT-AZO	I2	decaying and rotting fruits	Borges et al. (2005), Mendonça and Borges (2009)
Stelidota geminata (Say, 1825)	A	phytophagous, parasitic/ predator	C & S America	1900, IT	FR, IT, PT-AZO, SI, ES-CAN, CH	I	in insect galleries under oak bark, strawberries and other fruits	Audisio (1993), Borges et al. (2005), Mendonça and Borges (2009), Ratti. Coleotteri alieni in Italia.)
Urophorus humeralis (Fabricius, 1798)	A	detritivorous	Asia-Tropical	1976, IT	AL, AT, BA, BG, HR, CY, FR, FR-COR, GR, GR-CRE, GR-ION, GR-NEG, GR-SEG, IT, IT-SAR, IT-SIC, MT, ME, PT, PT-MAD, RU, RS, SI, ES, ES-BAL, ES-CAN, UA	J1	dry fruits and vegetables	Audisio (1993), Machado and Oromi (2000), Tomov (2009)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Passandridae								
Catogenus rufus (Fabricius, 1798)	A	parasitic/ predator	North America	2007, AT	AT	F9	predator of wood-boring Coleoptera in riverine forest	Mitter and Schuh (2008)
Phalacridae								
Phalacrus politus Melsheimer, 1844	A	phyto-phagous	North America	Unknown	PT-AZO	I	sweetcorn	Borges et al. (2005), Mendonça and Borges (2009)
Ptiliidae								
Acrotrichis henrici (Matthews, 1872)	A	detriti-vorous	North America	1966, GB	DK, DE, NL, NO, SE, GB	G, J6	compost	Duff (2008), Freude et al. (1971), Reemer (2003), Sörensson and Johnson (2004)
Acrotrichis insularis (Maklin, 1852)	A	detriti-vorous	North America	1965, NO, BG	AT, CZ, DK, FI, FR, DE, IE, NL, NO, PT-AZO, PT-MAD, SE, CH, GB	G, J6	compost, saprophagous, fungivore	Borges et al. (2005), Duff (2008), Freude et al. (1971), Freude et al. (1989), Mendonça and Borges (2009), Ødegaard and Tømmerås (2000), Sörensson and Johnson (2004), Wittenberg et al. (2006)
Acrotrichis josephi (Matthews, 1872)	A	detriti-vorous	North America	1987, GB	GB	I	grass moving; litter, roting organic material	Duff (2008), Sörensson and Johnson (2004)
Acrotrichis sanctaehelenae Johnson, 1972	A	detriti-vorous	Africa	1964, ES-CAN	FR, IT, PT, ES-CAN, CH, GB	I, J6	anthropogenic habitats, dung, compost, rotting organic substances	Duff (2008), Machado and Oromi (2000), Ratti. Coleotteri alieni in Italia., Sörensson and Johnson (2004), Wittenberg et al. (2006)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Baeocrara japonica (Matthews, 1884)	A	detritivorous	Asia	1974, FI	AT, BY, CZ, DK, FI, DE, HU, LV, NO, SK, SE	I, J	compost, saprophagous, fungivore	Freude et al. (1989), Ødegaard and Tømmerås (2000), Ratti. Coleotteri alieni in Italia., Sörensson and Johnson (2004)
Ptinella cavelli (Broun, 1893)	A	detritivorous	Australasia	1936, GB	IE, GB	G3, G4	under tight bark of dead broad-leaves and conifers	Sörensson and Johnson (2004)
Ptinella errabunda Johnson, 1975	A	detritivorous	Australasia	1925, GB	DE, IE, NL, GB	G3	under tight bark of most species of dead trees	Freude et al. (1989), Reemer (2003), Sörensson and Johnson (2004)
Ptinella simsoni (Matthews, 1878)	A	detritivorous	Australasia	1929, GB	GB	G,I2 ?	heap in crass cuttings in wooded areas around large coastal cities (e.g. London, Liverpool)	Sörensson and Johnson (2004)
Ptinella taylorae Johnson, 1977	A	detritivorous	Australasia	1967, GB	IE, GB	G3, G4	under tight bark of dead trees	Duff (2008), Sörensson and Johnson (2004)
Bambara contorta (Dybas, 1066)	A	detritivorous	Tropical, subtropical	1997, DE	DE	E5	forest litter	Ryndevich (2004)
Bambara fusca (Dybas, 1966)	A	detritivorous	North America	1997, DE	DE	E5	forest litter	Sörensson and Johnson (2004)
Ptinella johnsoni Rutanen, 1985	A	detritivorous	Asia	1978, FI, SE	FI, NO, SE	E5	taiga, litter	Sörensson and Johnson (2004)
Ptilodactylidae								
Ptilodactyla exotica Chapin, 1927	A	detritivorous	Africa	1971, IT	FR, IT, SI, CH	J1, J100	*Dracaena* in greenhouse; plants in appartments	Aberlenc and Allemand (1997), Mann (2006), Wittenberg et al. (2006)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Ptilodactyla luteipes Pic, 1924	C	detritivorous	Cryptogenic	1952, DE	DE	J100	greenhouse	
Ripiphoridae								
Ripidius pectinicornis Thunberg, 1806	A	parasitic/ predator	Asia	Unknown	DK, FI, IT, NL	J	*blatta* parasitoid, synanthropic	Bétis (1912), Falin (2001), Freude et al. (1969)
Rutelidae								
Popilia japonica Newman, 1841	A	phytophagous	Asia	2005, PT-AZO	PT-AZO	I2	polyphagous deciduous	Borges et al. (2005), Mendonça and Borges (2009), Paulian and Baraud (1982)
Salpingidae								
Aglenus brunneus (Gyllenhall)	C	detritivorous	Cryptogenic	2005, PT-AZO	PT-AZO	J1	anthropophilic: attic, stables, poultry, damage cultivated mushrooms; rodent nests in forests	Borges et al. (2005)
Silvanidae								
Ahasverus advena (Waltl, 1832)	A	detritivorous	C & S America	1875, CZ	AT, BY, BG, CZ, DK, EE, FI, DE, LT, MT, PL, PT-AZO, SE, CH	I, J1	saprophagous-stored products; compost, clethrophage in field	Borges et al. (2005), Mendonça and Borges (2009), Ødegaard and Tømmerås (2000), Šefrova and Lastuvka (2005), Tomov (2009), Wittenberg et al. (2006)
Cryptamorpha desjardinsi (Guérin-Méneville, 1844)	A	detritivorous, parasitic/ predator	Tropical, subtropical	1911, DE	BE, DK, DE, NL, PT-AZO, ES-CAN	G, I, J	banana, ananas; dead plants, bark, cadavers; larva predator	Borges et al. (2005), Machado and Oromi (2000), Mendonça and Borges (2009), Ratti (2007)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Nausibius clavicornis (Kugelann, 1794)	C	detritivorous	Cryptogenic	1906, FR	DK, FR, PT-AZO	J1	stored products	Borges et al. (2005), Mendonça and Borges (2009), Ratti (2007), Moncoutier (2002)
Oryzaephilus acuminatus Halstead, 1980	A	detritivorous	Asia	1980, GB	GB	J1	coconut, *azadirachta* seeds	Duff (2008)
Oryzaephilus mercator (Fauvel, 1889)	A	detritivorous	Tropical, subtropical	1962, CZ	AT, BY, BG, CZ, DK, EE, HU, LV, MT, NO, PT, PT-AZO, ES-CAN, CH	J1	psychophage, stored products	Borges et al. (2005), Machado and Oromi (2000), Mendonça and Borges (2009), Šefrova and Lastuvka (2005), Tomov (2009), Wittenberg et al. (2006)
Oryzaephilus surinamensis (Linnaeus, 1758)	C	detritivorous	Cryptogenic	1894, PT	AT, BY, BG, CZ, DK, EE, FR, DE, HU, LV, LT, MT, NO, PT, PT-AZO, RS, ES-CAN, CH	J1	psychophage, stored products	Borges et al. (2005), Glavendekic et al. (2005), Machado and Oromi (2000), Mendonça and Borges (2009), Šefrova and Lastuvka (2005), Tomov (2009), Wittenberg et al. (2006)
Silvanus lateritius (Broun, 1880)	A	detritivorous	Australasia	Unknown	PT-AZO	J1		Borges et al. (2005), Mendonça and Borges (2009), Ratti. Coleotteri alieni in Italia.)
Silvanus lewisi Reitter, 1876	A	detritivorous	Asia	Unknown	MT	J1, G	rice, manioc, stored products; under bark of dead trees in field	Ratti (2007), Ratti. Coleotteri alieni in Italia.)
Silvanus recticollis Reitter, 1876	A	detritivorous	Africa	Unknown	IT-SAR, IT-SIC	J1		Ratti. Coleotteri alieni in Italia.)
Staphylinidae								
Acrotona pseudotenera (Cameron, 1933)	A	parasitic/ predator	Asia	1988, FI	AT, DK, FI, DE, NO, SE, CH	I	compost, predator, fungivorous	Luka et al. (2009), Ødegaard and Tømmerås (2000), Wittenberg et al. (2006)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Adota maritima Mannerheim, 1843	A	parasitic/ predator	North America	Unknown	GB	B	decomposing seaweed, predator flies	Duff (2008)
Aleochara puberula Klug, 1833	C	parasitic/ predator	Crypto- genic	Unknown	AT, PT-AZO	I1, J	predator of cyclorrhaphous Diptera (*Musca*) in stables	Borges et al. (2005), Freude et al. (1974), Mendonça and Borges (2009)
Anotylus nitidifrons (Wollaston, 1871)	C	parasitic/ predator	Crypto- genic	Unknown	PT-AZO, ES-CAN	I	predator on *Delia* (carrots)	Borges et al. (2005), Machado and Oromi (2000), Mendonça and Borges (2009)
Atheta dilutipennis (Motschulsky, 1858)	A	parasitic/ predator	Africa, Asia	1995, IT	AL, IT, PT-AZO, ES-CAN	U		Borges (1990), Borges et al. (2005), Machado and Oromi (2000), Mendonça and Borges (2009)
Atheta mucronata (Kraatz, 1859)	A	parasitic/ predator	Tropical, subtropical	2002, ES	IT, ES	I2	decaying vegetals, citrus groves	Gamarra and Outerelo (2005), Monzo et al. (2005)
Bisnius palmi (Smetana, 1955)	A	parasitic/ predator	North America	Unknown	AL, CZ, IT, IT-SIC	I, J6		Newton. Staphylinini Species Catalog Draft)
Bisnius parcus (Sharp, 1874)	A	parasitic/ predator	Asia- Temperate	1950, FI, DE	AL, AT, DK, FI, FR, DE, IT, NO, ES-CAN, SE, CH, GB	I, J6	compost, predator	Cho (2008), Duff (2008), Korge (2005), Luka et al. (2009), Ødegaard and Tømmerås (2000), Ratti. Coleotteri alieni in Italia., Tronquet (2006)
Bohemiellina flavipennis (Cameron, 1921)	C	parasitic/ predator	Crypto- genic	1941, FI, DE	AT, BE, DK, FI, FR, DE, NO, SE, GB	B1, E3	compost	Ødegaard and Tømmerås (2000), Tronquet (2006)
Carpelimus bilineatus Stephens, 1834	C	phyto- phagous	Crypto- genic	2005, PT-AZO	PT-AZO	B1, E3	grassy coastal patches, sand dunes	Borges et al. (2005), Mendonça and Borges (2009), Tronquet (2006)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Carpelimus corticinus (Gravenhorst, 1806)	C	phyto-phagous	Crypto-genic	2005, PT-AZO	PT-AZO	B1, E3	floodplains, river banks, sand beaches	Borges (1990), Borges et al. (2005), Tronquet (2006)
Carpelimus gracilis (Mannerheim, 1830)	C	parasitic/predator	Crypto-genic	2005, PT-AZO	PT-AZO	B1, E3	floodplains, river banks, sand beaches	Borges et al. (2005), Tronquet (2006)
Carpelimus pusillus (Gravenhorst, 1802)	C	parasitic/predator	Crypto-genic	2005, PT-AZO	PT-AZO	B1, E3	floodplains, river banks, sand beaches	Borges et al. (2005), Mendonça and Borges (2009)
Carpelimus subtilis (Erichson, 1839)	C	unknown	Crypto-genic	2005, PT-AZO	PT-AZO	B	floodplains, river banks, sand beaches	Borges et al. (2005), Duff (2008), Vorst et al. (2007)
Carpelimus zealandicus (Sharp, 1900)	A	unknown	Australasia	2000, DE	AT, BE, DE, SE, CH, GB	E	Sandy banks	Cuppen (2003), Korge (2005), Luka et al. (2009)
Cilea silphoides (Linnaeus, 1767)	C	parasitic/predator	Crypto-genic	2005	PT-AZO, ES-CAN	U	cattle dung	Borges et al. (2005), Machado and Oromi (2000), Mendonça and Borges (2009), Tronquet (2006)
Coproporus pulchellus (Erichson, 1839)	A	unknown	North America	Unknown	PT-AZO, PT-MAD, ES-CAN	U		Borges et al. (2005), Machado and Oromi (2000), Mendonça and Borges (2009)
Diestota guadalupensis Pace, 1987	A	unknown	C & S America	1982, IT	IT	U		Ratti. Coleotteri alieni in Italia.)
Leptoplectus remyi (Jeannel, 1961)	A	parasitic/predator	Asia	Unknown	CH	U		Wittenberg et al. (2006)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Lithocharis nigriceps (Kraatz, 1859)	A	parasitic/ predator	Asia-Tropical	1912, CZ	AL, AT, BE, CZ, DK, EE, FI, FR, DE, HU, IT, LV, NL, NO, PL, PT-AZO, SK, ES, SE, CH, UA, GB	I, J6	compost, predator.	Borges et al. (2005), Duff (2008), Freude et al. (1964), Korge (2005), Luka et al. (2009), Ødegaard and Tømmerås (2000), Šefrova and Lastuvka (2005), Tronquet (2006)
Myrmecocephalus concinna (Erichson,1840)	C	detriti-vorous	Crypto-genic	1970, DE	DE, PT-AZO, PT-MAD, RU, ES-CAN, SE, GB	G	deadwood	Duff (2008), Korge (2005), Machado and Oromi (2000), Tronquet (2006)
Myrmecopora brevipes Butler, 1909	C	parasitic/ predator	Crypto-genic	Unknown	FR, IE, GB	U	in wet sand under plants	Anderson (1997), Scheerpeltz (1972)
Nacaeus impressicollis (Motschulsky, 1857)	A	unknown	Africa (or Asia?)	2005, PT-AZO	CZ, PT-AZO	I2,G?		Borges et al. (2005), Mendonça and Borges (2009), Rogé (2003), Tronquet (2006)
Oligota parva Kraatz, 1862	A	detriti-vorous	C & S America	1858, FR	AT, BE, BA, HR, DK, EE, FI, FR, FR-COR, DE, GR, GR-CRE, IT, IT-SIC, NL, NO, PL, PT-AZO, PT-MAD, ES-CAN, SE, CH, GB	I, J6	compost, predator, fungivorous. Synanthropic	Borges et al. (2005), Freude et al. (1974), Korge (2005), Luka et al. (2009), Machado and Oromi (2000), Mendonça and Borges (2009), Ødegaard and Tømmerås (2000), Reemer (2003), Wittenberg et al. (2006)
Oxytelus migrator Fauvel, 1904	A	detriti-vorous	Asia	1975, DK	AT, BE, CZ, DK, FR, DE, IT, LT, LU, NO, SE, CH	I, J6	compost, saprophagous	Korge (2005), Luka et al. (2009), Ratti. Coleotteri alieni in Italia., Šefrova and Lastuvka (2005), Wittenberg et al. (2006)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Paraphloeostiba gayndahensis (Mac Leay, 1871)	A	detritivorous	Australasia	1988, IT	FR, DE, IT, IT-SIC, PT, ES, ES-CAN, CH	I, J6	rotting fallen fruits of various trees, decaying vegetals	Duff (2008), Korge (2005), Luka et al. (2009), Machado and Oromi (2000), Ratti. Coleotteri alieni in Italia., Tronquet (2006), Wittenberg et al. (2006)
Philonthus rectangulus Sharp, 1874	A	parasitic/ predator	Asia-temperate	1920, IT	AL, AT, BE, BA, BG, HR, CZ, DK, EE, FI, FR, DE, GR, HU, IT, IT-SAR, LV, LT, LU, MD, ME, NL, NO, PT, PT-AZO, PT-MAD, RO, RS, SK, SI, ES, ES-CAN, SE, CH, UA, GB	I, J6	compost, predator	Borges et al. (2005), Coiffait (1972), Korge (2005), Luka et al. (2009), Machado and Oromi (2000), Ødegaard and Tømmerås (2000), Šefrova and Lastuvka (2005), Tomov (2009), Tronquet (2006), Wittenberg et al. (2006)
Philonthus spinipes Sharp, 1874	A	parasitic/ predator, detrivorous	Asia	1980, IT	AL, AT, BG, CZ, DK, FR, IT, LT, RU, CH	J1, J6	in stable litter, cadavers	Callot (1993), Luka et al. (2009), Ratti. Coleotteri alieni in Italia., Šefrova and Lastuvka (2005), Tomov (2009), Tronquet (2006)
Tachinus sibiricus Sharp, 1888	A	unknown	Asia	Unknown	AT	U		
Trichiusa immigrata Lohse, 1984	A	unknown	North America	1975, DE	AL, AT, BE, CZ, DK, FR, DE, IT, NO, ES-CAN, SE, CH	I, I2	compost, predator, fungivorous	Korge (2005), Luka et al. (2009), Ødegaard and Tømmerås (2000), Ratti. Coleotteri alieni in Italia., Tronquet (2006), Wittenberg et al. (2006)
Teropalpus unicolor (Sharp, 1900)	A	parasitic/ predator, detrivorous	Australasia	Unknown	GB	I2	halophilous	Duff (2008), Kuschel (1990)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Tenebrionidae								
Alphitobius diaperinus (Panzer, 1797)	A	parasitic/ predator, detrivorous	Tropical, subtropical	1921, ME	AT, BG, DK, EE, FR, FR-COR, DE, HU, IT, LV, LT, MT, ME, NO, ES-CAN, CH, GB	J1, J6, G	minor pest of residues, common inhabitant of chicken houses; feeds on faeces and wastes; outdoors in rotten trunks and bird/ bat nests	Borges et al. (2005), Duff (2008), Freude et al. (1969), Tomov (2009), Wittenberg et al. (2006)
Alphitobius laevigatus (Fabricius, 1781)	A	detritivorous	Tropical, subtropical	Unknown	DK, EE, FR, MT, ES-CAN, GB	J1, J6, G	minor pest of residues; stored products; outdoors on fungi in trunks	Borges et al. (2005), Duff (2008), Freude et al. (1969), Machado and Oromi (2000)
Alphitophagus bifasciatus (Say, 1823)	C	detritivorous	Cryptogenic	1940, BG	AL, AT, BG, HR, DK, FI, FR, DE, GR, HU, LT, NO, RO, SE, CH	J1, J6, G	minor pest of residues; compost, Mainly domestic in rotten fruits; under bark old stumps	Freude et al. (1969), Ødegaard and Tømmerås (2000), Tomov (2009), Wittenberg et al. (2006)
Cynaeus angustus (Leconte, 1851)	A	detritivorous	C & S America	1988, SE	FI, FR, DE, SE	J6	saprophagous, waste heaps	Ferrer (2004), Ferrer and Andersson (2002), Reibnitz and Schawaller (2006), Soldati (2007)
Cynaeus depressus Horn, 1870	A	detritivorous	C & S America	1988, SE	SE	U	waste heaps	Ferrer (2004), Mannerkoski and Ferrer (1992)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Gnathocerus cornutus (Fabricius, 1798)	A	detritivorous	C & S America	1900, CZ	AT, CZ, EE, FR, DE, IT, IT-SAR, IT-SIC, LV, MT, PT-AZO, ES-CAN, CH, GB	J1	cereal grains in warehouses	Borges et al. (2005), Duff (2008), Freude et al. (1969), Machado and Oromi (2000), Mendonça and Borges (2009), Šefrova and Lastuvka (2005), Wittenberg et al. (2006)
Gnathocerus maxillosus (Fabricius, 1801)	C	detritivorous	Cryptogenic	1977, IT	AL, FR, FR-COR, IT, ES-CAN	J1	cereal grains in warehouses	Machado and Oromi (2000), Tomov (2009)
Latheticus oryzae Waterhouse, 1880	A	detritivorous	Asia	1973, BG, CZ	AL, AT, BG, CZ, DK, EE, FR, IT, IT-SIC, RS, ES-CAN, CH, GB	J1	stored products, cereals in warehouses	Duff (2008), Freude et al. (1969), Glavendekic et al. (2005), Machado and Oromi (2000), Šefrova and Lastuvka (2005), Tomov (2009), Wittenberg et al. (2006)
Lyphia tetraphylla (Fairmaire, 1856)	A	detritivorous	Asia	1934, CZ	HR, CZ, FR, GR, ME	U		Šefrova and Lastuvka (2005)
Palorus ratzeburgi (Wissmann, 1848)	A	detritivorous	Africa	1976, LT	HR, DK, FR, GR, LT, ES-CAN, GB	J1	stored products, mainly cereals; mycophagous	Borges et al. (2005), Duff (2008), Freude et al. (1969), Machado and Oromi (2000)
Palorus subdepressus (Wollaston, 1864)	A	detritivorous	Africa	1975, BG	BG, HR, CZ, DK, FR, GR, MT, PT-AZO, ES-CAN, GB	J1	stored products, mainly cereals; mycophagous	Borges et al. (2005), Duff (2008), Freude et al. (1969), Machado and Oromi (2000), Šefrova and Lastuvka (2005), Tomov (2009)
Tribolium castaneum (Herbst, 1797)	C	detritivorous	Cryptogenic	1900, CZ	AL, AT, BG, CZ, DK, EE, FR, FR-COR, DE, GR, HU, LV, LT, MT, ME, NO, PT, PT-AZO, RO, ES-CAN, CH, GB	J1, J2	stored products	Borges et al. (2005), Duff (2008), Freude et al. (1969), Machado and Oromi (2000), Mendonça and Borges (2009), Šefrova and Lastuvka (2005), Tomov (2009), Wittenberg et al. (2006)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Tribolium confusum Jacquelin du Val, 1868	A	detritivorous	Africa	1900, CZ	AL, AT, BG, HR, CZ, DK, EE, FR, DE, GR, HU, IT, LV, LT, NO, PT-AZO, ES-CAN, CH, GB	J1, J2	stored products	Borges et al. (2005), Duff (2008), Freude et al. (1969), Machado and Oromi (2000), Šefrova and Lastuvka (2005), Tomov (2009), Wittenberg et al. (2006)
Tribolium destructor Uyttenboogaart, 1933	A	detritivorous	tropical	1927, DE	AL, AT, BG, CZ, DK, EE, DE, HU, IT, LV, LT, NO, ES-CAN, CH, GB	J1, J2	stored products	Duff (2008), Freude et al. (1969), Machado and Oromi (2000), Ratti. Coleotteri alieni in Italia., Šefrova and Lastuvka (2005), Tomov (2009), Wittenberg et al. (2006)
Zophobas morio (Fabricius, 1776)	A	detritivorous	C & S America	Unknown	LV	J	used as food for reptile pets	Thomas (1995)
Trogidae								
Omorgus subcarinatus (MacLeay, 1864)	A	detritivorous	Australasia	1997, ES	ES	J1, J6		Bercedo (1997)
Omorgus suberosus (Fabricius, 1775)	A	detritivorous	Australasia	1997, ES	ES	J1, J6		Bercedo (1997)
Trogossitidae								
Lophocateres pusillus (Klug, 1832)	A	detritivorous	Asia	1962, CZ	AL, CZ, DK, IT	J1	psychophage, necrophagous; rice, stored products	Šefrova and Lastuvka (2005)
Tenebroides maroccanus Reitter 1884	A	parasitic/ predator	Africa	2005, PT-AZO	PT-AZO	G	predator egg *Lymantria dispar*	Borges et al. (2005)

Family species	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Tenebroides mauritanicus (Linnaeus, 1758)	A	detritivorous	Africa	1803, PT	AT, BG, CZ, DK, EE, DE, IT, LV, LT, PT, PT-AZO, RS, CH	J1, G	psychophage, carnivorous; stored products, bark in field	Borges et al. (2005), Glavendekic et al. (2005), Mendonça and Borges (2009), Šefrova and Lastuvka (2005), Tomov (2009)
Zopheridae								
Microprius rufulus (Motschulsky, 1863)	A	unknown	Africa	Unknown	MT	U	timber	Schuh and Mifsud (2000)
Pycnomerus fuliginosus Erichson, 1842	A	unknown	Australasia	1962, GB	GB	B2, I2		Duff (2008)
Pycnomerus inexpectus (Jaquelin Du Val, 1859)	C	unknown	Cryptogenic	1901, IT	AL, AT, BE, CZ, FR, IT, ES, GB	J100	orchid greenhouses	Ratti. Coleotteri alieni in Italia.)

Table 9.5.2. List and characteristics of the Coleoptera species alien *in* Europe of families other than Cerambycidae, Curculionidae *sensu lato*, Chrysomelidae *sensu lato* and Coccinelidae. Country codes abbreviations refer to ISO 3166 (see Appendix I). Habitat abbreviations refer to EUNIS (see Appendix II).

Family *Species*	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Anobiidae							
Anobium punctatum De Geer, 1774	phyto-phagous	Europe	Unknown	PT-AZO, ES-CAN	J	wooden furnitures; twigs	Borges et al. (2005), Espanol (1992), Machado and Oromi (2000), Mendonça and Borges (2009)
Oligomerus ptilinoides (Wollaston, 1854)	phyto-phagous	Medi-terranean region	Unknown	AT, DE, HU, PL, PT-MAD, SK, ES-CAN, CH	G, J1	wood broadleaved trees and furnitures	De Laclos and Büche (2009), Espanol (1992), Machado and Oromi (2000), Wittenberg et al. (2006)
Ptinus dubius Sturm, 1837	detriti-vorous	Europe	Unknown	ES-CAN	J1	stored products	Machado and Oromi (2000)
Sphaericus gibboides (Boieldieu, 1854)	detriti-vorous	Medi-teranean	Unknown	DK, GB	J	psychophage; dry roots	Duff (2008)
Anthicidae							
Cordicomus instabilis (Schmidt, 1842)	unknown	Palaearctic	Unknown	PT-AZO	B1	sandy grounds	Borges et al. (2005)
Cyclodinus humilis (Germar, 1824)	unknown	Europe	Unknown	PT-AZO	U	clayey ground	Borges et al. (2005), Mendonça and Borges (2009)
Omonadus formicarius (Goeze, 1777)	detriti-vorous	Europe, cosmopolitan almost	Unknown	PT-AZO	J6	vegetal decay	Borges et al. (2005), Mendonça and Borges (2009)
Aphodiidae							
Calamosternus granarius (Linnaeus, 1767)	detriti-vorous	North Africa, Europe	Unknown	PT-AZO	E	dung	Borges et al. (2005), Mendonça and Borges (2009)
Pleurophorus caesus (Creutzer, 1796)	detriti-vorous	Eurasia, north America	Unknown	PT-AZO	E	dung	Borges et al. (2005), Mendonça and Borges (2009)
Buprestidae							
Agrilus angustulus (Illiger, 1803)	phyto-phagous	Europe	2005, PT-AZO	PT-AZO	G	*Quercus*	Borges et al. (2005), Cobos (1986), Freude et al. (1979), Schaefer (1949), Théry (1942)

Family *Species*	Regime	Native range	1st record in Europe	Invaded countries	Habitat	Host	References
Buprestis novemmaculata Linnaeus, 1758	phytophagous	All over Europe	2005, PT-AZO	PT-AZO	I2	conifers	Borges et al. (2005), Cobos (1986), Freude et al. (1979), Mendonça and Borges (2009), Schaefer (1949), Théry (1942)
Melanophila acuminata (De Geer, 1774)	phytophagous	holarctic	Unknown	GB	F4	conifers	Cobos (1986), Duff (2008), Freude et al. (1979), Schaefer (1949), Théry (1942)
Byrrhidae							
Simplocaria semistriata (Fabricius, 1794)	phytophagous	Central & southeast Europe	Unknown	FÖ	E	synathropic steppe; feeds on moss (*Mnium*)	Bengtson (1981), Enckell et al. (1987), Freude et al. (1979)
Carabidae							
Abax parallelus Duftschmid, 1812	parasitic/ predator	Central Europe	1800, GB	GB	G		Duff (2008), Jeannel (1942), Luff (2007), Valemberg (1997)
Amara aenea (De Geer, 1774)	phytophagous	Palaearctic	Unknown	PT-AZO, ES-CAN	E, I	Poaceae seeds	Borges et al. (2005), Machado and Oromi (2000), Mendonça and Borges (2009), Valemberg (1997)
Amara anthobia A. Villa & G.B. Villa, 1833	phytophagous	Mediterranean region, Central Europe	Unknown	GB	F4, B1	Poaceae seeds; sandy soils	Duff (2008), Luff (1998), Luff (2007)
Amara aulicus (Panzer, 1797)	phytophagous	Palaearctic	Unknown	FÖ	E, I	compositea & carduaceae seeds, waste lands	Bengtson (1981), Enckell et al. (1987)
Amara montivaga Sturm, 1825	phytophagous	Central Europe, mountains	1972, IE	IE	F4, B1, I	Poaceae seeds	Anderson et al. (2000)
Anisodactylus binotatus (Fabricius, 1787)	parasitic/ predator	Mediterranean region, Central Europe	Unknown	IS, IE, LI, PT-AZO, PT-MAD, GB	E3, I	Apiaceae seeds	Anderson et al. (2000), Duff (2008), Borges et al. (2005), Luff (2007), Mendonça and Borges (2009), Valemberg (1997)

Family *Species*	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Callistus lunatus (Fabricius, 1775)	parasitic/ predator	Europe, Asia minor	Unknown	GB	B1, F9, G	sandy soil, under felled trunks, bark, tree bases	Duff (2008), Luff (1998), Luff (2007)
Carabus auratus Linnaeus, 1758	parasitic/ predator	Western Europe	Unknown	GB	I1,E, G5	plains, waste lands, predator molluscs	Duff (2008), Luff (2007), Turin et al. (2003)
Carabus cancellatus Linnaeus, 1758	parasitic/ predator	Western and Central Europe	Unknown	GB	E5	dry soil, field, forest edge	Duff (2008), Luff (2007), Turin et al. (2003)
Carabus convexus Fabricius, 1775	parasitic/ predator	Eurosiberian	1836, GB	GB	G	forests	Duff (2008), Luff (2007), Turin et al. (2003)
Carabus nemoralis O.F. Müller, 1764	parasitic/ predator	West Palaearctic	Unknown	IS	I2, I1, G	woodlands, fields, gardens	Libungan et al. (2008), Turin et al. (2003)
Demetrias atricapillus (Linnaeus, 1758)	parasitic/ predator	Eurosiberian	Unknown	ES-CAN	F9, D	in vegetal decays along rivers and bogs, *Carex*, *Oenanthe*	Machado and Oromi (2000)
Epaphius secalis (Paykull, 1790)	parasitic/ predator	Eurosiberian	Unknown	IS	F9	along rivers, mountains (orophilous)	
Graniger femoralis (Coquerel, 1858)	phyto-phagous	Spain, Italy, Crimea	Unknown	ES-CAN	H	seeds, under stones	Machado and Oromi (2000)
Harpalus distinguendus (Duftschmid, 1812)	phyto-phagous	Medi-terranean	Unknown	ES-CAN	I	seeds; dry soils, paths, fields, dunes	Machado and Oromi (2000), Mendonça and Borges (2009)
Leistus rufomarginatus (Duftschmid, 1812)	parasitic/ predator	Eastern, central, western Europe	1942, GB	GB	G, I	mountains, forests, waste lands	Duff (2008), Luff (1998), Luff (2007)
Leistus terminatus (Panzer, 1793)	parasitic/ predator	Eurosiberian	Unknown	IS	F9, G	osieries	
Licinus punctatulus (Fabricius, 1792)	parasitic/ predator	Spain, North Africa	Unknown	PT-AZO, ES-CAN	H5	under stones, arid, sandy environments	Borges et al. (2005), Machado and Oromi (2000), Mendonça and Borges (2009), Valemberg (1997)

Family *Species*	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Lymnastis galilaeus Piochard de la Brûlerie, 1876	parasitic/ predator	Southern Europe	Unknown	AT, HU, UA	B, D	waste, near littoral, bogs	Valemberg (1997)
Microlestes minutulus (Goeze, 1777)	parasitic/ predator	Palaearctic	1976, GB	GB	G1	dry soil, under deciduous	Duff (2008), Luff (1998), Luff (2007)
Notaphus varius (Olivier, 1795)	parasitic/ predator	Europe, Minor Asia	Unknown	ES-CAN	D6, F9	salty marshes, along rivers, lakes	Machado and Oromi (2000), Ortuno and Toribio (2005)
Ocydromus tetracolus (Say, 1823)	parasitic/ predator	Palaearctic	Unknown	IS	F9	humid environments, herbs, along rivers	
Paranchus albipes (Fabricius, 1796)	parasitic/ predator	Europe, North Africa	Unknown	PT-AZO	F9, B	along rivers, coast	Borges et al. (2005), Mendonça and Borges (2009)
Philochthus guttula (Fabricius, 1792)	parasitic/ predator	Europe, Asia minor	1900, IE	IE	G, D	near bogs in forests	Anderson et al. (2000)
Pterostichus angustatus (Duftschmid, 1812)	parasitic/ predator	Northern and Central Europe	1900, GB	GB	H, G	associated with burnt sites	Duff (2008), Luff (1998), Luff (2007)
Pterostichus cristatus (Dufour, 1820)	parasitic/ predator	Europe	1800, GB	GB	G, F9	under stones in fresh, humid woods	Duff (2008), Luff (1998), Luff (2007)
Pterostichus vernalis (Panzer, 1796)	parasitic/ predator	Europe	Unknown	PT-AZO	E3	waste in wet grasslands, near bogs	Borges et al. (2005), Duff (2008), Mendonça and Borges (2009)
Scybalicus oblongiusculus (Dejean, 1829)	parasitic/ predator	Europe	1879, GB	GB	E2, I	in colonies in non-cultivated fields	Duff (2008), Luff (1998), Luff (2007)
Sphodrus leucophthalmus (Linnaeus, 1758)	parasitic/ predator	West Palaearctic	Unknown	IE, ES-CAN, GB	J2	cellars, stables	Anderson et al. (2000), Duff (2008), Machado and Oromi (2000), Luff (1998), Luff (2007), Valemberg (1997)
Tachyta nana (Gyllenhal, 1810)	parasitic/ predator	Holarctic	Unknown	ES-CAN	G3	under humid bark, in bark beetle galleries in *Abies* and *Cedrus*	Machado and Oromi (2000)

Family *Species*	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Trechus subnotatus Dejean, 1831	parasitic/ predator		1940, IE	IE, GB	J6, J2, I2	near littoral; in compost in Ireland	Duff (2008), Anderson et al. (2000), Luff (1998), Luff (2007)
Tschitscherinellus cordatus (Dejean, 1825)	phytophagous	Spain, North Africa, Crimea	Unknown	ES-CAN	H5	mountains under stones, arid, sandy environments; granivore	Machado and Oromi (2000)
Clambidae							
Clambus pallidulus Reitter, 1911	detritivorous	southern Europe, Minor Asia	Unknown	AL, DK, DE, HU, IE, NL, SE, CH, GB	G	in hollow *Malus*, debris in rotten stump, in moss among rotten logs	Duff (2008)
Cleridae							
Enoplium serraticorne (Olivier, 1790)	parasitic/ predator	Mediterranean Region	1990, CZ	CZ	J6	predatory	Freude et al. (1979), Šefrova and Lastuvka (2005)
Opilo domesticus (Sturm, 1837)	parasitic/ predator	Europe, North Africa	Unknown	PT-AZO	J	buildings, prey anobiids	Borges et al. (2005), Freude et al. (1979)
Opilo mollis (Linnaeus, 1758)	parasitic/ predator	Europe, North Africa	Unknown	PT-AZO	J	timber, prey larvae anobiids, buildings	Borges et al. (2005), Freude et al. (1979)
Corylophidae							
Sericoderus lateralis (Gyllenhal, 1827)	detritivorous	palaearctic	Unknown	PT-AZO	I, J1	moldy plant remains in warm places, especially garden compost and grass cuttings	Borges et al. (2005), Bowestead (1999), Mendonça and Borges (2009)
Cryptophagidae							
Atomaria apicalis Erichson, 1846	detritivorous	Europe	Unknown	FÖ, PT-AZO	J6	mycophage	Bengtson (1981), Borges et al. (2005), Enckell et al. (1987), Falcoz (1929), Freude et al. (1967)
Atomaria bella Reitter, 1875	detritivorous	Europe, north Africa	1967, GB	GB	G3	mycophage	Duff (2008)

Family *Species*	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Atomaria fuscata (Schönherr, 1808)	detritivorous	Europe	Unknown	GB	U	mycophage; also adults damaging beet	Duff (2008), Falcoz (1929)
Atomaria fuscipes (Gyllenhal, 1808)	detritivorous	Europe	Unknown	GB	U	mycophage; also adults damaging beet	Duff (2008), Falcoz (1929), Freude et al. (1967)
Atomaria hislopi Wollaston, 1857	detritivorous	Northern Europe	Unknown	GB	U	mycophage	Duff (2008), Falcoz (1929)
Atomaria lohsei Johnson & Strand, 1968	detritivorous	Central Europe, Spain	1976, GB	GB	G3	rotten wood debris abroad; mainly conifer forest	Duff (2008)
Atomaria munda Erichson, 1846	detritivorous	Eurasia	Unknown	PT-AZO, GB	J1	attic	Borges et al. (2005), Falcoz (1929), Freude et al. (1967)
Atomaria nitidula Marsham, 1802	detritivorous	Europe, north Africa	Unknown	GB	J1	mycophage	Duff (2008), Falcoz (1929)
Atomaria punctithorax Reitter, 1887	detritivorous	Central, Northern Europe	Unknown	GB	J1	mycophage	Duff (2008)
Atomaria pusilla (Paykull, 1798)	detritivorous	Europe, north Africa	Unknown	IE, GB	J2, I2	mycophage	Duff (2008), Falcoz (1929), Freude et al. (1967)
Atomaria strandi Johnson, 1967	detritivorous	Central, southern Europe	Unknown	IE, GB	J1	mycophage	Duff (2008)
Atomaria testacea Stephens, 1830	detritivorous	Europe	Unknown	GB	J1	mycophage	Duff (2008), Falcoz (1929)
Atomaria turgida Erichson, 1846	detritivorous	Northern, Central Europe	1996, IE, GB	IE, GB	G3	mycophage	Duff (2008), Falcoz (1929), Freude et al. (1967)
Cryptophagus dentatus (Herbst, 1793)	detritivorous	Palaearctic	1937, PT-MAD	PT-AZO, PT-MAD	J1	flour, dry fruits	Borges et al. (2005), Duff (2008), Falcoz (1929), Freude et al. (1967), Mendonça and Borges (2009)
Cryptophagus distinguendus Sturm 1845	detritivorous	Europe, Asia, Africa	Unknown	FÖ	J1	mills, stored products	Bengtson (1981), Enckell et al. (1987), Falcoz (1929), Freude et al. (1967)

Family *Species*	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Cryptophagus saginatus Sturm, 1845	detritivorous	Europe, North Africa	Unknown	PT-AZO	J1	attic	Borges (1990), Borges et al. (2005), Falcoz (1929), Freude et al. (1967), Mendonça and Borges (2009)
Cryptophagus scanicus (Linnaeus, 1758)	detritivorous	Europe	Unknown	FÖ	J1	grain, dry fruits	Bengtson (1981), Enckell et al. (1987), Falcoz (1929), Freude et al. (1967)
Cryptophagus schmidti Sturm, 1845	detritivorous	Eurasia	Unknown	PT-AZO	J1	mammals and *Vespa* nests	Borges et al. (2005), Falcoz (1929), Freude et al. (1967)
Ephistemus globulus Paykull, 1798	detritivorous	Europe	Unknown	IE, PT-AZO, GB	G1	ground, salix basis	Borges et al. (2005), Duff (2008), Falcoz (1929), Mendonça and Borges (2009)
Dermestidae							
Attagenus bifasciatus (Olivier, 1790)	detritivorous	southern Europe, Minor Asia	Unknown	DK	J1, E	stored products	
Attegenus brunneus Faldermann, 1835	detritivorous	Mediterranean region	Unknown	CH, GB	J1	domestic	Duff (2008), Freude et al. (1979)
Attegenus pellio Linnaeus, 1758	detritivorous	Europe	Unknown	IE, GB	J1, E5, I2	animal materials	Freude et al. (1979)
Attagenus quadrimaculatus Kraatz, 1858	detritivorous	southern Europe, Minor Asia	Unknown	CH	J1	domestic	Freude et al. (1979), Wittenberg et al. (2006)
Attagenus rossi Ganglbauer, 1904	detritivorous	Cosmopolitan (native? Europe, Africa, USSR)	Unknown	CH	J1	domestic	Wittenberg et al. (2006)

Family *Species*	Regime	Native range	1st record in Europe	Invaded countries	Habitat	Host	References
Attagenus simplex Reitter, 1881	detritivorous	North Africa, Italy	Unknown	SE	J	stored products	
Attagenus trifasciatus (Fabricius, 1787)	detritivorous	Mediterranean region	Unknown	DE, GB	J	stored products	Freude et al. (1979), Hermann and Baena (2004)
Anthrenus coloratus Reitter, 1881	detritivorous	East Mediterranean region	1983, GB	AT, GB	J1, E	skins, stuffed animals	Duff (2008), Freude et al. (1979)
Anthrenus festivus Erichson, 1846	detritivorous	Mediterranean region	Unknown	AT, CH	J1, E	insects in collection; adults on flowers	Freude et al. (1979), Wittenberg et al. (2006)
Anthrenus museorum (Linnaeus, 1761)	detritivorous	Holarctic	Unknown	PT-AZO	J1, E	insects in collection	Borges et al. (2005), Freude et al. (1979)
Anthrenus olgae Kalik, 1946	detritivorous	Central Europe	Unknown	AT, GB	J1, E	stored products	Duff (2008), Freude et al. (1979)
Dermestes murinus Linnaeus, 1758	detritivorous	Europe	Unknown	PT-AZO, ES-CAN	J	domestic on animal products	Borges et al. (2005), Freude et al. (1979), Machado and Oromi (2000)
Dermestes undulatus Brahm, 1790	detritivorous	Holarctic	Unknown	LV, PT-AZO, ES-CAN	J	domestic on animal products	Borges et al. (2005), Freude et al. (1979), Machado and Oromi (2000), Mendonça and Borges (2009)
Derodontidae							
Laricobius erichsonii Rosenhauer, 1846	parasitic/predator	europe (imported to USA)	1971, GB	GB	G3	aphid predator	Franz (1958), Freude et al. (1979)
Elateridae							
Athous haemorrhoidalis (Fabricius, 1801)	phytophagous	Western, central, Northern Europe	Unknown	PT-AZO	E5	roots cereals, potato	Borges et al. (2005), Laibner (2000), Leseigneur (1972)
Melanotus dichrous (Erichson, 1841)	phytophagous	southern Europe	Unknown	PT-AZO	F5	shrubs	Borges et al. (2005), Leseigneur (1972), Mendonça and Borges (2009)

Family *Species*	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Histeridae							
Acritus nigricornis (Hoffmann, 1803)	parasitic/ predator	Palaearctic	Unknown	PT-AZO, ES-CAN	E	cow, horse dung	Borges et al. (2005), Machado and Oromi (2000), Mendonça and Borges (2009)
Halacritus punctum (Aube, 1843)	parasitic/ predator	europe south	Unknown	PT-AZO	U		Borges et al. (2005), Mendonça and Borges (2009)
Hypocaccus dimidiatus (Illiger, 1807)	parasitic/ predator	Medi-terranean Region	Unknown	PT-AZO	B1	cadavers, feces, vegetal decays, sandy soil	Borges et al. (2005), Mendonça and Borges (2009)
Macrolister major (Linnaeus, 1767)	parasitic/ predator	Medi-terranean Region	Unknown	DK	B1	cow dung, nr litoral	Mazur (1989)
Saprinus acuminatus (Fabricius, 1798)	parasitic/ predator	euro-centrosasiatic	Unknown	PT-AZO	U	fish decaying, cadavers, feces, *Arum*	Borges et al. (2005), Mendonça and Borges (2009)
Saprinus caerulescens (Hoffmann, 1803)	parasitic/ predator	Europe	Unknown	PT-AZO	U	fish decaying, cadavers, feces, *Arum*	Borges et al. (2005)
Saprinus planiusculus Motschulsky, 1849	parasitic/ predator	palaearctic	Unknown	PT-AZO	B	fish decaying, cadavers, feces, *Arum*	Borges et al. (2005), Mendonça and Borges (2009)
Saprinus semistriatus (Scriba, 1790)	parasitic/ predator	palaearctic	Unknown	PT-AZO	B	fish decaying, cadavers, feces, *Arum*	Borges et al. (2005), Mendonça and Borges (2009)
Saprinus subnitescens Bickhardt, 1909	detriti-vorous	Europe	Unknown	PT-AZO	B	fish decaying, cadavers, feces, *Arum*	Borges et al. (2005), Mendonça and Borges (2009)
Hydrophilidae							
Cercyon depressus Stephens, 1829	parasitic/ predator	Northern, Central Europe	Unknown	PT-AZO	B	rotting seaweed on seashores	Borges et al. (2005), Mendonça and Borges (2009)
Cercyon haemorhoidalis (Fabricius, 1775)	parasitic/ predator	Europe	Unknown	PT-AZO	J6	decaying organic matter, flood debris	Borges et al. (2005), Mendonça and Borges (2009)

Family *Species*	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Cercyon obsoletus (Gyllenhal, 1808)	parasitic/ predator	Northern, Central Europe	Unknown	PT-AZO	U	mainly in dung of larger herbivores, but also recorded from arrion and manure	Vorst (2009)
Cercyon quisquilius (Linnaeus ,1761)	unknown	Europe	Unknown	PT-AZO	U		Borges et al. (2005), Mendonça and Borges (2009)
Enochrus bicolor (Fabricius, 1792)	unknown	All over Europe	Unknown	PT-AZO	B	halophil	Borges et al. (2005), Mendonça and Borges (2009)
Helochares lividus (Forster, 1771)	parasitic/ predator, phytophagous	central, western, southern Europe	Unknown	PT-AZO	C1, D	in standing waters	Borges et al. (2005)
Sphaeridium bipustulatum Fabricius, 1781	parasitic/ predator	Western, Central Europe	Unknown	PT-AZO	E	mammal dung, decaying organic matter, fungi, and on plant sap	Borges et al. (2005), Mendonça and Borges (2009)
Sphaeridium scarabaeoides (Linnaeus, 1758)	parasitic/ predator	Eurasia	Unknown	PT-AZO	E	dung	Borges et al. (2005)
Kateretidae							
Brachypterolus antirrhini (Murray, 1864)	phytophagous	Mediterranean Region	1926, GB	BE, LI, LU, NL, GB	E, I2	*Antirrhinum*, *Linaria*	Audisio (1993), Borges et al. (2005), Duff (2008)
Brachypterolus vestitus (Kiesenwetter, 1850)	phytophagous	West Mediterranean Region	1929, GB	AT, BE, CZ, DE, LI, CH, GB	E, I2	*Antirrhinum*, *Linaria*	Audisio (1993), Duff (2008), Šefrova and Lastuvka (2005)
Laemophloeidae							
Cryptolestes capensis (Waltl, 1834)	detritivorous	Mediterranean Region	1962, CZ	AL, AT, BE, CZ, DK, FI, DE, HU, PL, SE, UA, GB	J1	grain and grain products, nuts, oilseeds, dried root crops	Borges et al. (2005), Duff (2008), Šefrova and Lastuvka (2005)

Family *Species*	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Latridiidae							
Cartodere norvegica (Strand, 1940)	detritivorous	Europe	Unknown	PT-AZO, PT-MAD	FB	under populus bark	Borges et al. (2005), Rücker (1995)
Corticaria abietorum Motschulsky, 1867	detritivorous	Central northern Europe	Unknown	PL, GB	G3	conifer specialist (douglas-fir, abies)	Freude et al. (1967)
Dienerella ruficollis (Marsham, 1802)	detritivorous	Mediterranean region	1889, GB	DE, IT-SIC, PT-AZO, GB	J1	dry plants, flour	Borges et al. (2005), Bouget and Vincent (2008), Duff (2008)
Thes bergrothi (Reitter, 1880)	detritivorous	northeastern Europe	Unknown	GB	I, J	on fungus, on decaying plant material, attic; flour, dattes	Duff (2008)
Leiodidae							
Catops fuliginosus Erichson 1837	detritivorous	Western, Central, Southern Europe	Unknown	FÖ	F	fungi	Bengtson (1981), Duff (2008)
Meloidae							
Mylabris variabilis (Pallas, 1781)	parasitic/ predator, phytophagous	Eurasia	Unknown	IT-SAR	E	adult floricolous, parasite Acrididae	
Malachiidae							
Axinotarsus marginalis (Laporte de Castelnau, 1840)	detritivorous	Europe	Unknown	GB	G	saproxilic/ woodland	Duff (2008)
Monotomidae							
Monotoma bicolor A. Villa & G. B. Villa, 1835	detritivorous	Europe	2005, PT-AZO	PT-AZO	E, J	mole nest, vegetal waste	Borges et al. (2005)

Family *Species*	Regime	Native range	1st record in Europe	Invaded countries	Habitat	Host	References
Monotoma longicollis (Gyllenhal, 1827)	detritivorous	Europe	2005, PT-AZO	PT-AZO	J, J6	vegetal waste	Borges et al. (2005), Mendonça and Borges (2009)
Monotoma picipes Herbst, 1793	detritivorous	Europe	2005, PT-AZO	PT-AZO	J, J6	saprophage/ mycophage; vegetal waste	Borges et al. (2005), Mendonça and Borges (2009)
Monotoma quadrifoveolata Aube, 1837	detritivorous	Eurasia	2005, PT-AZO	PT-AZO	J, J6	decaying grains	Borges et al. (2005)
Monotoma spinicollis Aubé, 1837	detritivorous	Europe	2005, PT-AZO	PT-AZO	J	paddy residues, paddy storage	Borges et al. (2005), Mendonça and Borges (2009)
Rhizophagus grandis Gyllenhal, 1827	parasitic/ predator	Europe	1983, GB	GB	G3	predator *Dendroctonus- Picea* stands	Bouget and Moncoutier (2003), Duff (2008)
Mycetophagidae							
Berginus tamarisci Wollaston, 1854	detritivorous	southern Europe, Canary Isls	Unknown	AT, CH	G3	*Tamarix*, on pine	Borges et al. (2005), Freude et al. (1967)
Eulagius filicornis (Reitter, 1887)	detritivorous	southern France, North Africa	1993, GB	GB	G3	with the fungus *Stereum hirsutum* growing on dead branches of broad-leaved trees.	Duff (2008)
Nitidulidae							
Carpophilus quadrisignatus Erichson, 1843	phytophagous, detrivorous	Mediterranean region	2000, DE	AT, DE, PT-AZO	J1	dry fruits	Audisio (1993), Borges et al. (2005), Freude et al. (1967), Mendonça and Borges (2009)
Epuraea aestiva (Linnaeus, 1758)	detritivorous	Europe, Asia	2005, PT-AZO	PT-AZO	G, I		Audisio (1993), Borges et al. (2005)
Epuraea biguttata (Thunberg, 1784)	detritivorous	Northern Europe	2005, PT-AZO	PT-AZO	J1, I	mushrooms	Audisio (1993), Borges et al. (2005), Freude et al. (1967), Mendonça and Borges (2009)

Family *Species*	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Epuraea longula Erichson, 1845	detritivorous	Eurasia	2005, PT-AZO	PT-AZO	J		Audisio (1993), Borges (1990), Borges et al. (2005), Mendonça and Borges (2009)
Meligethes aeneus (Fabricius, 1775)	phytophagous	Europe	2005, PT-AZO	PT-AZO, ES-CAN	I1	rape, rosaceae, pollen-feeding	Audisio (1993), Borges et al. (2005), Duff (2008), Freude et al. (1967), Machado and Oromi (2000), Mendonça and Borges (2009)
Meligethes incanus Sturm, 1845	phytophagous	Southeastern Europe	1867, PT-AZO	PT-AZO, GB	FA, E5	*Nepeta cataria*	Audisio (1993), Borges et al. (2005)
Nitidula flavomaculata Rossi, 1790	detritivorous	southern Europe	1900, CZ	CZ	J1, J6	bones vertebrates	Audisio (1993), Freude et al. (1967), Šefrova and Lastuvka (2005)
Pocadius adustus Reitter, 1888	detritivorous	Eurasia	2004, GB	GB	E2	epigeous gastermyctes specialist	Audisio (1993), Duff (2008)
Oedemeridae							
Nacerdes melanura (Linnaeus, 1758)	detritivorous	Europe	2005, PT-AZO	PT-AZO	B	driftwood on beaches, moist wood	Borges et al. (2005), Mendonça and Borges (2009)
Phalacridae							
Phalacrus corruscus (Panzer, 1797)	phytophagous	Europe	Unknown	PT-AZO	I	seeds of yellow sowthistle *Sonchus arvensis*	Borges et al. (2005)
Ptiliidae							
Acrotrichis cognata (Matthews, 1877)	detritivorous	Europe	1932, SE	AT, DK, FI, DE, IE, NL, NO, SE, GB	E5, J6	dung, rotting fungi, carcasses, compost near forests	Duff (2008), Freude et al. (1971)
Actinopteryx fucicola (Allibert, 1844)	detritivorous	Europe	Unknown	PT-AZO	U	unknown	Borges et al. (2005), Mendonça and Borges (2009)
Ptenidium pusillum (Gyllenhal, 1808)	detritivorous	Europe	Unknown	PT-AZO	U		Borges et al. (2005), Mendonça and Borges (2009)
Scarabaeidae							
Onthophagus illyricus (Scopoli, 1763)	detritivorous	Europe	2005, PT-AZO	PT-AZO	E	dung	Baraud (1992), Borges et al. (2005), Bunalski (1999), Mendonça and Borges (2009)

Family *Species*	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Onthophagus taurus (Schreber, 1759)	detritivorous	Europe	2005, PT-AZO	PT-AZO	E	dung	Baraud (1992), Borges et al. (2005), Bunalski (1999), Mendonça and Borges (2009)
Onthophagus vacca (Linnaeus, 1767)	detritivorous	Europe	2005, PT-AZO	PT-AZO	E	dung	Baraud (1992), Borges et al. (2005), Bunalski (1999), Mendonça and Borges (2009)
Oryctes nasicornis (Linnaeus, 1758)	detritivorous	southern Europe	1880, DK	DK, FI, HU, LT, NO, SE	J	saprophagous, compost	Baraud (1992), Bunalski (1999)
Scydmaenidae							
Stenichnus collaris (Muller & Kunze, 1822)	detritivorous	Europe	Unknown	FÖ	I2	mosses, leaves	Bengtson (1981)
Silphidae							
Ablattaria laevigata (Fabricius, 1775)	parasitic/ predator	Western & southcentral Europe	Unknown	EE	E, I1	snail predator, fields	
Aclypea opaca (Linnaeus, 1758)	phytophagous	Central, Northern, Eastern Europe	2005, PT-AZO	PT-AZO	E, I1	chenopodiacées	Borges et al. (2005)
Silvanidae							
Silvanus unidentatus (Olivier, 1790)	detritivorous	Europe	Unknown	PT-AZO	J1		Borges et al. (2005), Mendonça and Borges (2009)
Sphindidae							
Sphindus dubius (Gyllenhal, 1808)	detritivorous	europe	2005, PT-AZO	PT-AZO	U	mycophage	Borges et al. (2005), Freude et al. (1967), Mendonça and Borges (2009)
Staphylinidae							
Aleochara bipustulata (Linnaeus, 1761)	parasitic/ predator	Palaearctic	Unknown	PT-AZO	I	solitary ectoparasitoids of cyclorrhaphous Diptera (*Delia*)	Borges et al. (2005), Freude et al. (1974), Mendonça and Borges (2009)

Family *Species*	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Aleochara clavicornis Redtenbacher, L., 1849	parasitic/ predator	Palaearctic	2005, PT-AZO	PT-AZO	I1, J6	feed on decaying meat, fly maggots and also on fly puparia	Borges et al. (2005), Freude et al. (1974), Mendonça and Borges (2009)
Aleochara sparsa Heer, 1839	parasitic/ predator	Europe	Unknown	FÖ	I1, J	predator of cyclorrhaphous Diptera (*Musca*) in stables	Bengtson (1981), Enckell et al. (1987), Freude et al. (1974)
Amischa analis (Gravenhorst, 1802)	parasitic/ predator	Italy	Unknown	PT-AZO	U		Borges (1990), Borges et al. (2005), Freude et al. (1974), Mendonça and Borges (2009)
Anotylus nitidulus (Gravenhorst 1802)	parasitic/ predator	Europe, cosmopolitan	2005, PT-AZO	PT-AZO	U		Borges et al. (2005), Mendonça and Borges (2009)
Anotylus speculifrons (Kraatz 1857)	parasitic/ predator	Europe, Asia Minor, North Africa	2005, PT-AZO	PT-AZO	U		Borges et al. (2005), Mendonça and Borges (2009)
Atheta acuticollis Fauvel, 1907	parasitic/ predator	palaearctic	2005, PT-AZO	PT-AZO	U		
Atheta amicula (Stephens,1832)	parasitic/ predator	Europe	2005, PT-AZO	PT-AZO, PT-MAD, ES-CAN	U		Borges (1990), Borges et al. (2005), Freude et al. (1974), Machado and Oromi (2000)
Atheta atramentaria (Gyllenhal,1810)	parasitic/ predator	Europe	Unknown	PT-AZO, PT-MAD, ES-CAN	U		Borges (1990), Borges et al. (2005), Freude et al. (1974), Mendonça and Borges (2009)
Atheta castanoptera (Mannerheim, 1830)	parasitic/ predator	Europe	2005, PT-AZO	PT-AZO	U		Borges et al. (2005), Freude et al. (1974), Mendonça and Borges (2009)
Atheta coriaria (Kraatz, 1858)	parasitic/ predator	Europe	2005, PT-AZO	PT-AZO, ES-CAN	U	predator, biological control soil-dwelling larvae of small Diptera	Borges et al. (2005), Freude et al. (1974), Machado and Oromi (2000), Mendonça and Borges (2009)

Family *Species*	Regime	Native range	1st record in Europe	Invaded countries	Habitat	Host	References
Atheta divisa (Maerkel, 1844)	parasitic/ predator	Europe	2005, PT-AZO	PT-AZO	U	bird and animal nest	Borges (1990), Borges et al. (2005), Freude et al. (1974), Mendonça and Borges (2009)
Atheta fungi (Gravenhorst,1806)	parasitic/ predator	Europe	Unknown	FÖ, PT-AZO, PT-MAD, ES-CAN	I1	predator, carrot fields	Bengtson (1981), Borges et al. (2005), Enckell et al. (1987), Freude et al. (1974), Machado and Oromi (2000), Mendonça and Borges (2009)
Atheta gregaria (Casey, 1910)	parasitic/ predator	europe	Unknown	FÖ	U		Bengtson (1981), Enckell et al. (1987), Freude et al. (1974)
Atheta harwoodi Williams, 1930	parasitic/ predator	europe	Unknown	FÖ, GB	J6	bird nest, compost	Bengtson (1981), Duff (2008), Enckell et al. (1987), Freude et al. (1974)
Atheta luridipennis (Mannerheim, 1830)	parasitic/ predator	Central, Northern Europe	2003, ES	FÖ, PT-AZO, ES	C3	streambanks	Bengtson (1981), Borges et al. (2005), Enckell et al. (1987), Freude et al. (1974), Mendonça and Borges (2009)
Atheta nigra (Kraatz,1856)	parasitic/ predator	Europe	2005, PT-AZO	PT-AZO, ES-CAN	U		Borges et al. (2005), Freude et al. (1974), Machado and Oromi (2000), Mendonça and Borges (2009)
Atheta nigricornis (Thomson,1852)	parasitic/ predator	Northern Europe	Unknown	FÖ	U	fungi *Meripilus giganteus*	Bengtson (1981), Enckell et al. (1987), Freude et al. (1974)
Atheta oblita (Erichson,1839)	parasitic/ predator	Northern Europe	2005, PT-AZO	PT-AZO	U		Borges et al. (2005), Freude et al. (1974), Mendonça and Borges (2009)
Atheta palustris (Kiesenwetter,1844)	parasitic/ predator	Morocco, France Italy	2005, PT-AZO	PT-AZO, PT-MAD	U		Borges et al. (2005), Freude et al. (1974), Mendonça and Borges (2009)
Atheta sordida Marsham,1802	parasitic/ predator	southern Europe, Minor Asia	2005, PT-AZO	PT-AZO, PT-MAD, ES-CAN	U		Borges (1990), Freude et al. (1974), Mendonça and Borges (2009)
Atheta triangulum (Kraatz,1856)	parasitic/ predator	Europe	2005, PT-AZO	PT-AZO	U		Borges et al. (2005), Freude et al. (1974)

Family *Species*	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Atheta trinotata (Kraatz,1856)	parasitic/ predator	europe	Unknown	FÖ, PT-MAD, ES-CAN	U		Bengtson (1981), Enckell et al. (1987), Freude et al. (1974), Machado and Oromi (2000)
Bisnius sordidus (Gravenhorst, 1802)	parasitic/ predator	Europe, Asia, North Africa	2005, PT-AZO	PT-AZO	I, J6	compost, predator	Borges et al. (2005), Mendonça and Borges (2009)
Brachygluta paludosa (Peyron, 1858)	unknown	Minor Asia, Bulgaria	Unknown	DK	U		
Cafius xantholoma (Gravenhorst, 1806)	unknown	Europe, Asia, Africa	2005, PT-AZO	PT-AZO	U		Borges et al. (2005), Mendonça and Borges (2009)
Cordalia obscura (Gravenhorst,1802)	unknown	Northern Europe	Unknown	PT-AZO, PT-MAD, ES-CAN	U		Borges et al. (2005), Freude et al. (1974), Machado and Oromi (2000), Mendonça and Borges (2009)
Creophilus maxillosus (Linnaeus, 1758)	unknown	Europe (intro NAm)	2005, PT-AZO	PT-AZO	U		Borges et al. (2005), Mendonça and Borges (2009)
Cypha pulicaria (Erichson,1839)	unknown	Europe	2005, PT-AZO	PT-AZO	U		Borges et al. (2005), Freude et al. (1974), Mendonça and Borges (2009)
Edaphus beszedesi Reitter, 1914	detriti-vorous	southern Europe	Unknown	AT, EE, CH	J6	compost, rotting plant material	Luka et al. (2009), Wittenberg et al. (2006)
Euplectus infirmus Raffray, 1910	unknown	Southern Europe	2005, PT-AZO	PT-AZO	U		Borges et al. (2005), Freude et al. (1974), Mendonça and Borges (2009)
Gabrius nigritulus (Gravenhorst, 1802)	unknown	Eurasia	2005, PT-AZO	PT-AZO	U		Borges et al. (2005), Freude et al. (1974), Mendonça and Borges (2009)
Gabronthus thermarum (Aubé, 1850)	parasitic/ predator	Europe	2005, PT-AZO	PT-AZO	I, J6	compost, predator	Borges et al. (2005), Mendonça and Borges (2009)
Gyrophaena bihamata Thomson,1867	unknown	Central, Northern Europe	2005, PT-AZO	PT-AZO	U		Borges et al. (2005), Freude et al. (1974), Mendonça and Borges (2009)
Gyrophinus fracticornis (O. Müller, 1776)	unknown	euroMedi-terranean	2005, PT-AZO	PT-AZO	J6	waste, decay	Borges et al. (2005), Mendonça and Borges (2009)

Family *Species*	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Hadrognathus longipalpis (Mulsant & Rey, 1851)	unknown	Western Europe	1989, GB	GB	G, J6	humus	Duff (2008)
Halobrecta flavipes Thomson,1861	unknown	Northern, Central Europe	2005, PT-AZO	PT-AZO	U		Borges et al. (2005), Freude et al. (1974), Mendonça and Borges (2009)
Heterota plumbea (Waterhouse,1858)	unknown	Europe	2005, PT-AZO	PT-AZO, PT-MAD, ES-CAN	U		Borges et al. (2005), Freude et al. (1974), Machado and Oromi (2000), Mendonça and Borges (2009)
Lathrobium fulvipenne (Gravenhorst, 1806)	unknown	Northern and Central Europe, siberia	Unknown	FÖ	D	bogs, mires, wet fields	Bengtson (1981), Enckell et al. (1987), Freude et al. (1974)
Leptacinus pusillus (Stephens, 1833)	unknown	Europe (introAF, AUS)	2005, PT-AZO	PT-AZO	U		Borges et al. (2005), Freude et al. (1974), Mendonça and Borges (2009)
Lithocharis ochracea (Gravenhorst, 1802)	unknown	Eurasia	Unknown	PT-AZO	U		Borges et al. (2005), Mendonça and Borges (2009)
Micropeplus marietti Jacquelin du Val, 1857	unknown	Southern Europe, Caucasus	Unknown	AT, CH	J6	rotten vegetals	Luka et al. (2009), Wittenberg et al. (2006)
Mycetoporus nigricollis (Stephens, 1832)	unknown	Europe	Unknown	ES-CAN	J6	rotten vegetals	Machado and Oromi (2000)
Myllaena brevicornis (Matthews,1838)	unknown	Europe	Unknown	FÖ	U		Bengtson (1981), Enckell et al. (1987), Freude et al. (1974)
Myrmecopora sulcata (Kiesenwetter,1850)	unknown	Europe	2005, PT-AZO	PT-AZO, ES-CAN	U		Borges et al. (2005), Freude et al. (1974), Machado and Oromi (2000), Mendonça and Borges (2009)
Myrmecopora uvida (Erichson, 1840)	unknown	Europe	2005, PT-AZO	PT-AZO	U		Borges et al. (2005), Freude et al. (1974), Mendonça and Borges (2009)

Family *Species*	Regime	Native range	1st record in Europe	Invaded countries	Habitat	Host	References
Neobisnius lathrobioides (Baudi, 1848)	unknown	Europe (intro NAm)	2005, PT-AZO	PT-AZO	U		Borges et al. (2005), Mendonça and Borges (2009)
Neobisnius procerulus (Gravenhorst, 1806)	unknown	Europe	2005, PT-AZO	PT-AZO	U		Borges et al. (2005)
Ocalea picata (Stephens,1832)	unknown	Northern, Central Europe	Unknown	FÖ	U		Bengtson (1981), Enckell et al. (1987), Freude et al. (1974)
Oligota pusillima (Gravenhorst,1806)	parasitic/ predator	Northern Europe	2005, PT-AZO	PT-AZO	U	mite predator	Borges et al. (2005), Freude et al. (1974), Mendonça and Borges (2009)
Olophrum fuscum (Gravenhorst, 1806)	unknown	Northern & Central Europe	Unknown	FÖ	D	bogs	Bengtson (1981), Enckell et al. (1987)
Omalium excavatum Stephens, 1834	unknown	Europe, caucasus	Unknown	FÖ	E, J	nests micromammals	Bengtson (1981), Enckell et al. (1987)
Omalium rivulare (Paykull, 1789)	unknown	Europe	Unknown	FÖ	J6	vegetal decay	Bengtson (1981), Enckell et al. (1987)
Oxypoda haemorrhoa (Mannerheim, 1830)	unknown	Northern, Central Europe	Unknown	FÖ	U		Bengtson (1981), Enckell et al. (1987), Freude et al. (1974)
Oxytelus sculptus Gravenhorst, 1806	unknown	Europe	2005, PT-AZO	PT-AZO	U		Borges et al. (2005), Mendonça and Borges (2009)
Phacophallus parumpunctatus (Gyllenhal, 1827)	unknown	Europe	1854, IE	IE, PT-AZO, GB	U		Anderson (1997), Borges et al. (2005), Duff (2008), Mendonça and Borges (2009)
Philonthus cephalotes (Gravenhorst, 1802)	parasitic/ predator	Holarctic	Unknown	FÖ	U		Bengtson (1981), Enckell et al. (1987)
Philonthus concinnus (Gravenhorst, 1802)	parasitic/ predator	Eurasia (intro Nam)	2005, PT-AZO	PT-AZO	U		Borges et al. (2005)

Family *Species*	Regime	Native range	1st record in Europe	Invaded countries	Habitat	Host	References
Philonthus discoideus (Gravenhorst, 1802)	parasitic/ predator	Eurasia, North Africa	2005, PT-AZO	PT-AZO, ES-CAN	U		Borges et al. (2005), Freude et al. (1974), Machado and Oromi (2000), Mendonça and Borges (2009)
Philonthus fenestratus Fauvel, 1872	parasitic/ predator	Europe, caucasus	2005, PT-AZO	PT-AZO	U		Borges et al. (2005)
Philonthus fimetarius (Gravenhorst, 1802)	parasitic/ predator	Palaearctic	Unknown	FÖ	G		Bengtson (1981), Enckell et al. (1987)
Philonthus longicornis Stephens, 1832	parasitic/ predator	Eurasia	2005, PT-AZO	PT-AZO	U		Borges et al. (2005), Mendonça and Borges (2009)
Philonthus marginatus (O. Muller, 1764)	parasitic/ predator	Europe, Siberia	Unknown	FÖ	U		Bengtson (1981), Enckell et al. (1987)
Philonthus politus (Linnaeus, 1758)	parasitic/ predator	Europe	2005, PT-AZO	PT-AZO	E		Borges et al. (2005), Mendonça and Borges (2009)
Philonthus quisquiliarius (Gyllenhal, 1810)	parasitic/ predator	Eurasia, North Africa	2005, PT-AZO	PT-AZO	U		Borges et al. (2005), Mendonça and Borges (2009)
Philonthus umbratilis (Gravenhorst, 1802)	parasitic/ predator	Europe (intro NAm)	2005, PT-AZO	PT-AZO, ES-CAN	U		Borges et al. (2005), Machado and Oromi (2000), Mendonça and Borges (2009)
Phloeopora angustiformis Baudi, 1870	unknown	Europe	2005, PT-AZO	PT-AZO	U		Borges et al. (2005), Freude et al. (1974), Mendonça and Borges (2009)
Phloeopora teres (Gravenhorst, 1802)	unknown	Europe	2005, PT-AZO	PT-AZO	U		Borges et al. (2005), Freude et al. (1974), Mendonça and Borges (2009)
Phloeopora testacea (Mannerheim, 1830)	unknown	Northern Europe	2005, PT-AZO	PT-AZO	U		Borges (1990), Borges et al. (2005), Freude et al. (1974), Mendonça and Borges (2009)

Family *Species*	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Proteinus brachypterus (Fabricius, 1792).	detritivorous	Palaearctic	Unknown	FÖ	J6	rotten vegetals	Bengtson (1981), Enckell et al. (1987), Gamarra and Outerelo (2009)
Quedius mesomelinus (Marsham, 1802)	parasitic/ predator	Alps, Central Europe	Unknown	FÖ	U		Bengtson (1981), Enckell et al. (1987)
Remus pruinosus (Erichson, 1840)	parasitic/ predator	southern Europe	2005, PT-AZO	PT-AZO	U		Borges et al. (2005), Mendonça and Borges (2009)
Geostiba circellaris (Gravenhorst, 1806)	unknown	Europe	Unknown	FÖ	E,G1		Freude et al. (1974)
Sunius propinquus (Brisout de Barneville, 1867)	unknown	Europe	Unknown	PT-AZO	U		Borges et al. (2005), Freude et al. (1974)
Tachinus laticollis Gravenhorst, 1802	detritivorous	Europe	Unknown	FÖ	U		Bengtson (1981), Enckell et al. (1987)
Tachinus signatus Gravenhorst, 1802	unknown	Europe (intro NAm)	Unknown	FÖ	U		Bengtson (1981), Enckell et al. (1987)
Tachyporus chrysomelinus (Linnaeus, 1758)	unknown	Eurasia	2005, PT-AZO	PT-AZO	U		Borges et al. (2005), Mendonça and Borges (2009)
Tachyporus nitidulus (Fabricius, 1781)	unknown	Europe (Int AUS)	2005, PT-AZO	PT-AZO	U		Mendonça and Borges (2009)
Thecturota marchii (Dodero,1922)	detritivorous	Southern Europe	Unknown	AT, DK, EE, CH, GB	I,J6	waste land, compost	Luka et al. (2009), Wittenberg et al. (2006)
Xantholinus linearis (Olivier, 1795)	parasitic/ predator	All over Europe	Unknown	FÖ, PT-AZO	E, G, I2	stones, mosses, fungi	Bengtson (1981), Borges et al. (2005), Enckell et al. (1987), Freude et al. (1974), Mendonça and Borges (2009)
Xantholinus longiventris Heer, 1839	parasitic/ predator	Europe	Unknown	PT-AZO	U		Borges et al. (2005)

Family *Species*	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Xylodromus concinnus (Marsham, 1802)	parasitic/ predator	Europe	Unknown	FÖ	G, F, I2, J1	forests, gardens, cellars	Bengtson (1981), Enckell et al. (1987)
Xylodromus depressus (Gravenhorst, 1802)	parasitic/ predator	Europe	Unknown	FÖ	G, I2	bark, wet wood	Bengtson (1981), Enckell et al. (1987)
Tenebrionidae							
Blaps gigas (Linnaeus, 1758)	detritivorous	Mediterranean region	1888, CZ	CZ, DK, PT-AZO	J6		Borges et al. (2005), Šefrova and Lastuvka (2005)
Blaps lethifera Marsham, 1802	detritivorous	Europe	Unknown	PT-AZO, GB	J1, J2		Borges et al. (2005), Duff (2008)
Blaps mortisaga (Linnaeus, 1758)	detritivorous	Eastern and Central Europe	Unknown	GB	J1, J2	detrivorous	Duff (2008), Ferrer and Martinez Fernandez (2008)
Blaps mucronata Latreille, 1804	detritivorous	Europe, Mediterranean	Unknown	IE, GB	J1, J2		Duff (2008)
Corticeus linearis (Fabricus, 1790)	detritivorous	Europe	Unknown	GB	G3	old broadleaved forests	Duff (2008)
Corticeus pini (Panzer, 1799)	detritivorous	Europe	Unknown	GB	G3		
Scaurus punctatus Fabricius, 1798	detritivorous	Mediterranean region	Unknown	ES-CAN	U		Machado and Oromi (2000)
Tenebrio obscurus Fabricius, 1792	detritivorous	Europe	Unknown	IE, PT-AZO, ES-CAN, GB	J1, J2	stored products	Borges et al. (2005), Duff (2008), Machado and Oromi (2000)
Trachyscelis aphodioides Latreille, 1809	detritivorous	Mediterranean region	Unknown	ES-CAN	J	stored products	Borges et al. (2005), Machado and Oromi (2000)

Family *Species*	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Host**	**References**
Throscidae							
Throscus dermestoides (Linnaeus, 1766)	detritivorous	Europe	2005, PT-AZO	PT-AZO	G	bark, in forest	Borges et al. (2005), Mendonça and Borges (2009), Freude et al. (1979)
Trogidae							
Trox scaber (Linnaeus, 1767)	detritivorous	Eurasia	2005, PT-AZO	PT-AZO	U	nests	Borges (1990), Borges et al. (2005), Mendonça and Borges (2009)
Zopheridae							
Aulonium ruficorne (Olivier, 1790)	unknown	Mediteranean	Unknown	GB	U		Duff (2008)

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True Bugs (Hemiptera, Heteroptera)
Chapter 9.1

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Abstract

The inventory of the alien Heteroptera of Europe includes 16 species alien *to* Europe, 25 species alien *in* Europe and 7 cryptogenic species. This is approximately 1.7% of the Heteroptera species occurring in Europe. Most species belong to Miridae (20 spp.), Tingidae (8 spp.), and Anthocoridae (7 spp.). The rate of introductions has exponentially increased within the 20th century and since 1990 an approximate arrival rate of seven species per decade has been observed. Most of the species alien *to* Europe are from North America, almost all of the species alien *in* Europe originate in the Mediterranean region and were translocated to central and northern Europe. Most alien Heteroptera species are known from Central and Western Europe (Czech Republic, Germany, Netherlands, Great Britain). Ornamental trade and movement as stowaways with transport vehicles are the major pathways for alien Heteroptera. Most alien Heteroptera colonize habitats under strong human influence, like agricultural, horticultural, and domestic habitats, parks and gardens. A few species prefer woodland including plantations of non-native forest trees. Impacts of alien Heteroptera in Europe are poorly investigated. A few species are considered pests in agriculture, forestry, or on ornamentals. More research is needed for a better understanding of the ecological and economic effects of introduced Heteroptera.

Keywords

alien, non-native, Hemiptera, Heteroptera, Europe

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9.1.1 Introduction

The Heteroptera, or true bugs, is a highly diverse insect taxon with approximately 42,300 described species worldwide, separated into seven infraorders and 75–89 families (Henry 2009, Schuh and Slater 1995). Their body size ranges from less than 1 mm to 10 cm. True bugs feed on many different resources (e.g., haemolymph of insects, blood of endotherms, fungi cytoplasma, phloem-, xylem- or parenchym-sap of mosses, ferns, monocotyledons, mostly dicotyledons, algae, the endosperm of seeds, plant pollen). Heteropterans live in virtually all terrestrial and aquatic ecosystems from Antarctic birds' nests to rainforest canopies, from the open surface of the ocean (almost uniquely for insects), to torrential and stagnant rivers, from ephemeral rain pools and phytotelmata to large lakes, and in aphotic caves and man-made buildings (Schuh and Slater 1995).

Among the characteristic features are the mouthparts, which evolved as sucking stylets for the uptake of liquid food and the injection of secretions from the salivary gland; restricted diets are commonly observed. Most species are phytophagous, some feed exclusively on particular plant species, genera or families, whereas others are polyphagous species feeding on dozens to hundreds of different host plants. Some species are of considerable economic concern in agriculture or (more rarely) forestry, many species are predatory and some are used as biocontrol agents against agricultural pests (Schaefer and Panizzi 2000).

Although some heteropteran species have reduced wings or wing musculature, and some are sexually dimorphic in this respect, many species are good flyers and capable of negotiating long distances. Subsequent spread after introduction by humans into a new area is commonly observed. Eggs and nymphs are translocated with host plants over long distances. Unlike the situation in many other Hemiptera, sexual reproduction prevails, with only one parthenogenetic species known in the European fauna, and depending on the species, one to several generations develop under temperate conditions. Many species deposit their eggs inside the host plant, which effectively fosters passive translocation and facilitates spread.

9.1.2 Methods

Previously published information on alien Heteroptera species is available for some countries, e.g., Germany (Geiter et al. 2002) but see Hoffmann (2003) for a critical review, Austria (Essl and Rabitsch 2002), Switzerland (Kenis 2005), Czech Republic (Kment 2006b, Šefrová and Laštùvka 2005), and the Azores (Borges et al. 2005). Comparison of these lists is hindered by the use of different terminology and criteria for selecting species. The first attempt at a comprehensive treatment of the alien Heteroptera of Europe was published recently Rabitsch (2008) and serves as basis for this work, but is supplemented by new data (up to May 2009 including a few works in press). The reader is referred to Rabitsch (Rabitsch 2008) for a more detailed account on the history of introductions for each species.

This present chapter deals with species alien *to* Europe and species alien *in* Europe, but excludes continental European species alien to European islands. For example, Borges et al. (2005) stated that *Tingis cardui* (Linnaeus, 1758) and *Gastrodes grossipes* (De Geer, 1773), which both feeding on non-native host plants, are alien to the Azores. On the contrary, Heiss & Péricart (2007) argued that *Aradus canariensis* Kormilev, 1954 may have been introduced to Mallorca. The anthropogenic contribution of some recent range changes of continental "European" species to Great Britain and to Scandinavia, and hence their alien status, is particularly difficult to identify. For example, Ødegaard & Endrestøl (2007) present three hypotheses, not mutually exclusive, for the recent occurrence of *Chilacis typhae* (Perris, 1857) in Norway. For the time being, only *Deraeocoris lutescens* is here considered alien in Sweden and Norway, but the status of additional species needs careful re-examination, e.g. *Pinalitus atomarius* (Meyer-Dür, 1843) in Sweden (Lindskog and Viklund 2000), *Chilacis typhae* and *Heterogaster urticae* (Fabricius, 1775) in Norway (Ødegaard and Endrestøl 2007). Kirby et al. (2001) review several similar cases for Great Britain.

9.1.3 Taxonomy of the alien Heteroptera of Europe

Alien Heteroptera are non-uniformly distributed across the seven infraorders. There are no alien species in Enicocephalomorpha and Dipsocoromorpha, the basal infraorders with 420 and 340 species worldwide, respectively. These predatory, usually tiny and fragile species live their secret lives in seclusion of riparian habitats and ground litter. No alien Gerromorpha are known in Europe; members of this predatory infraorder with more than 2100 species worldwide are commonly known as "Jesus-bugs" due to their ability to move on the surface of running and standing waters. Among Nepomorpha, the aquatic true bugs, with 2300 species worldwide, and Leptopodomorpha, the "shore bugs", with 380 species worldwide, there is a single alien species in each infraorder, *Trichocorixa verticalis* and *Pentacora sphacelata*, both originally from North America, being introduced to the western Mediterranean region. Most alien Heteroptera belong to the most species-rich infraorders Cimicomorpha (20,500 species worldwide, 37 alien species in/to Europe) and Pentatomomorpha (16,200 species worldwide, 9 alien species in/to Europe).

Within Hemiptera, Heteroptera constitute only a small fraction of alien species compared to aphids and scales (see chapters 9.2 and 9.3). At the end of the chapter, Table 9.1.1 and 9.1.2 list 48 Heteroptera species considered alien in this study of which 16 species are alien to Europe (i.e., species introduced from outside Europe), 25 species are alien in Europe (i.e., species introduced from one part of Europe to another), and seven cryptogenic species are of unknown origin. According to Aukema & Rieger (1995–2006), there are approximately 2860 Heteroptera species (including subspecies) in Europe, which means that 1.7% of the European fauna is alien.

At the family level, Miridae (20 spp.) and Tingidae (8 spp.) prevail, followed by Anthocoridae (7 spp.) and Lygaeidae *sensu lato* (5 spp.) (Figure 9.1.1). The systematic classification of Lygaeidae is still under discussion. While most heteropterists agree that Lygaeidae are paraphyletic (Henry 1997), there is no consensus on how to arrange them.

The most species-rich family is Miridae, both in the native and the non-native faunas. Species of nine families are represented in the alien fauna, which is only 10% of the known families worldwide. Genera with more than one alien species are *Amphiareus* (2), *Anthocoris* (2), *Corythucha* (2), *Deraeocoris* (2), *Orthotylus* (4), *Stephanitis* (4), and *Tuponia* (5). Whereas all alien species belong to families present in Europe, 10 genera (13 genera including the cryptogenics, asterisked here) are alien at the genus level (*Amphiareus*, *Belonochilus*, **Buchananiella*, *Corythucha*, *Halyomorpha*, **Nesidiocoris*, *Nezara*, *Pentacora*, *Perillus*, **Taylorilygus*, *Trichocorixa*, *Tropidosteptes*, *Tupiocoris*).

Anthocoridae

All Anthocoridae (flower bugs or minute pirate bugs) are small insects (< 5 mm body size) and most species are predatory, actively searching and hunting for their prey, which regularly consist of soft-bodied Sternorrhyncha. About 450 species are known at the world level (Henry 2009) of which 75 are considered native in Europe (Aukema and Rieger 1995–2006). The alien Heteroptera of Europe only include 4 species alien *to* Europe and 3 alien *in* Europe (Figure 9.1.1). Hence several species, especially in the genera *Anthocoris* and *Orius*, are successfully used commercially in biological control programs in greenhouses and sometimes in the wild, e.g., (Lattin 1999, Schaefer and Panizzi 2000). Apparently, only one species, the western and southern European *Orius laevigatus* is established outside its natural range in the Netherlands (Aukema and Loomans 2005) although these authors do not rule out the possibility that this species has shifted northwards due to climate change. Similarly, the true cause of the recent westward spread of the East-Palaearctic *Amphiareus obscuriceps* cannot definitely be identified. Although predatory, several anthocorid species are specialized to host plants, where they search for prey, e.g., *Anthocoris butleri* on *Buxus* and *A. sarothamni* on *Cytisus*. Both host plants are widely used as ornamentals and introduction of the Heteroptera with the host plants, as well as a range shift from western to eastern Europe, is possible. The origin of the pan-tropical *Buchananiella continua* is unknown. It is known from western Europe and appears to have spread both in Great Britain and in continental Europe (Aukema 2007, Aukema and Hermes 2009, Kirby 1999). Likewise, the origin of the cosmopolitan *Amphiareus constrictus* is unclear. It was introduced to the Netherlands (Aukema and Hermes 2009) and may further spread in Europe. The alien status of *Lyctocoris campestris* in Europe is debatable.

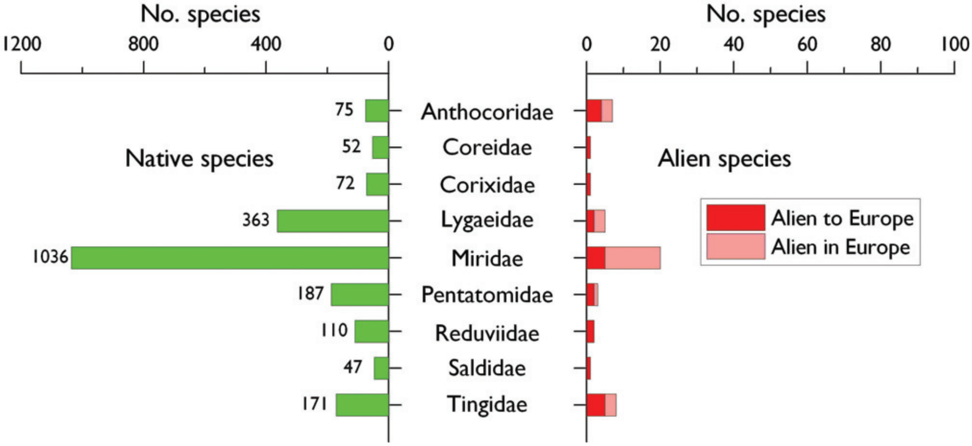

Figure 9.1.1. Taxonomic overview of the alien Heteroptera of Europe at the family level. Species alien *to* Europe include cryptogenics.

Coreidae

The leaf-footed or squash bugs is a species-rich family with species of medium to large body size. A total of 1900 species have been described throughout the world (Henry 2009), including 52 in Europe (Aukema and Rieger 1995–2006) but only one alien species has so far established on the continent. For several reasons, this single alien species, *Leptoglossus occidentalis*, is of particular interest. The native range is presumed to be west of the Rocky Mountains and following its spread in North America since the 1950s, it was introduced to Europe only in the late 1990s. The first date recorded in European record was 1999 in northern Italy (Bernardinelli and Zandigiacomo 2001) and the species rapidly spread over most of Europe (Dusoulier et al. 2007, Rabitsch 2008) with no foreseeable stop (Lis et al. 2008). This spread is likely to be the result of multiple introductions into Europe, and secondary translocations within it. When feeding on conifer seeds, fertility of the seeds is reduced, causing an economic impact for forestry. Recently, infrared receptive organs were found in *L. occidentalis*, orienting specimens towards conifer cones (Takács et al. 2009). Because individuals aggregate in autumn seeking hibernation sites in buildings, this species may also become a nuisance to people. Recently, it was found in Japan (Tokyo) (Ishikawa and Kikuhara 2009).

Corixidae

The family has about 600 described species in the world (Henry 2009), and 72 in Europe (Aukema and Rieger 1995–2006). The single aquatic species yet recognized as alien to Europe, *Trichocorixa verticalis*, is of nearctic origin and was introduced to

Europe (Portugal) between 1997 and 2003 (Sala and Boix 2005). Its pathway and potential impact is not known, but it may well have been introduced as a stowaway with mosquitofish (*Gambusia* sp.) and may outcompete native corixids and lead to a simplification of the aquatic community (Kment 2006a, Millán et al. 2005, Rodríguez-Pérez 2009).

Lygaeidae *sensu lato*

Lygaeidae or seed-bugs are a species-rich group of about 4000 species (Henry 2009) of medium body size that include both seed-feeding and predatory species with economic impact that is sometimes significant (Schaefer and Panizzi 2000). A total of 363 species are native to Europe (Aukema and Rieger 1995–2006) but only two species are alien to Europe, *Nysius huttoni* from New Zealand, and *Belonochilus numenius* from North America. Both species currently are locally distributed, but have the potential to spread over large parts of Europe. The former is known from the Netherlands, Belgium, northern France and Great Britain, where it occurs in ruderal sites, waste grounds and abandoned fields (Smit et al. 2007). *N. huttoni* feeds on several weeds and crops and attains pest status in its native area (Sweet 2000). The latter has been found in Corsica and mainland southern France in the vicinity of a railway station and at a university campus (Montpellier) (Matocq 2008) as well as in Catalonia, Spain (Castelldefels, Barcelona) (Gessé et al. 2009) on or near ornamental sycamore (*Platanus* sp.). These almost simultaneous findings and the fact that its host plant is regularly planted in urban parks and gardens, indicates that the species is already much more widely distributed and that further spread in Europe is very likely.

Three further lygaeid species are here considered alien in Europe. The first is *Arocatus longiceps*, an eastern Mediterranean species living on sycamore, whose occurrence is restricted to urban settings where it sometimes reaches high abundance causing a nuisance to people. Due to its variability, heteropterists debate its separation from native *Arocatus* species, considering possible hybridization and post-invasion colour changes (Hoffmann 2008). The second, *Orsillus depressus*, is a Mediterranean species living on Cupressaceae. Its adaptation to ornamental *Thuja*, *Chamaecyparis*, and *Juniperus* promoted its northward spread. Intraguild competition on native *Juniperus*-stands is likely, but so far not investigated. Lastly, *Oxycarenus lavaterae* is a western Mediterranean species living on Malvaceae s.l. with a preference for lime trees (*Tilia* sp.). The species builds spectacular large aggregations of millions of individuals, also sometimes causing nuisance to people, e.g., at market places in cities or when entering buildings.

Miridae

With more than 10,000 described species (Henry 2009) of which 1036 in Europe (Aukema and Rieger 1995–2006), Miridae or plant bugs is the most species-rich family within Heteroptera. Plant bugs include tiny to large, soft-bodied, dull to brightly coloured, phytophagous, zoophytophagous and predatory species (Wheeler 2001). Only 5 species alien *to* Europe have established whereas 15 species are considered alien *in* Europe (Figure 9.1.1.). Whereas some species are considered serious agricultural pests, others are used in biological control programmes. *Closterotomus trivialis* and *Dicyphus escalerae* are examples of Mediterranean species occurring locally in central Europe, the latter recently also found in Great Britain (Kirby et al. 2009), being introduced with their host plants. The same is most likely true for *Deraeocoris lutescens*, a western Palaearctic species introduced to Scandinavia. Another predatory, remarkably fast spreading species, is the Mediterranean *Deraeocoris flavilinea*, that presumably has been introduced unintentionally along transportation routes. *Tupiocoris rhododendri* was described from specimens collected in 1971 in Kew Gardens, London, but it originally comes from North America. Recently, this predatory species was found in continental Europe, and its further spread is to be expected (Aukema 2007, Aukema et al. 2005a). One of the most recent members of the European alien Heteroptera fauna is *Tropidosteptes pacificus* from North America, collected on European ash (*Fraxinus excelsior*) in a natural environment in the Netherlands (Aukema et al. 2009a). Three *Orthotylus* species live zoophytophagously on *Cytisus* and probably were introduced with their host plant to central and eastern Europe. The mediterranean *Orthotylus caprai* was only recently observed in central and western Europe on Cupressaceae, and is considered an alien species in Europe north of the Alps. Five *Tuponia* species, living phytophagously on *Tamarix*, were most likely introduced with their ornamental host plants.

Pentatomidae

Pentatomidae or stink bugs are a species-rich and medium to large body-sized heteropteran family with often stout and colourful bodies. About 4700 species have been recognized (Henry 2009), including 187 species in Europe (Aukema and Rieger 1995–2006). Members of one subfamily (Asopinae) are predatory and some are used in biocontrol programmes. This is true for *Perillus bioculatus*, native to North America and used against the Colorado potato beetles *Leptinotarsa decemlineata* in several European countries (De Clercq 2000). However, successful establishment in the wild apparently so far only occurred in Turkey and Greece. Recently, the Brown Marmorated Stink Bug *Halyomorpha halys*, native to Asia, was introduced to Switzerland (see factsheet 14.49) (Wermelinger e al. 2008). This species lives on ornamentals, vegetables and fruit trees where it may become a pest and it is regarded as a nuisance when seeking hibernation sites. The Southern Green Stink Bug *Nezara viridula*, a polyphytophagous pest species on several crops, is presumably of African and/or Mediterranean origin. *Nezara viridula* is a clear case of establishment of populations outside its original distribution in Germany, Hungary, Great Britain, and northern Switzerland. In addition, this species is found regularly in other parts of Europe, and is regularly intercepted by plant quarantine (Malumphy and Reid 2007).

Reduviidae

Reduviidae, the assassin bugs, are a species-rich and morphologically highly diverse predatory heteropteran family including 6900 species in the world (Henry 2009) of which 110 occur in Europe (Aukema and Rieger 1995–2006). However, only two cryptogenic, pantropical species are included here. *Empicoris rubromaculatus* is found in southwestern Europe with isolated records in Belgium, Croatia and Greece; the latter records may reflect a recent eastward range shift, but maybe this species was previously overlooked in the eastern Mediterranean region. *Ploiaria chilensis* is known from Macaronesia and Spain, with doubtful records from the central and eastern Mediterranean.

Saldidae

Shore bugs or Saldidae are a species-poor (340 species in the world (Henry 2009)), medium-sized, predatory family, living in littoral habitats along the edges of running and standing waters, marine shoreline and bogs. Whereas the native fauna includes 47 species (Aukema and Rieger 1995–2006), there is only one species alien to Europe. This single species, *Pentacora sphacelata*, is known since the 1950s from the Iberian Peninsula and Sardinia. This is a halophilous species living in the tidal-zone and close to saline waters.

Tingidae

Lace bugs or Tingidae are a species-rich, small-sized (< 8 mm body size), phytophagous family, with characteristic ornate and lacelike hemelytra and pronotum. Most species live on or near their host plants with a usually tight preference to particular plant species or families. About 2100 species are recognized in the world (Henry 2009) but only 171 are native to Europe (Aukema and Rieger 1995–2006). Thus, the alien fauna which includes 5 species alien to Europe is proportionally a little more important than in Miridae (2.9% of the total fauna vs. 0.5%; Figure 9.1.1). Both *Corythucha*-species were introduced from North America to Italy and live arboreally on their host plants, including the oak lace bug *C. arcuata* on *Quercus* (see factsheet 14.51) and the sycamore lace bug *C. ciliata* on *Platanus* (see factsheet 14.52). The former species was introduced a decade ago and only started to spread (Dioli et al. 2007), whereas the latter was introduced in the 1960s and nowadays is very widespread across Europe. *Stephanitis pyrioides* and *S. takeyai* were introduced from Japan and *S. rhododendri* from North America with ornamental Ericaceae (*Rhododendron*, *Azalea*, *Pieris*). *Dictyonota fuliginosa* and *Elasmotropis testacea* are both considered alien in parts of Europe where the host plants are also alien, although unambiguous evidence on their introduction status often is lacking. The alien status of *Stephanitis oberti* in Central Europe is debatable.

9.1.4 Temporal trends of introduction of alien Heteroptera in Europe

The (published) year when first recorded is known for all species (Table 9.1.1 and 9.1.2; see also Rabitsch (2008) for all country records), although it is evident that this need not be identical with the year of introduction. Usually it takes a few years for introduced insects to increase in abundance above a certain threshold to establish reproducing populations and to get recognized. This time-lag is known as a common characteristic of biological invasions and it can extend over long time periods in some organisms, e.g. decades or even centuries in some plants (Kowarik 1995). For insects, however, this time-lag usually extends over much shorter periods, but several years may still elapse since an alien species is discovered and information is communicated.

Some Heteroptera were already introduced in ancient times, such as the notorious bed bug *Cimex lectularius* Linnaeus, 1758 and maybe some others following human expansion associated with agricultural land reclamation. Those ancient introductions were rarely if ever documented and are therefore excluded in this study. However, there is no doubt that the rate of introductions has exponentially increased within the 20th century and reached unprecedented magnitudes in the 21st century (Figure 9.1.2). Since 1990, an approximate arrival rate of seven species per decade has been observed (Rabitsch 2008). Currently, Heteroptera alien *to* and alien *in* Europe both establish at a rate of 0.33 species per year; this means that on average every third year an Heteroptera species from outside Europe arrives in Europe. Even within the last eight years, five species have been detected: *Corythucha arcuata*, *Tropidosteptes pacificus* and *Belonochilus numenius* from North America (2000, 2007, 2008, respectively), *Nysius huttoni* from New Zealand (2002) and *Halyomorpha halys* from East Asia (2007).

Some species are suspected of having been introduced in the 19th century together with ornamental plants, e.g. *Anthocoris butleri* on *Buxus sempervirens*, *Anthocoris sarothamni*, *Orthotylus adenocarpi*, *O. concolor*, *O. virescens*, *Dictyonota fuliginosa* on *Cytisus scoparius*, and *Macrolophus glaucescens*, *Elasmotropis testacea* on *Echinops sphaerocephalus*. More recently, several *Tuponia* species were introduced with the increasing use of ornamental *Tamarix* species in public and private gardens.

The time of introduction for cryptogenic species into Europe is unclear and may well be several centuries before present. Most are pan-tropically distributed, zoophagous species.

9.1.5 Biogeographic patterns of the alien Heteroptera of Europe

9.1.5.1 Origin of alien species

A total of 16 species are alien to Europe, 10 of these from North America, 4 from the eastern Palaearctic and East Asia and one each from South America and Oceania. Almost all of the 25 species alien in Europe originate in the Mediterranean region and

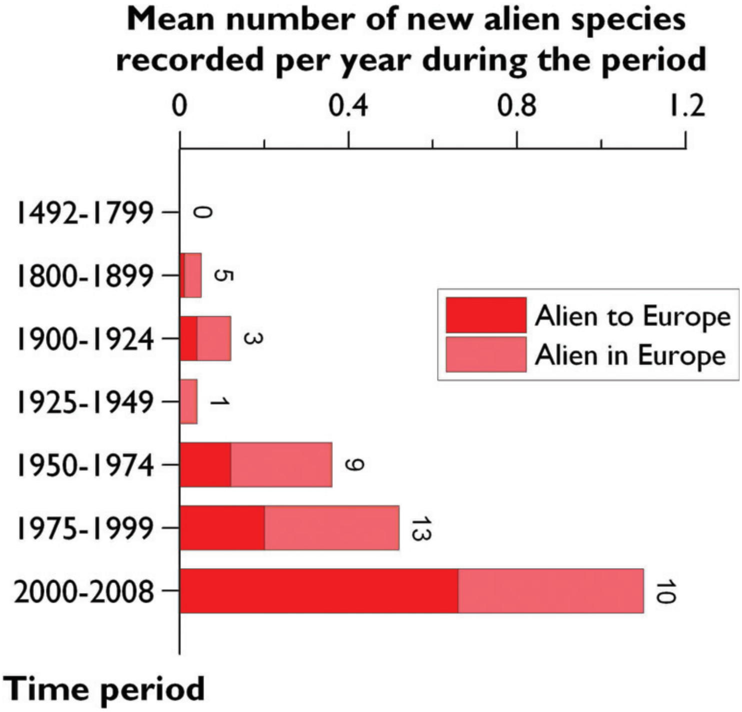

Figure 9.1.2. Temporal trends in the mean number of new records per year for Heteroptera species alien *to* Europe and alien *in* Europe from 1492 to 2008. Cryptogenic species are excluded. The number above the bar indicates the absolute number of species in this time period.

were translocated to central and northern Europe. Seven species are considered cryptogenic with unknown origin and cosmopolitan distribution (Figure 9.1.3).

Rabitsch (2008) mentioned the increasing trend of North American species arriving in Europe (Figure 9.1.4). This is corroborated by the most recent introductions of *Tropidosteptes pacificus* in the Netherlands (Aukema et al. 2009a) and *Belonochilus numenius* in Corsica, continental France and Spain (Gessé et al. 2009, Matocq 2008). Few species have been introduced from Oceania (New Zealand, *Nysius huttoni,* see factsheet 14.47) and South America (*Fulvius borgesi*). The latter species was only recently described as new to science, based on specimens collected in banana plantations at low altitudes on the Azores (Chérot et al. 2006). The authors argued, based on morphological characters, that the species was introduced from South America. *Nezara viridula* is considered the only alien species of African origin, although some were previously intercepted during plant health inspections, e.g. the Grain Chinch Bug, *Macchiademus diplopterus* (Distant, 1903) (Lygaeidae) and *Natalicola pallidus* (Westwood, 1837) (Tessaratomidae) at Heathrow Airport, London, on fruits and plants imported from South Africa (Malumphy and Reid 2007, 2008). Suitable climate seems to be a significant factor for the establishment of Heteroptera alien to Europe since 87% (14 species) come from temperate climates and only two species were introduced from the southern hemisphere.

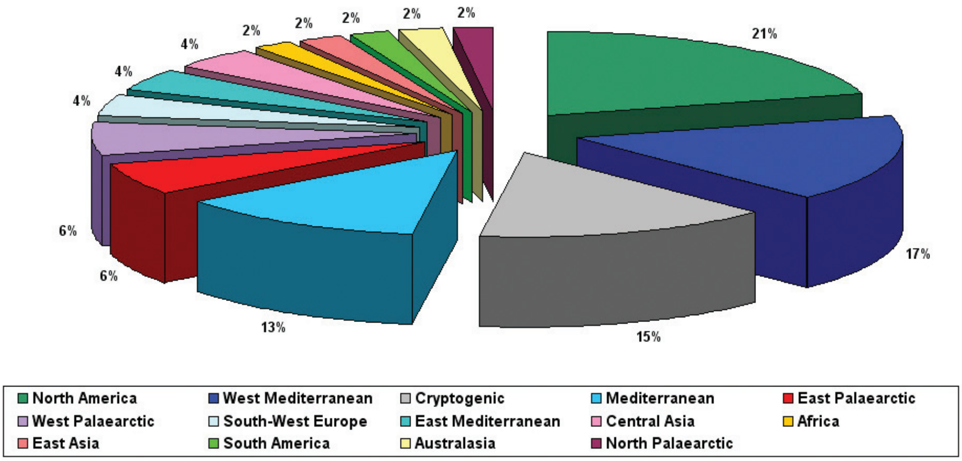

Figure 9.1.3. Geographic origin of the alien Heteroptera species of Europe.

9.1.5.2 Distribution of alien species in the European countries

Most alien Heteroptera species are known from Central Europe (Czech Republic: 22 species, that is 47% of all species, Germany: 20 species) and Western Europe (Netherlands: 20 species, Great Britain: 17 species) (Figure 9.1.5). One reason for the subordinate relevance of South Europe as a recipient for alien Heteroptera lies in the fact that almost all species alien *in* Europe originate in the Mediterranean region and were translocated north. This is likely a consequence of the increasing north-south exchange of people and merchandise (e.g., summer holiday tourism, fruits, vegetables) (Rédei and Torma 2003). A west-east pattern, however, can be found in suspected previous introductions of species living on western European ornamental plants, which were later widely planted across Europe. This concerns species living on *Buxus sempervirens*, *Cytisus scoparius*, and *Echinops* spp. Those plants are nowadays widely planted in cemeteries and private gardens and host monophagous Heteroptera species (e.g. *Anthocoris butleri*, *A. sarothamni*, *Dictyonota fuliginosa*, *Elasmotropis testacea*, *Macrolophus glaucescens* and *Orthotylus* spp.).

This northwest-southeast gradient is also demonstrated by a significant negative rank correlation of alien species numbers and longitude when the diversity of alien heteropterans is tentatively correlated to environmental and economic variables using a Spearman rank correlation ($\varrho= -0.548$; $P < 0.001$; Rabitsch, unpublished data). Whereas the number of native Heteropteran species per country appears to be significantly correlated with both the number of native plant species ($\varrho= 0.887$; $P < 0.001$) and the country size ($\varrho= 0.576$; $P < 0.001$), the number of alien Heteroptera species does not ($\varrho= -0.548$ and $\varrho= 0.093$, respectively, n.s.). On the contrary, whereas the number of alien Heteroptera is positively correlated with some economic variables (GDP per capita, $\varrho = 0.417$; $P < 0.01$; average trade import 1990–1997, $\varrho= 0.748$;

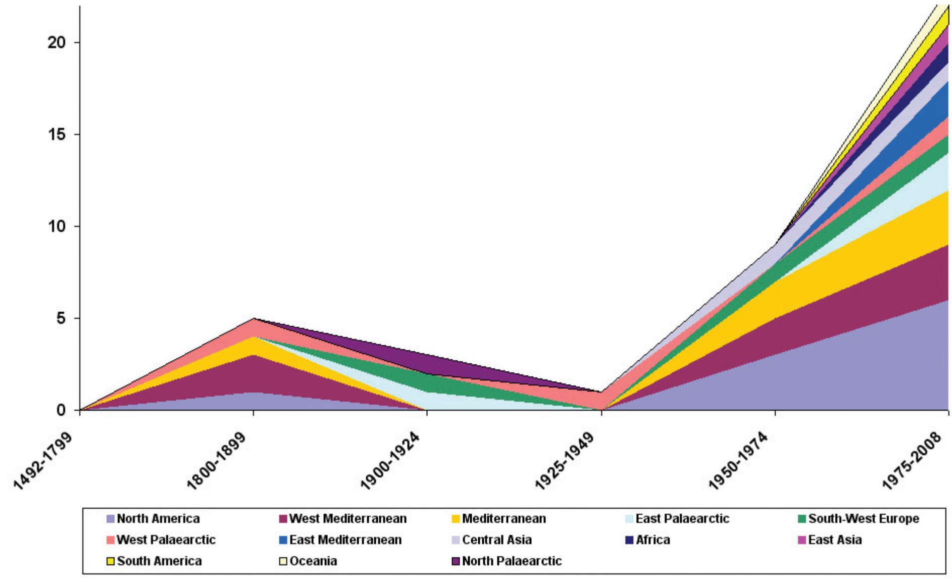

Figure 9.1.4. Numbers of established alien Heteroptera species of Europe by period of introduction and geographic origin. Cryptogenic species are excluded.

$P < 0.001$), the number of native species is not ($\varrho = -0.049$, n.s.). The distribution patterns of alien Heteropterans also seem to match these of alien plants ($\varrho = 0.394$; $P<0.05$) and alien terrestrial invertebrates ($\varrho = 0.703$; $P<0.001$); this likely is a fact of the overwhelming importance of urbanisation and trade import for the establishment of alien terrestrial invertebrate species in Europe (Roques et al. 2008). The Netherlands must be regarded as an invasion focus for the alien Heteroptera of Europe, with seven species having been first recorded in this country (Tables 9.1.1 and 9.1.2). A more sophisticated statistical analysis with several explanatory variables and taking into account area and sample effects, autocorrelation, multicollinearity, etc. will be presented elsewhere (Rabitsch and Moser, in prep.).

9.1.6 Pathways of introduction of the alien species of Heteroptera

Heteroptera are rarely intercepted (Roques and Auger-Rozenberg 2006) or at least rarely reported, in part due to their ancillary role as pest organisms. Recently, however, a number of such cases were published from regular plant health inspections in Great Britain. For example, *Natalicola pallidus* (Tessaratomidae) was found on *Crassula multicava* from South Africa (Malumphy and Reid 2008) and one specimen of *Leptoglossus occidentalis* was found in a timber shipment from the USA (Malumphy et al. 2008) indicating multiple introductions of this species into Europe. Ornamental trade and movement as stowaways with transport vehicles are the major pathways for alien Heteroptera (Rabitsch

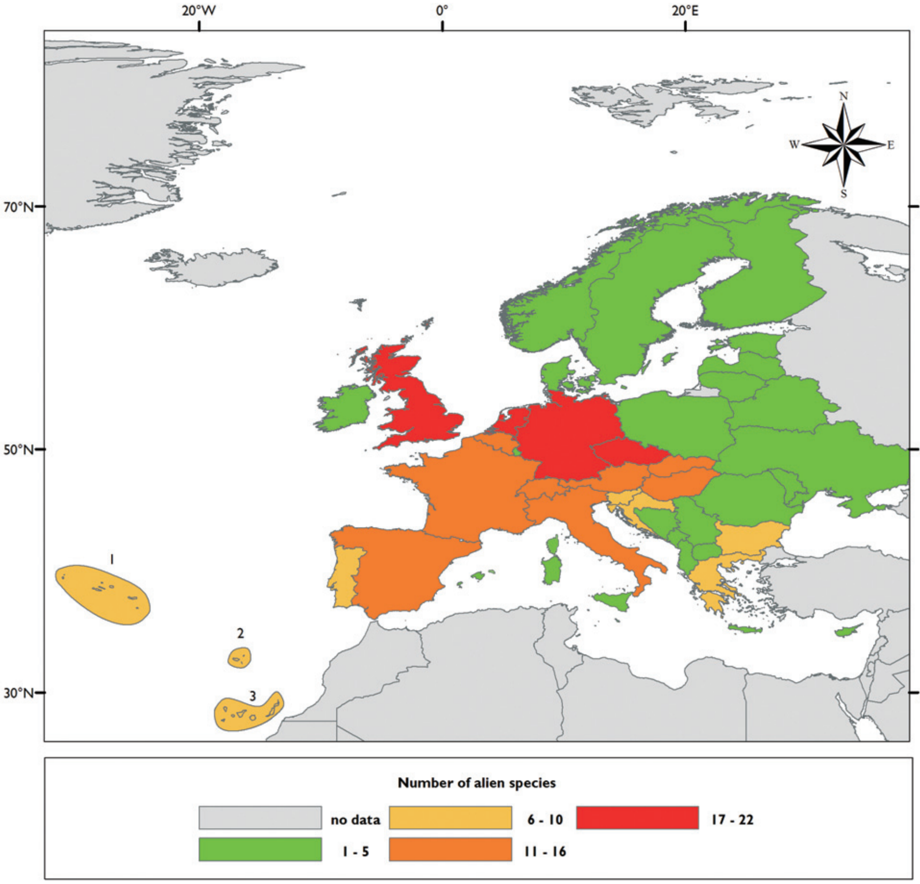

Figure 9.1.5. Numbers of established alien Heteroptera species per European country. Data rely on Tables 9.1.1 and 9.1.2. Aliens with doubtful status are included. Archipelago: **1** Azores **2** Madeira **3** Canary islands.

2008), also confirmed by the interruption of introductions between 1925 and 1949 (Figure 9.1.4).

9.1.7 Ecosystems and habitats invaded by alien Heteroptera in Europe

Most alien Heteroptera colonize habitats under strong human influence, like agricultural, horticultural, and domestic habitats (51%) and parks and gardens (27%) (Figure 9.1.6). Some species prefer woodland including plantations of non-native forest trees. It is worth mentioning that *Leptoglossus occidentalis* has not only spread across Europe, but has also

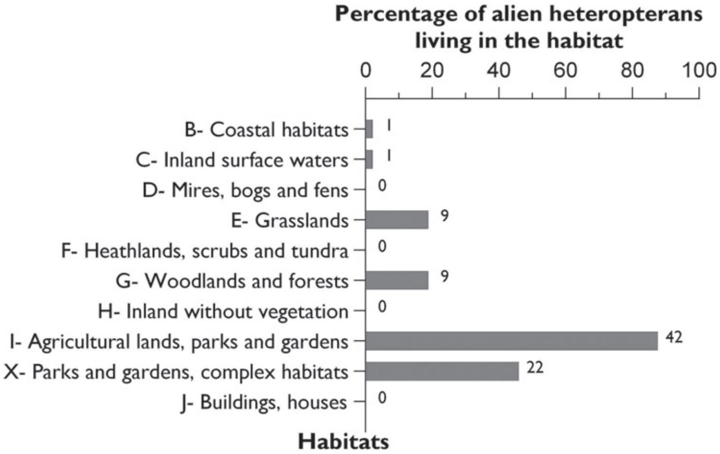

Figure 9.1.6. Main habitats colonized by alien Heteroptera species in Europe. The number above each bar indicates the absolute number of alien species recorded per habitat. Note that a species may have colonized several habitats.

expanded its occupied habitat: first records in most countries are indoors, from cities and harbours, but increasingly records in the field are observed at higher elevations. In France, *L. occidentalis* has twice been captured above 1000 m (Dusoulier et al. 2007) and in Austria (Styria) there is a documented record at 1500 m (Gepp, in litt.) (see factsheet 14.42).

9.1.8 Ecological and economic impact of alien Heteroptera in Europe

Impacts of alien Heteroptera in Europe are poorly investigated (Rabitsch 2008). A few species are considered pests in agriculture or forestry, e.g. *Nysius huttoni*, and *Leptoglossus occidentalis*, or on ornamental plants, e.g. *Corythucha ciliata* and *Stephanitis takeyai*, but damage is only locally reported in Europe to date. No data are available on any negative ecological impact on native species either due to predation, hybridization, competition or pathogen-transfer. However, as mentioned by Rabitsch (2008), no one has yet looked at such effects. It may be worth investigating intraguild competition within the juniper-feeding guild or the effects of *Trichocorixa verticalis* in aquatic communities.

9.1.9 Conclusion

It is essential to observe and document range changes of species. Clearly, the number of introduced Heteroptera will increase. Climate change and habitat modification will further promote establishment of additional species. Some introduced species, currently considered as not established, were excluded in this study, but may establish populations in the near

Figure 9.1.7. Adults of some alien Heteroptera species: **a** *Arocatus longiceps* (Credit: Wolfgang Rabitsch) **b** *Leptoglossus occidentalis* feeding on Scots pine (Credit: Alain Roques) **c** *Oxycarenus lavaterae* aggregating on trunk (Credit: Wolfgang Rabitsch) **d** *Oxycarenus lavaterae* detail (Credit: Wolfgang Rabitsch) **e** *Stephanitis takeyai* (Credit: Wolfgang Rabitsch) **f** *Tupiocoris rhododendri* (Credit: Ab Baas).

future; e.g., *Orius flagellum* Linnavuori, 1968 in the Netherlands (Aukema and Hermes 2009), *Xylocoris flavipes* (Reuter, 1875) in several European countries (Péricart 1972, 1996). Also, recent range changes of some continental European species need to be carefully reconsidered when new data become available as some of these may deserve alien status; e.g. Ødegaard & Endrestøl (2007), see Rabitsch (2008) for additional examples. Taking into account the increasing number of Heteroptera species introduced from North America and the often observed previous range increase in the native areas, it is recommended for Europe to keep an eye on range changes in North America, which may be an early indicator for possible future alien species to Europe. Finally, more research is needed for a better understanding of the ecological and economic effects of introduced Heteroptera.

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References

Aukema B (1996) *Stephanitis takeyai* on *Pieris japonica*. *Mededelingen van de Plantenziektenkundige Dienst* 179: 46–47.

Aukema B (1999) Heteroptera. In: Ackerman RA, van Halteren P, Jenniskens MJ (Eds) Annual Report Diagnostic Centre 1998. *Mededelingen van de Plantenziektenkundige Dienst* 200: 62–63.

Aukema B (2007) *Buchananiella continua* (Anthocoridae) in south Devon (VC3). *HetNews* 9: 12.

Aukema B (2008) De invasieve noord-amerikaanse wants *Leptoglossus occidentalis* bereikt ook Nederland (Heteroptera: Coreidae). *Nederlandse Faunistische Mededelingen* 29: 78–80.

Aukema B, Hermes D (2009) Nieuwe en interessante Nederlandse Wantsen III (Hemiptera: Heteroptera). *Nederlandse Faunistische Mededelingen* 31: 52–88.

Aukema B, Loomans A (2005) *Orius laevigatus* in the NL (Heteroptera, Anthocoridae). *Nederlandse Faunistische Mededelingen* 23: 125–127.

Aukema B, Rieger C (1995–2006). *Catalogue of the Heteroptera of the Palaearctic Region*. Vols 1–5. Amsterdam: The Netherlands Entomological Society. Vol. 1, 222 pp., Vol. 2, 361 pp., Vol. 3, 577 pp., Vol. 4, 346 pp., Vol. 5, 550 pp.

Aukema B, Bos F, Hermes D, Zeinstra P (2005a) Nieuwe en interessante nederlandse wantsen II, met een geactualiseerde naamlijst (Hemiptera: Heteroptera). *Nederlandse Faunistische Mededelingen* 23: 37–76.

Aukema B, Bruers JM, Viskens G (2005b) A New Zealand endemic *Nysius* established in the NL and BE (Heteroptera: Lygaeidae). *Belgian Journal of Entomology* 7: 37–43.

Aukema B, Bruers JM, Viskens GM (2007) Nieuwe en zeldzame Belgische wantsen II (Hemiptera: Heteroptera). *Bulletin van de Koninklijke Belgische Vereniging voor Entomologie* 143: 83–91.

Aukema B, Schwartz MD, Den Bieman K (2009a) *Tropidosteptes pacificus* (Van Duzee, 1921), another Nearctic mirid in Europe (Hemiptera: Heteroptera: Miridae: Mirinae). *Zootaxa* 2135: 65–68.

Aukema B, Bruers JM, Viskens GM (2009b) Nieuwe en zeldzame Belgische wantsen III (Hemiptera: Heteroptera). *Bulletin van de Koninklijke Belgische Vereniging voor Entomologie* 145: 25–31.

Barclay M (2004) The Green Vegetable Bug *Nezara viridula* (L., 1758) (Hem.: Pentatomidae), new to Britain. *Entomologist's Record* 116: 55–58.

Barclay M, Nau BS (2003) A second species of Tamarisk bug in Britain, *Tuponia brevirostris* Reuter, and the current status of *T. mixticolor* (A. Costa) (Hem., Miridae). *Entomologist's Monthly Magazine* 139: 176–177.

Benedek P, Jászai,VE (1968) On some species of the genus *Tuponia* Reuter, 1875 (Heteroptera: Miridae, Phylinae). *Acta Zoologica Academiae Scientiarum Hungaricae* 14: 7–13.

Bernardinelli I, Zandigiacomo P (2001) *Leptoglossus occidentalis* Heidemann (Heteroptera, Coreidae): a conifer seed bug recently found in northern ItalyT. *Journal of Forestry Science* 47: 56–58.

Borges PAV, Cunha R, Gabriel R, Martins AF, Silva L, Vieira V (2005) *A list of the terrestrial fauna (Mollusca and Arthropoda) and flora (Bryophyta, Pteridophyta and Spermatophyta) from the Azores*. Angra do Heroísmo: Universidade dos Açores. 318 pp.

Bruers J, Viskens G (1999) *Stephanitis oberti* (Kolenati, 1856) Belg. n. sp. *Entomo-Info* 10: 11.

Bryja J, Kment P (2002) New and interesting records of plant bugs (Heteroptera: Miridae) from the Czech and SKs. *Klapalekiana* 38: 1–10.

Carapezza A (1980) *Saldula sardoa* Fil., specie propria e *Pentacora sphacelata* (Uhler) in Sardegna. *Bollettino della Societá Sarda di Scienze Naturali* 20: 49–54.

Chérot F, Ribes J, Gorczyca J (2006) A new *Fulvius* species from Azores Islands (Heteroptera: Miridae: Cylapinae). *Zootaxa* 1153: 63–68.

Cuming N (2008) New to British Isles: *Nysius huttoni* White, 1878. *HetNews* 11: 10.

De Clercq P (2000) Predaceous Stinkbugs (Pentatomidae: Asopinae). In Schaefer C, Panizzi A (Eds) *Heteroptera of Economic Importance*. Boca Raton, Florida: CRC Press, 737–789.

Dioli P, Forini IG, Moretti M, Salvetti M (2007) Note sulla distribuzione di *Corythucha arcuata* (Insecta, Heteroptera, Tingidae) in Cantone Ticino (Svizzera), Valtellina e alto Lario (Lombardia, Italia). *Il Naturalista Valtellinese* 18: 59–68.

Dolling WR (1972) A new species of *Dicyphus* Fieber (Hem., Miridae) from southern England. *Entomologist's Monthly Magazine* 107: 244–245.

Dusoulier F, Lupoli R, Aberlenc HP, Streito JC (2007) L'invasion orientale de *Leptoglossus occidentalis* en France: bilan de son extension biogéographique en 2007 (Hemiptera Coreidae). *L'Entomologiste* 63: 303–308.

Essl F, Rabitsch W (2002) *Neobiota in Österreich*. Wien: Umweltbundesamt, 432 pp.

Forster B, Giacalone I, Moretti M, Dioli P, Wermelinger B (2005) Die amerikanische Eichennetzwanze *Corythucha arcuata* (Say) (Heteroptera, Tingidae) hat die Südschweiz erreicht. *Mitteilungen der Schweizerischen Entomologischen Gesellschaft* 78: 317–323.

Frieß T, Rabitsch W (2009) *Checkliste und Rote Liste der Wanzen Kärntens (Insecta: Heteroptera)*. Carinthia II 199/119, in press.

Geiter O, Homma S, Kinzelbach R (2002) *Bestandsaufnahme und Bewertung von Neozoen in Deutschland*. Berlin: Umweltbundesamt 25: 1–173.

Gessé F, Ribes J, Goula M (2009) *Belonochilus numenius*, the sycamore seed bug, new record for the Iberian fauna. *Bulletin of Insectology* 62: 121–123.

Göricke P (2008) Zum Auftreten von *Arocatus longiceps* Stål, 1872 (Lygaeidae) und Vorkommen von *Cephalocteus scarabaeoides* (Fabricius, 1803) (Cydnidae) an der Atlantikküste Portugal. *Heteropteron* 28: 27.

Halstead AJ, Malumphy CP (2003) Outbreak in Britain of *Stephanitis takeyai* Drake & Mao (Hemiptera: Tingidae), a pest of *Pieris japonica*. *The British Journal of Entomology and Natural History* 16: 3–6.

Heiss E, Péricart J (2007) *Hemiptères Aradidae Piesmatidae et Dipsocoromorphes euro-méditerranéens. Faune de France 91.* Paris: Fédération Française des Sociétés de Sciences Naturelles. 509 pp.

Henry TJ (1997) Phylogenetic analysis of family groups within the infraorder Pentatomomorpha (Hemiptera: Heteroptera), with emphasis on the Lygaeoidea. *Annals of the Entomological Society of America* 90: 275–301.

Henry TJ (2009) *Biodiversity of Heteroptera*. In Foottit RG, Adler PH (Eds) Insect Biodiversity: Science and Society. Chichester, UK: Wiley-Blackwell, 223–263.

Hoffmann HJ (2003) Neozoen bei Wanzen. *Heteropteron* 16: 25–28.

Hoffmann HJ (2008) On Plane trees, not only *Arocatus longiceps* (Lygaeidae) but also *Arocatus roeselii*? *HetNews* 12: 4–6.

Hollier J, Matocq A (2004) *Dicyphus escalerae* Lindberg, 1934 (Hemiptera: Miridae), a plant-bug species new for Switzerland. *Mitteilungen der Schweizerischen Entomologischen Gesellschaft* 77: 333–335.

Hradil K (2008) *Leptoglossus occidentalis* (Heteroptera: Coreidae) a new alien species in Montenegro. *Acta entomologica serbica* 13: 77–79.

Hradil K, Kapitola P, Jindra Z, Kment P (2002) Faunistic records from the Czech Republic – 146. *Klapalekiana* 38: 113–114.

Hradil K, Kment P, Bryja J, Roháčová M, Baňař P, Ďurčová K (2008) New and interesting records of true bugs (Heteroptera) from the Czech Republic and Slovakia IV. *Klapalekiana* 44: 165–206.

Ishikawa T, Kikuhara Y (2009) *Leptoglossus occidentalis* Heidemann (Hemiptera: Coreidae), a presumable recent invader to Japan. *Japanese Journal of Entomology* 12: 115–116.

Jindra Z, Kment P (2006) Faunistic records from the Czech Republic – 212. *Klapalekiana* 42: 333–334.

Kenis M (2005) Insects-Insecta. In: Wittenberg R (Ed) *An inventory of alien species and their threat to biodiversity and economy in Switzerland*. Delémont: CABI Bioscience Switzerland, 131–212.

Kerzhner IM, Josifov M (1999) *Miridae Hahn, 1831*. In: Aukema B, Rieger C (Eds) Catalogue of the Heteroptera of the Palaearctic Region. Vol. 3. The Netherlands Entomological Society, Amsterdam, 577 pp.

Kirby P (1999) *Buchananiella continua* (B. White) (Hemiptera: Anthocoridae) established in Britain. *British Journal of Entomology and Natural History* 12: 221–223.

Kirby P, Stewart A, Wilson M (2001) True bugs, leaf- and planthoppers, and their allies. In: Hawksworth, DL (Ed) *The changing wildlife of Great Britain and Ireland*. London: Taylor & Francis, 262–299.

Kirby P, Bantock T, Nau B (2009) *Dicyphus escalerae* Lindberg, 1934. *HetNews* 13: 7–8.

Kivan M (2004) Some observations on *Perillus bioculatus* (F.) (Heteroptera: Pentatomidae) a new record for the entomofauna of Turkey. *Turkish Journal of Entomology* 28: 95–98.

Kment P (2006a) A contribution to the faunistics of aquatic and semiaquatic bugs (Heteroptera: Nepomorpha, Gerromorpha) in Portugal, with the review of biology of the Nearctic corixid *Trichocorixa verticalis* (Fieber, 1851). *Boletín Sociedad Entomológica Aragonesa* 38: 359–361.

Kment P (2006b) Heteroptera – Plostice. In: Mlíkovský J, Stýblo P (Eds) *Nepuvodní druhy fauny a flory Ceske Republiky.* Praha: Èeský svaz ochráncù pøírody, 255–266.

Kment P (2007) First record of the alien lace bug *Stephanitis pyrioides* in Greece and note on *Corythucha ciliata* in Portugal (Heteroptera: Tingidae). *Linzer Biologische Beiträge* 39: 421–429.

Kment P (2009) *Oxycarenus lavaterae*, an expansive species new to Romania (Hemiptera: Heteroptera: Oxycarenidae). *Acta Musei Moraviae, Scientiae biologicae* 94: 23–25. 55. Kment P, Baňar P (2008) Additional records of the invasive nearctic bug *Leptoglossus occidentalis* (Heteroptera: Coreidae) in Croatia. *Natura Croatica* 17: 141–147.

Kment P, Bryja J, Hradil K, Jindra Z (2005) New and interesting records of true bugs (Heteroptera) from the Czech Republic and Slovakia III. *Klapalekiana* 41: 157–213.

Kment P, Vahala O, Hradil K (2006) First records of *Oxycarenus lavaterae* (Heteroptera: Oxycarenidae) from the CZ, with review of its distribution and biology. *Klapalekiana* 42: 97–127.

Kondorosy E (1997) Other species of Heteroptera, new for fauna of Hungary. *Folia Entomologica Hungarica* 58: 249–251.

Kondorosy E (2005) New true bug species in the Hungarian fauna. *Folia Entomologica Hungarica* 66: 17–22.

Kowarik I (1995) Time lags in biological invasions with regard to the success and failure of alien species. In: Pyšek P, Prach K, Rejmánek M, Wade PM (Eds) *Plant invasions – general aspects and special problems*. Amsterdam: SPB Academic Publishers, 15–38.

Lattin JD (1999) Bionomics of the Anthocoridae. *Annual Review of Entomology* 44: 207–231.

Lindskog P, Viklund B (2000) On *Deraeocoris lutescens* (Schilling) and *Pinalitus atomarius* (Meyer-Dür) in SE (Heteroptera: Miridae). *Entomologica Fennica* 11: 231–238.

Lis JA, Lis B, Gubernator J (2008) Will the invasive western conifer seed bug *Leptoglossus occidentalis* Heidemann (Hemiptera: Heteroptera: Coreidae) seize all of Europe? *Zootaxa* 1740: 66–68.

Malumphy C, Reid S (2007) Non-native Heteroptera associated with imported plant material in England during 2006 & 2007. *HetNews* 10: 2–3.

Malumphy C, Reid S (2008) First interception of *Natalicola pallidus* (Westwood) (Tessaratomidae) in the UK. *HetNews* 12: 9.

Malumphy C, Botting J, Bantock T, Reid S (2008) Influx of *Leptoglossus occidentalis* Heidemann (Coreidae) in England. *HetNews* 12: 7–9.

Matocq A (2008) Présence en France et en Corse d'un Hétéroptère néarctique, *Belonochilus numenius* (Say, 1831) (Hemiptera, Lygaeidae, Orsillinae). *Bulletin de la Société entomologique de France* 113: 533–534.

Millán A, Hernando C, Aguileira P, Castro A, Ribera I (2005) Los coleópteros acuáticos y semiacuáticos de Donana: Reconocimiento de su biodiversidad y prioridades de conservación. *Boletín Sociedad Entomológica Aragonesa* 36: 157–164.

Nau BS (1980) *Tuponia carayoni* Wagner (Hem., Miridae) new to Britain. *Entomologist's Monthly Magazine* 116: 83–84.

Nau BS (2007) „Unknown" orthotyline on Wellingtonia in Oxford. *HetNews* 9: 9.

Nau BS, Straw N (2007) *Arocatus roeselii* established in Britain? *HetNews* 9: 8.

Ødegaard F, Endrestøl A. (2007) Establishment and range expansion of some new Heteroptera (Hemiptera) in Norway. *Norwegian Journal of Entomology* 54: 117–124.

Péricart J (1965) Contribution à la faunistique de la Corse: hétéroptères Miridae et Anthocoridae. *Bulletin Mensuel de la Société Linnéenne de Lyon* 34: 377–384.

Péricart J (1972) *Hémiptères Anthocoridae, Cimicidae, Microphysidae de l'Ouest Paléarctique*. Faune de l'Europe et du bassin méditerranéen. Paris: Masson. 403 pp.

Péricart J (1996) Anthocoridae Fieber, 1836. In: Aukema B, Rieger C (Eds) *Catalogue of the Heteroptera of the Palaearctic Region. Vol. 2.* Amsterdam: The Netherlands Entomological Society, 108–140.

Péricart J, Stehlík JL (1998) *Amphiareus obscuriceps* (Popp.) in the Czech Republic and in the Balkan Peninsula (Heteroptera: Anthocoridae). *Acta Musei Moraviae, Scientiae biologicae* 83: 217–218.

Protić L (2008) *Leptoglossus occidentalis* Heidemann (Heteroptera: Coreidae) in Serbia. *Acta entomologica serbica* 13: 81–84.

Putshkov PV, Putshkov VG (1996) Reduviidae Latreille, 1807. In Aukema B, Rieger C (Eds) *Catalogue of the Heteroptera of the Palaearctic Region. Vol. 2.* Amsterdam: The Netherlands Entomological Society, 148–266.

Rabitsch W (2002) Die Arten der Gattung Tuponia (Heteroptera: Miridae) im östlichen Österreich. *Beiträge zur Entomofaunistik* 3: 97–102.

Rabitsch W (2008) Alien True Bugs of Europe (Insecta: Hemiptera: Heteroptera). *Zootaxa* 1827: 1–44.

Rabitsch W, Adlbauer K (2001) Erstnachweis und bekannte Verbreitung von *Oxycarenus lavaterae* (Fabricius, 1787) in Österreich (Heteroptera: Lygaeidae). *Beiträge zur Entomofaunistik* 2: 49–54.

Rédei D, Torma A (2003) Occurrence of the Southern Green Stink Bug, *Nezara viridula* (Heteroptera: Pentatomidae) in Hungary. *Acta Phytopathologica et Entomologica Hungarica* 38: 365–367.

Ribes J, Pagola-Carte S (2008) *Arocatus longiceps* Stal, 1872, primera cita para la península Ibérica (Hemiptera: Heteroptera: Lygaeidae). *Boletín Sociedad Entomológica Aragonesa* 42: 353–354.

Rodríguez-Pérez H, Florencio M, Gómez-Rodríguez C, Green AJ, Díaz-Paniagua C, Serrano L (2009) Monitoring the invasion of the aquatic bug *Trichocorixa verticalis verticalis* (Hemiptera: Corixidae) in the wetlands of Doñana National Park (SW Spain). *Hydrobiologia* 634: 209–217.

Roques A, Auger-Rozenberg MA (2006) Tentative analysis of the interceptions of non-indigenous organisms in Europe during 1995–2004. *EPPO Bulletin* 36: 490–496.

Roques A, Rabitsch W, Lopez-Vaamonde C, Nentwig W, Kenis M (2008) Alien terrestrial invertebrates of Europe. In: DAISIE (Ed) *The Handbook of Alien Species in Europe*. Dordrecht: Springer, 63–79.

Ruicănescu A (2009) *Leptoglossus occidentalis* Heidemann, 1910 (Heteroptera: Coreidae) in România. In Rákosy L, Momeu L (Eds) *Neobiota din Romania*. Cluj: Presa Universitară Clujeană, 153–154.

Sala J, Boix D (2005) Presence of the nearctic water boatman *Trichocorixa verticalis verticalis* (Fieber, 1851) (Heteroptera: Corixidae) in the Algarve region (South Portugal). *Graellsia* 61: 31–36.

Schaefer CW, Panizzi AR (2000) *Heteroptera of Economic Importance*. Boca Raton, Florida: CRC Press. 828 pp.

Schuh RT, Slater JA (1995) *True bugs of the World (Hemiptera: Heteroptera)*. Ithaca: Cornell University Press. 336 pp.

Šefrová H, Laštùvka Z (2005) Catalogue of alien animal species in the Czech Republic. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis* 53: 151–170.

Servadei A (1966) Un Tingide nearctico comparso in Italia (*Corythucha ciliata* Say). *Bollettino della Societa Entomologica Italiana* 96: 94–96.

Simon H (1995) Nachweis von *Dicyphus escalerai* <sic> Lindberg, 1934 (Heteroptera: Miridae) in Mitteleuropa. *Fauna und Flora Rheinland-Pfalz* 8: 53–63.

Simon H (2007) 1. Nachtrag zum Verzeichnis der Wanzen in Rheinland-Pfalz (Insecta: Heteroptera). *Fauna und Flora Rheinland-Pfalz* 11: 109–135.

Simov N (2008) Western conifer seed bug *Leptoglossus occidentalis* Heidemann, 1910 (Heteroptera: Coreidae) already in Bulgaria. *Historia naturalis Bulgarica* 19: 179–180.

Simov N, Pencheva A (2007) *Stephanitis rhododendri* Horváth, 1905 (Heteroptera: Tingidae) – a new American pest on rhododendrons in Bulgaria. *Plant Science (Sofia)* 43: 483–485.

Smit JT, Reemer M, Aukema B (2007) Een invasie van de nieuw-zeelandse tarwewants *Nysius huttoni* in Nederland (Heteroptera: Lygaeidae). *Nederlandse Faunistische Mededelingen* 27: 51–70.

Stehlík JL (1997) *Corythucha ciliata* (Say), a pest of plane trees, now also in the Czech Republic (Tingidae, Het.). *Acta Musei Moraviae, Scientiae Natural*es 81: 299–306.

Streito JC (2006) Note sur quelques espèces envahissantes de Tingidae: *Corythucha ciliata* (Say, 1832), *Stephanitis pyrioides* (Scott, 1874) et *Stephanitis takeyai* Drake & Maa, 1955 (Hemiptera Tingidae). *L'Entomologiste* 62: 31–36.

Sweet MH (2000) Seed and Chinch Bugs (Lygaeoidea). In: Schaefer CW, Panizzi AR (Eds) *Heteroptera of Economic Importance*. Boca Raton, Florida: CRC Press, pp. 143–264.

Takács S, Bottomley H, Andreller I, Zaradnik T, Schwarz J, Bennett R, Strong W, Gries G (2009) Infrared radiation from hot cones on cool conifers attracts seed-feeding insects. *Proceedings Royal Society London B* 276: 649–655.

Velimirovic V, Durovic Z, Raicevic M (1992) Bug *Oxycarenus lavaterae* Fabricius (Lygaeidae, Heteroptera) new pest on lindens in southern part of Montenegro. *Zastita Bilja* 43: 69–72.

Voigt K (1977) Bemerkenswerte Wanzenfunde aus Baden-Württemberg, mit einem Erstnachweis für Deutschland. *Beiträge zur naturkundlichen Forschung in Südwestdeutschland* 36: 153–158.

Wermelinger B, Wyniger D, Forster B (2005) Massenauftreten und erster Nachweis von *Oxycarenus lavaterae* (F.) (Heteroptera, Lygaeidae) auf der Schweizer Alpennordseite. *Mitteilungen der Schweizerischen Entomologischen Gesellschaft* 78: 311–316.

Wermelinger B, Wyniger D, Forster B (2008) First records of an invasive bug in Europe: *Halyomorpha halys* Stål (Heteroptera: Pentatomidae), a new pest on woody ornamentals and fruit trees? *Mitteilungen der Schweizer Entomologischen Gesellschaft* 81: 1–8.

Werner DJ (2005) *Nezara viridula* (Linnaeus, 1758) in Köln und in Deutschland (Heteroptera, Pentatomidae). *Heteropteron* 21: 29–31.

Wheeler AG (2001) *Biology of the Plant Bugs (Hemiptera: Miridae). Pests, Predators, Opportunists*. Ithaca: Cornell University Press. 506 pp.

Table 9.1.1. List and main characteristics of Heteroptera species alien *to* Europe. Status: **A** Alien *to* Europe **C** cryptogenic species. For details see Rabitsch (2008). ? = occurrence doubtful, * = probably not established. New data since Rabitsch (2008) are given in bold. Country codes abbreviations refer to ISO 3166 (see appendix I). Habitat abbreviations refer to EUNIS (see appendix II). Only selected references are given. Last update May 2009.

Family *Species*	**Status**	**Feeding Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**Refs**
Anthocoridae								
Amphiareus obscuriceps (Poppius, 1909)	A	Zoo-phagous	East Palaearctic	1987, BG	AT, BE, BG, BY, CZ, DE, EE, FI, HU, IT, NL, SK	E, I	–	Aukema (2007), Aukema et al. (2005a), Hradil et al. (2008), Péricart and Stehlík (1998)
***Amphiareus constrictus* (Stål, 1860)**	C	Zoo-phagous	Cosmopolitan	2007, NL	**NL**	E	–	Aukema and Hermes (2009)
Buchananiella continua (White, 1880)	C	Zoo-phagous	Pantropical	1880, PT-MAD	**BE,** ES, ES-CAN, FR, GB, IT, **NL,** PT, PT-AZO, PT-MAD	I, X	–	Aukema and Hermes (2009), Aukema et al. (2009b), Kirby (1999)
Lyctocoris campestris (Fabricius, 1794)	C	Zoo-phagous	West Palaearctic? Cosmopolitan	?	AL, AT, BA, BE, BG, BY, CH, CZ, DE, DK, EE, ES, ES-CAN, FI, FR, GB, GR, HR, HU, IE, IT, IT-SAR, IT-SIC, LT, LU, LV, MD, ME, MK, MT, NL, NO, PL, PT, PT-AZO, PT-MAD, RS, SE, SI, SK, UA	I	–	Péricart (1972)
Coreidae								
Leptoglossus occidentalis Heidemann, 1910	A	Phyto-phagous	North America	1999, IT	AT, BE, **BG,** CH, CZ, DE, ES, FR, GB, **GR** , HR, HU, IT, **ME, NL,** PL, **RO,** RS, SI, SK	G, I, X	Pinaceae (*Pinus*, *Pseudotsuga*, *Picea*, *Abies*), Cupressaceae (*Libocedrus*)	Aukema (2008), Bernardinelli and Zandigiacomo (2001), Dusoulier et al. (2007), Hradil (2008), Kment et al. (2005), Malumphy et al. (2008), Protić (2008), Ruicănescu (2009)

Family *Species*	Status	Feeding Regime	Native range	1st record in Europe	Invaded countries	Habitat	Hosts	Refs
Corixidae								
Trichocorixa verticalis (Fieber, 1851)	A	Omnivorous	North America	1997, PT	ES, PT	C	–	Kment (2006a), Sala and Boix (2005)
Lygaeidae								
Nysius huttoni F.B.White, 1878	A	Phytophagous	New Zealand	2002, NL	BE, FR, **GB,** NL	I	Poaceae, Brassicaceae and others (polyphagous)	Aukema et al. (2005b), Cuming (2008)
***Belonochilus numenius* (Say, 1831)**	A	Phytophagous	North America	2008, FR	**ES, FR, FR-COR**	I	Platanaceae (*Platanus*)	Gessé et al. (2009), Matocq (2008)
Miridae								
***Fulvius borgesi* Chérot, J. Ribes & Gorczyca, 2006**	A	Zoophytophagous?	South America	2003, PT-AZO	**PT-AZO**	I	–	Chérot et al. (2006)
Nesidiocoris tenuis (Reuter, 1895)	C	Zoophytophagous	Pantropical	?	CY, ES, ES-CAN, FR, GR, GR-CRE, IT, MT, PT-MAD	I	–	Kerzhner and Josifov (1999)
Taylorilygus apicalis (Fieber, 1861)	C	Phytophagous	Pantropical	?	AL, BA, BG, CY, ES, ES-CAN, FR, FR-COR, GR, HR, IT, IT-SAR, IT-SIC, MT, PT, PT-AZO, PT-MAD, SI, UA	I	Asteraceae and others (polyphagous)	Kerzhner and Josifov (1999)
***Tropidosteptes pacificus* Van Duzee, 1921**	A	Phytophagous	North America	2007, NL	**NL**	G	Oleaceae (*Fraxinus excelsior*)	Aukema et al. (2009a)
Tupiocoris rhododendri (Dolling, 1972)	A	Zoophagous	North America	1971, GB	BE, DE, GB, NL	I, X	Ericaceae (*Rhododendron*)	Aukema et al. (2005a), Aukema et al. (2007), Dolling (1972)

Family *Species*	Status	Feeding Regime	Native range	1st record in Europe	Invaded countries	Habitat	Hosts	Refs
Pentatomidae								
Halyomorpha halys (Stål, 1855)	A	Phyto-phagous	East Asia	2007, CH	CH	I, X	fruit trees and ornamentals (polyphagous)	Wermelinger et al. (2008)
Perillus bioculatus (Fabricius, 1775)	A	Zoo-phagous	North America	1992, TU	GR, TU	G, I	–	Kivan (2004)
Reduviidae								
Empicoris rubromaculatus (Blackburn, 1889)	C	Zoo-phagous	Pantropical	?	**BE,** ES, ES-CAN, FR, FR-COR, **GR,** HR, IT, PT, PT-AZO, PT-MAD	I	–	Aukema et al. (2009b)
Ploiaria chilensis (Philippi, 1862)	C	Zoo-phagous	Pantropical	?	?CY, ES, ES-CAN, ?IT, PT-AZO, PT-MAD	I	–	Putshkov and Putshkov (1996)
Saldidae								
Pentacora sphacelata (Uhler, 1877)	A	Zoo-phagous	North America	1953, ES	ES, IT, PT	B	–	Carapezza (1980)
Tingidae								
Corythucha arcuata (Say, 1832)	A	Phyto-phagous	North America	2000, IT	CH, IT	G	Fagaceae (*Quercus*, *Castanea*)	Dioli et al. (2007), Forster et al. (2005)
Corythucha ciliata (Say, 1832)	A	Phyto-phagous	North America	1964, IT	AT, BE, BG, CH, CZ, DE, ES, FR, GB, GR, HR, HU, IT, ME, **NL,** PT, RS, SK, SI	I, X	Platanaceae (*Platanus*)	Aukema and Hermes (2009), Kment (2007), Servadei (1966), Stehlík (1997), Streito (2006)
Stephanitis pyrioides (Scott, 1874)	A	Phyto-phagous	Japan	1904, NL	CH, *FR, GR, IT, NL	I, X	Ericaceae (*Rhododendron*)	Kment (2007), Streito (2006)
Stephanitis rhododendri Horváth, 1905	A	Phyto-phagous	North America	<1900, NL	*BE, BG, CH, CZ, DE, DK, *FI (J100), *FR, GB, NL, *PL, SE	I, X	Ericaceae (*Rhododendron*)	Halstead and Malumphy (2003), Jindra and Kment (2006), Simov and Pencheva (2007)
Stephanitis takeyai Drake & Maa, 1955	A	Phyto-phagous	Japan	1994, NL	BE, **CZ**, DE, FR, GB, IT, NL, PL	I, X	Ericaceae (*Pieris*, *Rhododendron*)	Aukema (1996), Halstead and Malumphy (2003), Ishikawa and Kikuhara (2009), Streito (2006)

Table 9.1.2. List and characteristics of the Heteroptera species alien *in* Europe. For details see Rabitsch (2008). ?N = Alien status doubtful (species could be native), ? = occurrence doubtful, * = probably not established. New data since Rabitsch (2008) are given in bold. Country codes abbreviations refer to ISO 3166 (see appendix I). Habitat abbreviations refer to EUNIS (see appendix II). Only selected references are given. Last update May 2009.

Family *Species*	**Feeding Regime**	**Native range**	**1st record in invaded areas**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Anthocoridae							
Anthocoris butleri Le Quesne, 1954	Zoophagous	Southwest Europe	1962, CZ	AT, BE, CH (?N), CZ, DE (?N), IE, LU, NL, SE (Gotland), SK	I, X	Buxaceae (*Buxus*)	Kment et al. (2006)
Anthocoris sarothamni Douglas & Scott, 1865	Zoophagous	West Mediterranean	1953, CZ	*AT, CZ	I, X	Fabaceae (*Cytisus*)	Kment (2006b)
***Orius laevigatus* (Fieber, 1860)**	Zoophagous	Southwest Europe	2005, NL	**NL**	I	–	Aukema and Loomans (2005)
Lygaeidae							
Arocatus longiceps Stål, 1872	Phytophagous	East Mediterranean	1990, HU	AT, BE, CH, CZ, DE, **ES,** FR (N?), **GB,** HU, NL, **PT,** SI (?N), SK	I, X	Platanaceae (*Platanus*)	Göricke (2008), Kondorosy (1997), Nau and Straw (2007), Ribes and Pagola-Carte (2008)
Orsillus depressus (Mulsant & Rey, 1852)	Phytophagous	Mediterranean	1971, DE	AT (?N), BE, CZ, DE, *FI, GB, HU (?N), LU, NL, SK	E, I, X	Cupressaceae	Hradil et al. (2002), Voigt (1977)
Oxycarenus lavaterae (Fabricius, 1787)	Phytophagous	West Mediterranean	1985, ME	AT, BG, CH (north), CZ, DE, *FI, FR(north), HU, ME, ***NL**, **RO,** RS, **SI,** SK	G, I, X	Malvaceae (*Tilia*)	Hradil et al. (2008), Kment (2009), Kondorosy (1997), Rabitsch and Adlbauer (2001), Velimirovic et al. (1992), Wermelinger et al. (2005)
Miridae							
Closterotomus trivialis (A. Costa, 1853)	Phytophagous	Mediterranean	1998, NL	NL	I	Weeds, olive trees, Citrus (polyphagous)	Aukema (1999), Aukema and Hermes (2009)
***Deraeocoris lutescens* (Schilling, 1837)**	Zoophagous	West Palaearctic	1990, NO	**NO, SE**	I, X	Malvaceae (*Tilia*)	Lindskog and Viklund (2000), Ødegaard and Endrestøl (2007)

Family *Species*	**Feeding Regime**	**Native range**	**1st record in invaded areas**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Deraeocoris flavilinea (A. Costa, 1862)	Zoophagous	Mediterranean	1961, FR-COR	AL, AT, BE, CH, CZ, DE, FR (Alsace), FR-COR, GB, LU, MT, NL, SE, SI	I, X	Many trees and shrubs	Kment et al. (2006), Péricart (1965)
Dichrooscytus gustavi Josifov, 1981	Phytophagous	European – Cryptogenic	1934, DE	AT, BE, CZ, DE, FI, FR, GB, HU, ?IT, LU, NL, SK	I	Cupressaceae	Bryja and Kment (2002), Hradil et al. (2008)
Dicyphus escalerae Lindberg, 1934	Phytophagous	West Mediterranean	1994, DE	CH, DE, **GB**	I	Veronicaceae (*Antirrhinum majus*)	Hollier and Matocq (2004), Kirby et al. (2009), Servadei (1966)
Macrolophus glaucescens Fieber, 1858	Zoophagous	Mediterranean	<1858, CZ	CZ	E	Asteraceae (*Echinops*)	Kment (2006b)
Orthotylus adenocarpi (Perris, 1857)	Zoophytophagous	West Mediterranean	<1892?, CZ	CZ (?N)	E, G, I	Fabaceae (*Cytisus*)	Kment (2006b)
Orthotylus caprai Wagner, 1955	Zoophytophagous	Mediterranean	2006, GB	DE, GB	I	Cupressaceae	Nau (2007), Simon (2007)
Orthotylus concolor (Kirschbaum, 1856)	Zoophytophagous	West Mediterranean	<1892?, CZ	***AT,** CZ (?N)	E, G, I	Fabaceae (*Cytisus*)	Frieß and Rabitsch (2009), Kment (2006b)
Orthotylus virescens (Douglas & Scott, 1865)	Zoophytophagous	West Mediterranean	2003, HU	CZ (?N), HU	E, G, I	Fabaceae (*Cytisus*)	Kment (2006b), Kondorosy (2005)
Tuponia brevirostris Reuter, 1883	Phytophagous	West Mediterranean	2001, GB	DE, GB, **GR (?N)**, HR	I, X	Tamaricaceae (*Tamarix*)	Barclay and Nau (2003), Simon (2007)
Tuponia elegans (Jakovlev, 1867)	Phytophagous	Central Asia	1964, HU	AT, CZ, HU, SK	I, X	Tamaricaceae (*Tamarix*)	Benedek and Jászai (1968), Bryja and Kment (2002), Hradil et al. (2008), Rabitsch (2002)
Tuponia hippophaes (Fieber, 1861)	Phytophagous	Mediterranean	<1982, SK	CZ, BE, SK	I, X	Tamaricaceae (*Tamarix*)	Bryja and Kment (2002), Hradil et al. (2008)
Tuponia macedonica Wagner, 1957	Phytophagous	East Mediterranean	2003, SK	SK	I, X	Tamaricaceae (*Tamarix*)	Hradil et al. (2008)

Family *Species*	**Feeding Regime**	**Native range**	**1st record in invaded areas**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Tuponia mixticolor (A. Costa, 1862)	Phyto-phagous	Mediterranean-Central Asia	1979, GB	DE, GB, SI (?N)	I, X	Tamaricaceae (*Tamarix*)	Nau (1980), Simon (2007)
Pentatomidae							
Nezara viridula (Linnaeus, 1758)	Phyto-phagous	Mediterranean and/or Africa	1979, DE	*AT, *BE, BG (?N), CH (north), DE, *FI, GB, HU, *UA	I, X	Fabaceae, cultivated and uncultivated plants (polyphagous)	Barclay (2004), Rédei and Torma (2003), Wheeler (2001)
Tingidae							
Dictyonota fuliginosa A. Costa, 1853	Phyto-phagous	West Mediterranean	1954, CZ	CZ	E, G, I	Fabaceae (*Cytisus*)	Kment (2006b)
Elasmotropis testacea (Herrich-Schäffer, 1830)	Phyto-phagous	Palaearctic	<1844, CZ	CZ, DE (?N), ?PL	E, I	Asteraceae (*Echinops*)	Kment (2006b)
Stephanitis oberti (Kolenati, 1857)	Phyto-phagous	North Palaearctic	<1906?, DE	*AT, BE (?N), CZ (?N), DE (?N), NL (?N)	I, X	Ericaceae (*Rhodo-dendron*, *Vaccinium*)	Bruers and Viskens (1999)

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Aphids (Hemiptera, Aphididae)
Chapter 9.2

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Abstract

Our study aimed at providing a comprehensive list of Aphididae alien *to* Europe. A total of 98 species originating from other continents have established so far in Europe, to which we add 4 cosmopolitan species of uncertain origin (cryptogenic). The 102 alien species of Aphididae established in Europe belong to 12 different subfamilies, five of them contributing by more than 5 species to the alien fauna. Most alien aphids originate from temperate regions of the world. There was no significant variation in the geographic origin of the alien aphids over time. The average introduction rate was 0.5 species per year since 1800. The mean number of newly recorded species per year decreased since 2000 but this pattern may change in the following years.

Keywords

alien, Hemiptera, Aphid, Aphididae, Europe

9.2.1. Introduction

About 4700 species of Aphididae have been described worldwide (Remaudière and Remaudière 1997). About one third of these species are present in Europe. As for many other taxonomic groups, very few checklists of alien Aphididae have been available for Europe until recently. In 2002, Geiter et al. (2002) published a list of 131 species

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considered non-indigenous in Germany and Nobanis (2005) listed 34 species of non-native Aphididae in its geographic area in 2005. Lampel and Gonseth (2005) listed 37 species alien to Switzerland in 2005 whilst Rabitsch and Essl (2006) listed 40 alien aphid species from Austria in 2006. The differences in the number of species considered non-indigenous clearly reflect differences in the composition of the fauna of each country, but also reflect differences in the definition of 'alien'. Lampel and Gonseth (2005) considered only species of non-European origin whereas Geiter et al. (2002) included all species considered non-native to Germany.

The goal of this work is to provide a first comprehensive list of Aphididae alien *to* Europe. Aphid species originating from one European country and introduced into another, i.e. species alien *in* Europe such as *Diuraphis noxia* (Kurdjumov, 1913) and *Brachycorynella asparagi* (Mordvilko, 1929), will not be considered in this work. These species may have an invasive status in the area where they were introduced but it appeared difficult to disentangle human- mediated introductions from natural expansion.

To define the species present in Europe, we used the list of European Aphididae elaborated by Nieto Nafria for Fauna Europaea (Nieto Nafria et al. 2007). We compiled information about each species from published sources and experts to define their origin, i.e. European vs non-European. Among the references consulted, the lists cited above and the three comprehensive books by Blackman & Eastop (Blackman and Eastop 1994, 2000, 2006) proved to be particularly useful. Once a first list of alien aphids had been defined, we sought additional information, such as the date of first occurrence in Europe. June 2008 was the cut-off date for our literature survey. All the information collected for the 102 species considered is provided in Table 9.2.1.

9.2.2. Taxonomy of alien species

The delineation of the taxa included under the family name Aphididae has varied over the last 50 years. Here, we use Aphididae *sensu* Eastop and Hille Ris Lambers (1976) and Remaudière and Remaudière (1997). Therefore, we did not consider Adelgidae and Phylloxeridae in this chapter. Taxonomy and nomenclature are as described by Remaudière and Remaudière (1997), Nieto Nafria et al. (1998), Quednau (1999, 2003), and Eastop and Blackman (2005). Some of the names cited in published studies could not be clearly attributed to a currently valid taxon and were therefore excluded.

A total of 98 species present in Europe but originating from another continent have been listed to date, to which we can add four cosmopolitan species of uncertain origin (cryptogenic) (Table 9.2.1). For comparison, the European aphid fauna currently includes 1,373 species (Nieto Nafria et al. 2007), meaning that 7.4 % of the European aphid fauna is of alien origin.

The 102 alien species of Aphididae established in Europe belong to 12 different subfamilies, most of which are already represented among the native entomofauna (Figure 9.2.1). However, three subfamilies (Greenideinae, Lizerinae and Neophyllaphidinae) were not known in Europe before introductions. Each of these three subfamilies is represented by a single species. *Greenidea ficicola* is a member of the Greenideinae subfamily widespread in eastern regions and living on several species of *Ficus.* It was introduced into Italy in 2004 and seems to be widespread in Southern Europe (Italy, Spain and Malta) (Barbagallo et al. 2005a, Mifsud 1998). *Paoliella eastopi*, a species belonging to the Lizerinae described from Kenya, has only been found in one European country, England. All *Paoliella* species are of African origin. *Neophyllaphis podocarpi*, the only Neophyllaphidinae species known in Europe, originates from Asia and was recorded on *Podocarpus* in Italy in 1990 (Limonta 1990) but appears to have spread. Five subfamilies contribute more than five species to the alien fauna (Figure 9.2.1). The subfamily Aphidinae predominates, accounting for 59% of the alien Aphididae, followed by Calaphidinae (16%), Lachninae (5.8%), Eriosomatinae (4.8%) and Chaitophorinae (4.8%). These five subfamilies are also the most species-rich in native species. Each of the other seven subfamilies accounts for less than 1% of the alien Aphididae (Figure 9.2.1). The Hormaphidinae is the only subfamily represented by more alien than native species (4 species vs 1).

The taxonomic composition of the alien entomofauna is highly diverse at genus level. The 102 alien species belong to 58 different genera (Table 9.2.1). Thirty-two (55%) of these genera are represented in Europe by only non-native species and 40 (69%) contribute only one species to the alien fauna. The genus *Aphis* is the most represented, with eight species. This is not surprising, given that this genus contains more than 10% of the world's Aphididae and is abundant in all biogeographical regions of the world. This is not the case for another two species-rich genera, the North American *Illinoia* (seven alien species *in* Europe and 54 species worldwide) and the Asian *Tinocallis* (six alien species *in* Europe and 25 species worldwide). Although the genus *Cinara* is the second most species-rich genus in the world, with 222 species worldwide, three quarters of which being of non-European origin, surprisingly only three alien species from this genus are present in Europe

9.2.3. Temporal trends

The date of the first record in Europe is known, with various degrees of precision, for 94 of the 102 alien aphid species (Table 9.2.1). The precise date of arrival is unknown for most species because their introduction was unintentional (see below 9.2.5) and large delays may occur between the date of introduction and the date of reporting. However, in certain cases, introduction is relatively well documented, available data suggesting that the date of the first report was close to the date of introduction. This is the case for recent introductions, such as the species detected and monitored by the permanent aerial suction-trap network "Euraphid". This system of aphid flight surveys, based on a 12.2 m.-high suction trap, was developed by the Rothamsted Experimental Station in the 1960s (Taylor and Palmer 1972). This device is now used in several European countries, as part of integrated control networks, and has also proved useful for studies of the long-range dispersal of alates and for the regular detection of

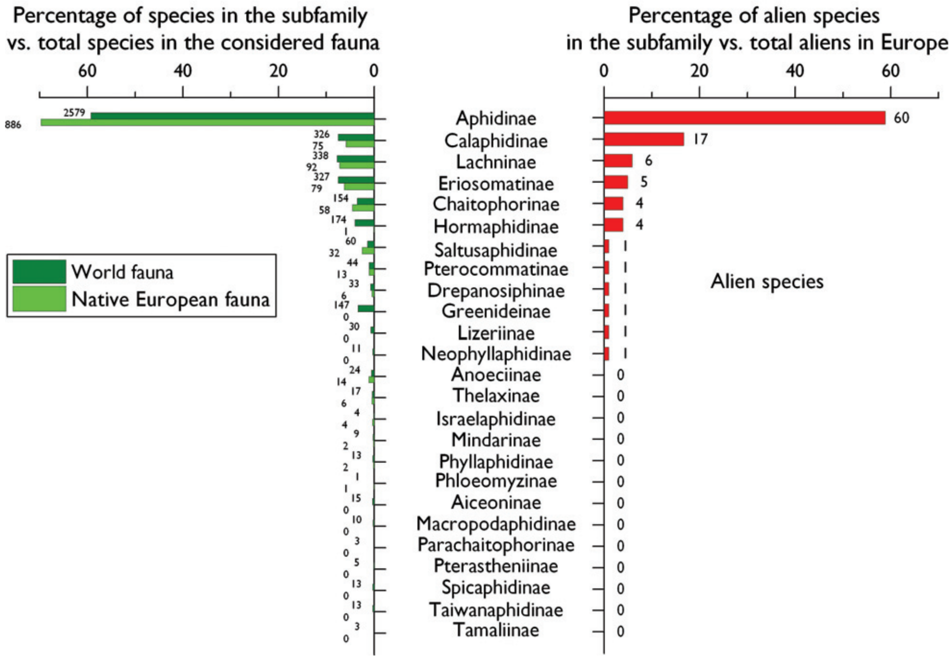

Figure 9.2.1. Taxonomic overview of the aphid species alien to Europe compared to the native European fauna and the world fauna. Subfamilies are presented in a decreasing order based on the number of alien species. Species alien *to* Europe include cryptogenic species. Data about native European aphids from Fauna europaea (Nieto Nafria et al. 2007); world data from Remaudière and Remaudière (1997). The number over each bar indicates the number of species observed per subfamily.

aphid species new to the national or European fauna (Hullé et al. 1998). In France, a network of five such traps spread over the territory has been monitoring the aphid species trapped since 1978. This system detected four species new to Europe between 1984 and 1988 (Hullé et al. 1998): *Essigella californica* (Turpeau and Remaudière 1990), *Klimaszewskia salviae* (Leclant and Remaudière 1986), *Myzocallis walshii* (Remaudière 1989), and *Tinocallis takachihoensis* (Leclant and Remaudière 1986), and has monitored the extension of their geographical range in France. In a very small number of cases, more ancient introductions have also been documented, generally for important pest species. For example, the occurrence of *Eriosoma lanigerum*, a pest of apple trees originating from North America, was noted for the first time in a nursery in the outskirts of London in 1787 (Balachowsky and Mesnil 1935). The species was described by Hausmann in 1802, based on material from Germany, where aphids had been found in nurseries, causing extensive damage. In 1812, the species was found in France, by 1841, it was found in Italy and in 1870 it was reported in Switzerland. *E. lanigerum* has subsequently spread gradually to all temperate countries of the world (Balachowsky and Mesnil 1935, Marchal 1928).

For most alien species, the date of first report sighting may not correspond to the date of introduction and secondary expansion. For example, the pest species *Myzus persicae*, *Panaphis juglandis*, and *Chromaphis juglandicola* were all reported for the first time in Europe between 1800 and 1849, but they were probably introduced long before along with their host plants. The primary host of *Myzus persicae,* the peach tree, grown since classical times in the Mediterranean basin, was imported to Europe from Persia, but probably originated from western China, where it has been cultivated since 5,000 yr BP (Faust and Timon 1995). The host plant of *Chromaphis juglandidola* and *Panaphis juglandis,* the walnut, may have been introduced to Europe from Persia during the classical era, but this remains a matter of debate (Huntley and Birks 1983). Even for more recent introductions, the time lag between introduction and the first reported sighting may be considerable, particularly if the species concerned is not a pest. The date on which a taxonomic group was first recorded is therefore more likely to refer to the period during which it was studied for the first time. Börner between 1930 and 1952 made the largest single advance to studies of the aphid fauna of Europe, with the publication of "Europae Centralis Aphid" (Börner 1952). This catalysed intensive studies of the aphid fauna in various European countries over the following 20 years. The increase in the number of introduced species observed between 1950 and 1974 is partly attributable to this increase in taxonomic and faunistic activity.

Bearing these biases in mind, and taking the first recorded sighting as a proxy for the date of introduction, the mean rate of introduction since 1800 was 0.5 species per year. A similar rate has also been reported for a more recent period (0.42 between 2000 and 2007). The number of introductions increased in the second half of the 20th century (Figure 9.2.2). The mean number of new records increased from 0.3–0.4 per year before 1950 to more than 1.3 per year between 1950 and 1974. The mean number of introductions per year has decreased since 2000, but this pattern may change again in the future. The three most recent alien aphid species introduced to Europe are *Aphis illinoisensis*, a Nearctic species and a pest of vineyards introduced into Crete in 2005 (Tsitsipis et al. 2005), *Prociphilus fraxiniifolii*, also of Nearctic origin, introduced into Europe in 2003, (Remaudière and Ripka 2003), and *Greenidea ficicola*, a tropical species, probably originating from Asia, introduced into Sicily in 2004 (Barbagallo et al. 2005a).

9.2.4. Biogeographic patterns

9.2.4.1 Origin of alien species

A precise continent of origin was ascertained for 90.2% (92 species) of the alien Aphididae species, whereas 5.9% (six species) of the alien species were known only to be native to tropical or subtropical regions and 3.9% (four species) were of unknown origin (cryptogenic, Table 9.2.1, Figure 9.2.3).

The cryptogenic species include the polyphagous pest species *Myzus persicae* and *M. cymbalariae*, which have a cosmopolitan distribution. Data concerning their host plant relationships and the distribution of other species of the genus *Myzus*, strongly

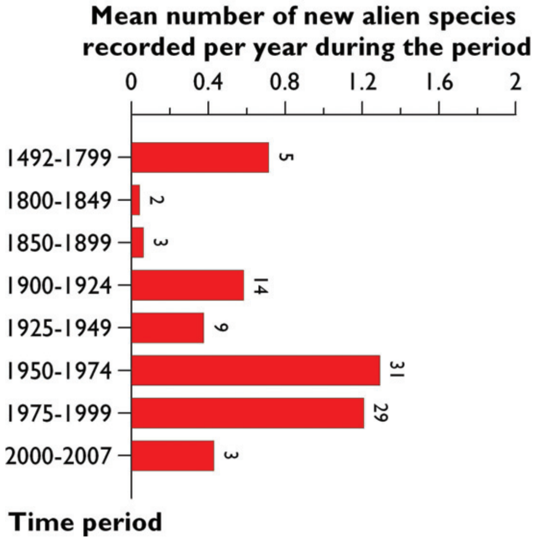

Figure 9.2.2. Changes over time in the mean number of first sightings per year of aphid species alien *to* Europe from 1492 to 2007. The number to the right of the bar indicates the absolute number of species reported for the first time during the corresponding time period.

suggest that these species originate from a continent other than Europe. Many other cosmopolitan species are not included in this list because they are thought to be of European origin, e.g. *Acyrthosiphon pisum*, *Brevicoryne brassicae*, although their origin is unclear and it remains possible that they were introduced into Europe by humans a long time ago.

Most of the alien aphid species in Europe originate from temperate regions of the world. Asia and North America have contributed the largest numbers (each 43.1%, Figure 9.2.3). Most of the Asian species originated from temperate zones (32 species), and only four species (*Cerataphis brasiliensis*, *Cerataphis orchidearum*, *Greenidea ficicola*, and *Stomaphis mordvilkoi*) are known to have originated from tropical Asia. Only four alien species in Europe are of African origin. Two of these species come from North Africa (*Cinara laportei* and *C. cedri*) and two from sub-Saharan regions (*Aloephagus myersi* and *Paoliella eastopi*). No alien aphid species has yet been introduced into Europe from Australasia or South America. The proportions of aphids of different geographical origins in the alien aphid fauna of Europe have remained fairly constant over time (Figure 9.2.4) and seem to reflect the species diversity of the donor continents. Most of the described aphid species are of temperate origin, with Aleyrodidae and Coccoidea appearing to replace aphids in the tropics and subtropics (Dixon 1998). With only 219 (Remaudière et al. 1985) and 180 (Hales 2005) species, respectively, sub-Saharan Africa and Australia have a very poor aphid fauna. By contrast, 1,416 species are found in North America (Foottit et al. 2006) and 1,007 species are found in China (Qiao and Zhang 2004). Thus, the origins of the alien species in Europe might reflect regional species di-

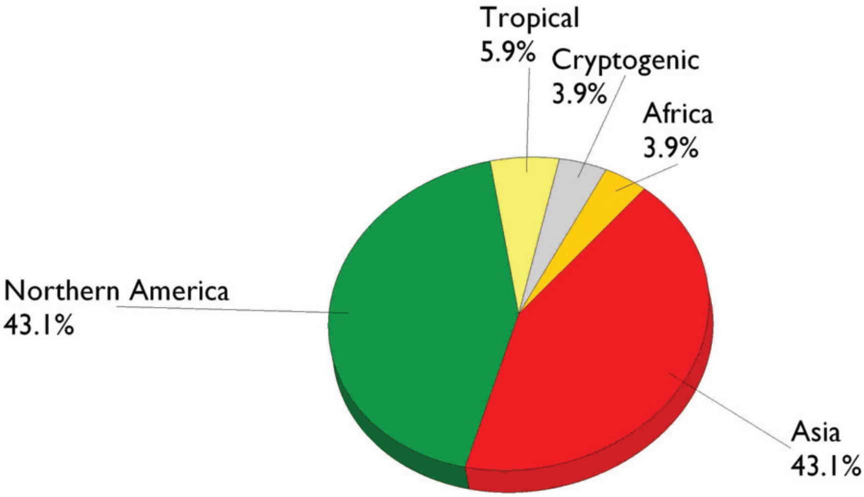

Figure 9.2.3. Geographic origin of the alien species of Aphididae established in Europe.

versity rather than preferential routes of introduction from North America and temperate Asia.

9.2.4.2. Distribution of alien species in Europe

Alien Aphididae species are not evenly distributed within Europe (Figure 9.2.5). The number of alien species present in a country is significantly and positively correlated with the number of native species recorded in that country (r=0.6226, p<0.001). This may reflect differences in sampling intensity and in the number of local taxonomists. The number of alien species also seems to be weakly positively correlated with the total area covered by each country (r=0.3361, p=0.0182). Similarly, the number of native species is strongly correlated with the area of the country (r=0.6803, p<0.001).

The top ten countries/regions within Europe with the largest numbers of recorded alien aphid species are: Great Britain (64), mainland France (63), mainland Italy (58), mainland Spain (56), Sicily (Italy) (45), Germany (44), Switzerland (37), Madeira (Portugal) (36), mainland Portugal (31), Czech Republic (29).

Alien aphid species are well distributed across Europe, with 58% present in at least five European countries and 38% occurring in more than 10 countries or regions. The polyphagous pest species, *Myzus persicae*, *Macrosiphum euphorbiae* and *Aphis gossypii* are the most widely distributed alien species: they have been recorded in 43, 41 and 40 countries or regions, respectively. Only one of the 15 species occurring in more than half of the countries of Europe, *Acyrthosiphon caraganae*, is not considered to be a pest of crop plants. This species, probably originating from the Altai region, is now found in temperate regions throughout the Northern hemisphere, where it lives on woody Leguminosae, particularly *Caragana* and *Colutea* species. In

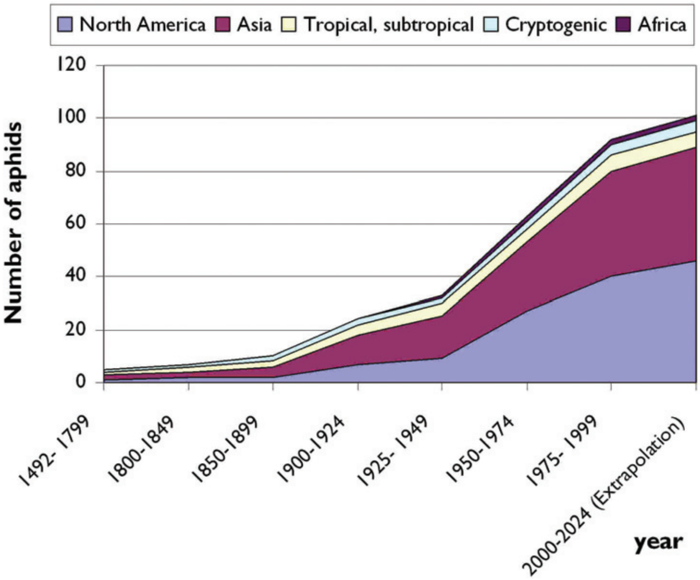

Figure 9.2.4. Cumulative numbers of alien aphid species established in Europe, by year and by geographic origin

most cases, it is not known whether the species expanded naturally after its establishment in a country, or whether the extension of its distribution was driven by repeated introductions from abroad.

Thirteen of the 19 species present in only two European countries have discontinuous distributions, probably resulting from independent introductions. Thus, for example *Ericaphis wakibae* has been found in Great Britain and the Czech Republic, *Chaitophotus populifolii* in Germany and Serbia and *Macrosiphum ptericolens* in Poland and Great Britain. A continuous but restricted area may be accounted for by recent introductions, as for *Aphis illinoisensis* Shimer, 1866, a pest of grapevines introduced into Greece in 2005 (Tsitsipis et al. 2005). This species has extended its range from Crete to continental Greece and recently (2007) to the Mediterranean part of Montenegro (Petrovic, personal communication).

Eight alien aphid species have each been found in only one European country. Four of these species are confined to England, two to Italy, one to Swirtzerland and one to the Ukraine. These species were all introduced before 2000 and have not spread elsewhere since. They may be unable to colonise a wider geographical area in Europe, they may have disappeared or they may simply have been overlooked.

9.2.5. Main routes and vectors for introduction into Europe

No cases of intentional introduction of aphids into Europe are known. All alien species were therefore introduced accidentally. In a very small number of cases, the pathway

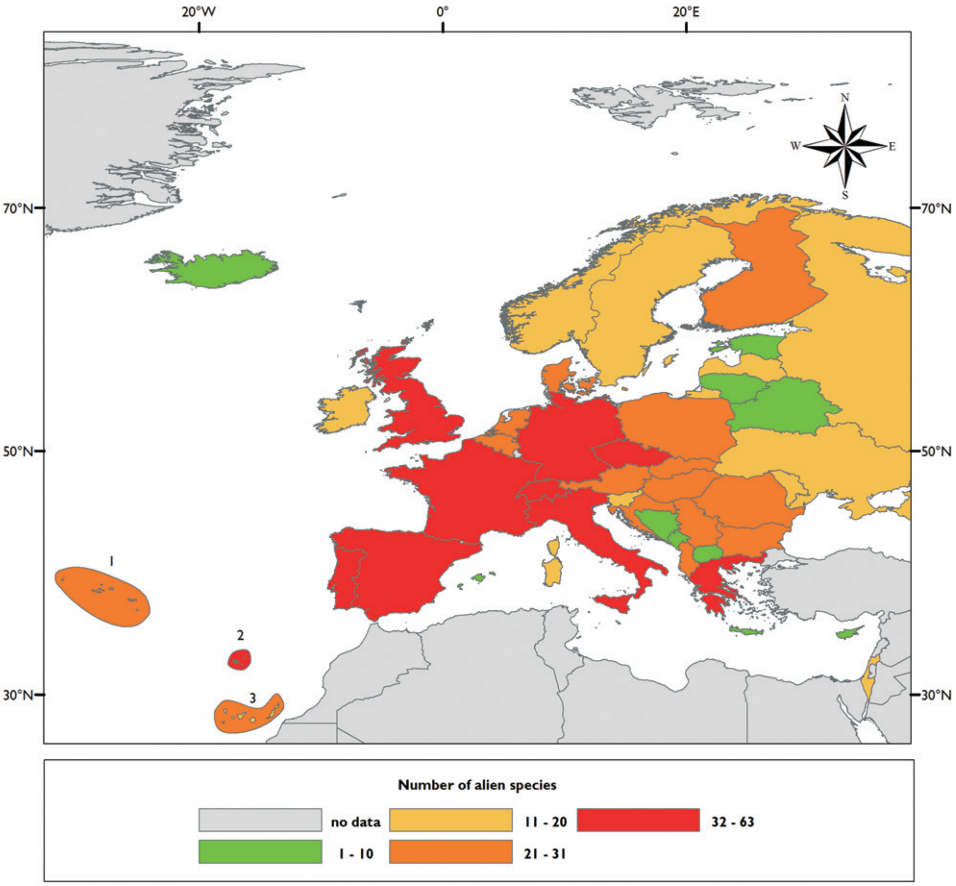

Figure 9.2.5. Comparative colonization of continental European countries and islands by Aphididae species alien to Europe. Archipelago: **1** Azores **2** Madeira **3** Canary islands.

and vector are precisely known. For example, two Japanese aphids, *Tinocallis ulmiparvifoliae* and *T. zelkovae* were introduced into Europe in 1973 with their hosts, bonsai trees that were imported into Great Britain directly from Japan. The infested bonsai trees had been in Great Britain for about six months before the aphids were detected, and were growing in slatted wood buildings providing no effective physical barrier to insect dispersal (Prior 1971).

In most cases, it is difficult to identify the vector of accidental introductions; most have been inferred from the known biological requirements of the aphid species. Most Aphididae have a high level of host-plant specificity and most alien species are therefore thought to have been introduced into Europe with their host plants. For example, the *Takecallis* species included in our list feed on bamboos of Asian origin. The Ne-

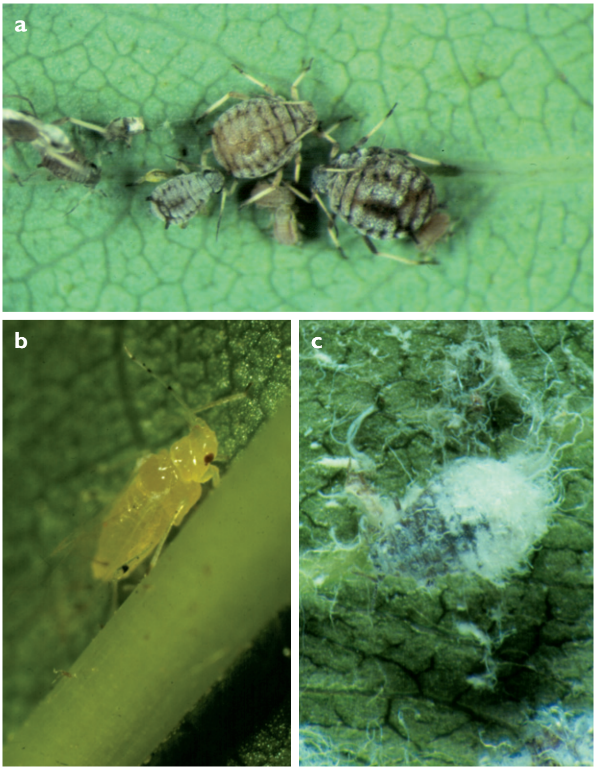

Figure 9.2.6. Some alien aphids. **a** Spiraea aphid, *Aphis spiraephaga*. (Credit: Olivera Petrović-Obradović) **b** Walnut aphid, *Chromaphis juglandicola*. (Credit: Olivera Petrović-Obradović) **c** Woolly apple aphid, *Eriosoma lanigerum*. (Credit: Olivera Petrović-Obradović).

arctic aphid *Prociphilus fraxinifolii* has recently been detected in Budapest (Hungary) (Remaudière and Ripka 2003), but only on the North American red ash tree, *Fraxinus pennsylvanica* Marsh. This aphid has not been found on European ash planted in the same area. Two oriental species, *Reticulaphis distylii* and *Greenidea ficicola,* live on several species of *Ficus,* all originating from tropical regions. These *Ficus* species have been planted as ornamental trees in the warmest areas of the Mediterranean basin (Barbagallo et al. 2005a). These two species of aphids are found on tropical fig trees, but never on *Ficus carica,* the only European species of this genus. All these alien species are thought to have been introduced into Europe through trade, but the aphid species may have been introduced several years after their hosts. *Impatientinum asiaticum* is a species originating from Central Asia. It was introduced into Europe in 1967, whereas its host, *Impatiens parviflora* DC. was introduced into Europe much earlier, in the 19th Century, subsequently escaping from botanic gardens to establish itself as a common weed. The aphid was not introduced at the same time as its host plant in this case because the host plant is an annual, which was imported in the form of seeds. The aphid arrived more than 100 years later, probably on an aeroplane (Holman 1971, Tambs-Lyche and Heie 1973). Another example is provided by *Rhopalosiphoninus latysiphon*, a pest species particularly damaging to potato. This species was not introduced into Europe until the end of the 1st World War, long after the introduction of its host plant, and was transported with potatoes from the USA. It was subsequently found in Italy (1921), the Netherlands (1930), Germany (1943), England (1945), Switzerland and Austria (1949) (Remaudière 1952).

Finally, we cannot exclude the possibility that some species originating in areas close to Europe may have been transferred into Europe by wind, air streams or windstorms. For example, it is difficult to determine whether *Cinara laportei* and *C. cedri* were transferred with their host, the Atlas cedar, which was planted in Europe, or whether these species colonised Europe following their introduction via wind or air streams.

9.2.6. The ecosystems and habitats most frequently invaded

All aphids are phytophagous and their distribution is limited by the presence of their host plants. Aphid species with a limited spectrum of host plants of exotic origin, not present at natural sites, are restricted to artificial habitats, such as agricultural land, greenhouses and parks and gardens. For example, *Illinoia liriodendri* and *Neophyllaphis podocarpi* feed on exotic trees (*Liriodendron tulipifera* L. and *Podocarpus* spp., respectively). As a result, these aphids are restricted to parks, gardens and city areas in which these trees have been planted in Europe. Similarly, *Cinara cedri* and *C. laportei* which feed specifically on *Cedrus* are restricted to forest areas in which their hosts have been planted. Other species restricted to artificial habitats include tropical and subtropical aphids present only in indoor conditions in Europe. These species were included in the list because it is clear that they have become established in Europe. For example, *Cerataphis* spp., particularly *C. lataniae* and *C. orchidearum* have repeatedly been found in European greenhouses (Chapin and Germain 2005). Similarly, *Sitobion luteum* and *Pentalonia nigronervosa* are considered to have been introduced into hothouses in Europe (Blackman and Eastop 2000). Another subtropical *Cerataphis*, *C. brasiliensis*, has recently been found established outdoors in the south of the France (Chapin and Germain 2005, 2004). Some aphid species have a less limited host range spectrum. They can adapt to new hosts when introduced and may disperse in natural habitats. *Cinara curvipes*, a species recently introduced into Europe, is known to feed on various species of *Abies* in its native area (North America). In Europe, it is found on North American *Abies* species, but also on native *Abies* species and has recently been reported on many other conifers, including *Picea*, *Tsuga*, and *Pinus* (Scheurer and Binazzi 2004). *C. curvipes* is found in parks, gardens and forests. It could potentially colonise all European coniferous forests. Finally, polyphagous aphids, notably *Myzus persicae*, *M. ascalonicus*, *M. ornatus*, *Macrosiphum euphorbiae* and *Aphis gossypi,* have established themselves on many native plants in natural habitats.

Most of the alien aphids seem to have become established in the European environment and habitats. However, some species, such as *Paoliella eastopi* and *Macrosi-*

phum ptericolens have been recorded only once or twice, and it remains unclear whether these species are truly established. Other species, such as *Rhopalosiphum parvae* Hottes & Frison (1931), a North American aphid found in Sicily in 1982 (Barbagallo and Stroyan 1982), or *Tuberocephalus higansakurae hainnevilleae* Remaudière & Sorin, 1993, detected in France in 1990 on trees of *Prunus subhirtella* Miq. var. *pendula* Y.Tanaka imported from Japan (Remaudière and Sorin 1993), have been observed in Europe but have since been eradicated. Such species are not included in our list.

9.2.7. Ecological and economic impact

Most of the alien Aphididae are recognised pests, feeding on crops, ornamental plants and forest trees in Europe. Other alien Aphididae species may have remained undetected because they feed on plants that are not commercially exploited. As for most insects, much more is known about the economic impact of aphids than about their ecological impact. Aphids cause direct (sap-feeding, deformation of their hosts) and indirect (transmission of plant diseases, deposition of honeydew on the leaves) damage.

The economic impact of each species depends on (i) the type and extent of the damage caused and (ii) the economic importance of the host. Of the 102 alien aphid species in Europe, 52 are recognised pests of agricultural and horticultural crops (Blackman and Eastop 2000). The polyphagous species *Myzus persicae*, *Macrosiphum euphorbiae* and *Aphis gossypii* attack a wide range of vegetable crops, both indoors and outdoors. They are vectors of many viral diseases and are probably the aphids with the greatest economic impact in vegetable crops (Lampel and Gonseth 2005).

European orchards are attacked by several alien aphid species. Apple trees can be severely damaged by the North American wolly aphid *Eriosoma lanigerum* and the Asian species *Aphis spiraecola.* The recent introduction of *Toxoptera citricidus* into the Iberian Peninsula (Portugal and Spain) (Ilharco et al. 2005) poses a serious threat to Mediterranean citrus fruit production because this aphid is the principal vector of the *Triteza* closterovirus of *Citrus*. *Citrus* trees in Europe are also the hosts of *Aphis spiraecola* and *Toxoptera aurantii,* two polyphagous species also capable of transmitting this closterovirus, albeit with a lower efficiency.

The recent introduction and rapid dispersion of *Aphis illinoiensis,* a grapevine aphid, poses a particular threat to viticulture in the Mediterranean area (Remaudière et al. 2003, Tsitsipis et al. 2005). Some alien aphids attack agricultural crops, often as potential virus vectors. *Rhopalosiphum maidis* is known as a pest of maize and other grain crops in Europe and transmits the persistent luteovirus "yellow dwarf" virus of barley. The grass aphid, *Hysteroneura setariae* Thomas, 1878, has recently been recorded in Spain (Meliá Masiá 1995). Its impact it difficult to predict because it usually lives on wild grass species, but it may occasionally infect cereals and can transmit several viral diseases to these crops. *Macrosiphum albifrons* is a widespread species in North America that has been introduced into Europe (Stroyan 1981) where the damage it causes to lupins (Ferguson 1994) has stimulated recent research (Blackman and Eastop 2000). Finally, *Acyrthosiphon kondoi*, which currently has a restricted distribution in Europe, is known to be a serious pest of lucerne (Blackman and Eastop 2000).

Exotic Aphididae are not considered to be serious pests of forest species in Europe (EUROFOR 1994) by contrast to the major damage caused to agricultural and horticultural crops. However, some species may cause economic losses. For example, the North African species *Cinara cedri* and *C. laportei* have been reported to damage plantations of *Cedrus* in southern France (Emonnot et al. 1967, Fabre 1976).

Finally, in addition to their measurable economic impact, some alien aphids may have an aesthetic impact. The production of abundant honeydew and the distortions induced by feeding may significantly modify the appearance of the foliage of ornamental plants in parks and private gardens. *Appendiseta robiniae* has such an aesthetic impact on *Robinia pseudacacia* L., as does *Prociphilus fraxinifolii* on the red ash tree *Fraxinus pennsylvanica* and *Illinoia liriodendri* on *Liriodendron tulipifera*.

9.2.8. Conclusion

There are several possible reasons for the overrepresentation of Aphididae in the alien insect fauna of Europe. First, aphids are phytophagous insects and many are pests of economically important host plants (Blackman and Eastop 2000). For this reason, many studies are carried out on the distribution, taxonomy and biology of this family. New alien species of Aphididae are therefore more likely to be detected than new members of other taxonomic groups, and this effect is enhanced by standard phytosanitary procedures. Second, aphids have the ability to reproduce both parthenogenetically and sexually. Several species can reproduce exclusively by parthenogenesis, and all species can potentially maintain parthenogenetic populations throughout the year in areas of mild climate. Consequently, very few introduction events, and theoretically even the introduction of a single parthenogenetic female, may lead to the development of a population and the establishment of an alien species. Third, although aphids, as a group, are cosmopolitan, they are most strongly represented in temperate regions. Consequently, most of the World's aphids live in climatic conditions similar to those of Europe and are therefore preadapted to establishment where suitable hostplants are present. Moreover, global warming is also likely to promote the survival of alien tropical and subtropical species, at least locally (e.g. along the Mediterranean coast). Finally, aphids are small insects easily transported around the globe with plant materials.

These factors and trends are unlikely to change and the number of introductions of alien Aphididae observed in Europe will probably continue to increase, due to both environmental (climate change) and economic factors (expanding markets and globalisation, and the ever increasing numbers of goods transported and agents of transport).

References

Aguiar AMF, Fernandez A, Ilharco FA (1994) On the sudden appearance and spread of the black citrus aphid *Toxoptera citricidus* (Kirkaldy) (Homoptera Aphidoidea) on the island of Madeira. *Bocagiana* 168: 1–7.

Aguiar AMF, Ilharco FA (1997) New records for aphids (Homoptera: Aphidoidea) from Madeira Island. *Boletín de Sanidad Vegetal* – 23: 565–570.

Aguiar AMF, Ilharco FA (2001) Aphids (Homoptera : Aphidoidea) from Madeira Island – New records and Corrections. *Boletín de Sanidad Vegetal - Plagas* 27: 323–336.

Angst A, Scheurer S, Forster B (2007) First record of Cinara curvipes (Patch) (Homoptera, Aphididae, Lachnidae) on Abies concolor in Switzerland. *Mitteilungen der Schweizerischen Entomologischen Gesellschaft* 80: 247–252.

Arzone A, Vidano C (1990) Exotic insects newly introduced in Italy and Piedmont. *Informatore Fitopatologico* 40: 47–54.

Balachowsky A (1933) I. Sur la présence en France de *Capitophorus fragaefolii* Ckll., Aphide nouvellement introduit et nuisible au frasier. II. Sur l'existence de nouveaux foyers d'*Aphis forbesi* Weed. *Revue de Pathologie Végétale et d'Entomologie Agricole de France* 20: 256–267.

Balachowsky A, Mesnil L (1935) Les insectes nuisibles aux plantes cultivées. Paris, France: Mery L. 1921 pp.

Barbagallo S (1994) Considerazioni faunistiche e biogeografiche sugli afidi italiani. *Atti Accademia Nazionale italiana di entomologia* XLII: 141–178.

Barbagallo S, Stroyan HLG (1982) Osservazioni biologiche, ecologiche e tassinomiche sull'afidofauna delle Sicilia - Biological, ecological and taxonomic notes on the aphid fauna of Sicily. *Frustula Entomologica (N.S.)* 3: 1–182.

Barbagallo S, Coccuzza GE (1998) Sulla presenza in Sicilia dell'afide *Neotoxoptera violae* (Pergande). *Bolletino di Zoologia Agraria e di Bachicoltura* 30 (2): 321–326.

Barbagallo S, Bosio G, Brussino G, Scarpelli F (1998) Aphids infesting cultivated blueberries and cranberries in Italy. *Informatore Fitopatologico* 10: 65–71.

Barbagallo S, Bosio G, Brussino G, Patti I, Scarpelli F (1999) Annotazioni morfo-biologiche sull'afide dei Mirtilli americani, Ericaphis scammeli (Mason) (Rhynchota Aphidoidea). *Bollettino di Zoologia Agraria e di Bachicoltura* 31: 207–227.

Barbagallo S, Suma P (1999) Recenti infestacioni in Sicilia dell'afide giallo del Pecan, *Monelliopsis pecanis* Bissell. *Bollettino di Zoologia Agraria e di Bachicoltura* 31: 241–249.

Barbagallo S, Ciampolini M (2000) Rinvenimento in italia dell' afide della cipolla *Neotoxoptera formosana* (Takahashi). *Bollettino di Zoologia Agraria e di Bachicoltura* 32: 245–258.

Barbagallo S, Bella S, Cocuzza G (2005) Rinvenimento dell'afide orientale *Greenidea ficicola* su Ficus ornamentali in Italia meridionale. *Informatore Fitopatologico* 55: 25–29.

Barbagallo S, Ilharco FA, Nieto Nafria JM, Sousa-Silva RC (2005) D Recent aphid records in Southern Europe: Towards the tropicalization of the Mediterranean ?. 7 th International Symposium on Aphids, Freemantle, WA Australia. 2–7. October 2005.

Binazzi A, Barbagallo S (1991) Annotazioni faunistico-ecologiche sugli afidi del genere *Chaitophorus* Koch in Italia. XVI. Congr. Naz. Ital. Entomol., Settembre 1991, pp. 59–63.

Biurrun R, Nieto Nafría JM (1987) Sobre la presencia en España de *Illinoia azaleae* (Mason, 1925) (Hom., Aphididae). *Boletín de la Asociación Española de Entomologí.* 11:418.

Blackman RL, Eastop VF (1994) *Aphids on the World's Trees: an Identification and Information Guide*. Wallingford, UK: CAB International. 1024 pp.

Blackman RL, Eastop VF (2000) *Aphids on the World's Crops - an Identification and Information Guide.* 2nd edn. Chichester UK: John Wiley & Sons. 476 pp.

Blackman RL, Eastop VF (2006) *Aphids on the world's herbaceous plants and shrubs*. Chichester, UK: John Wiley & Sons. 1460 pp.

Blackman RL, Eastop VF (2007) Taxonomic Issues. In Van Emden H, Harrington R., *Aphids as Crop Pests*. CAB International, 1–29.

Blanchard E (1840) *Aphidiens. Histoire Naturelle des insectes. Orthoptères, Hémiptères, Hyménoptères, Lépidoptères et Diptères.* Paris, France: Duménil. 672 pp.

Boisduval JA (1867) Essai sur l'entomologie horticole comprenant l'histoire des insects nuisibles à l'horticulture avec l'indication des moyens propres à les éloigner ou à les détruire, et l'histoire des insectes et autres animaux utiles aux cultures. Paris, France: Librairie Centrale d'Agriculture et de Jardinage. 664pp.

Börner C (1952) Europae centralis Aphides. Die Blattläusse Mitteleuropas. Namen, Synonyme, Wirtspflanzen, Generationszyklen. *Mitteilungen der Thüringischen Botanischen Gesellschaft* 3:1–488.

Bozhko MP (1976) New and little known aphids (Homoptera, Aphidoidea) in the south of the European part of the USSR (in Russian). *Entomologicheskoe Obozrenie* 55: 863–874.

Boyer de Foscolombe M (1841) Description des pucerons qui se trouvent aux environs d'Aix. *Annales de la Société Entomologique de France* 10:157–198.

Buckton GB (1876) *Monograph of the British aphides Vol.I.* London, UK: The Ray Society. 190pp. + 38 plates.

Buckton GB (1879) *Monograph of the British aphides Vol.2.* London, UK; The Ray Society. 176pp.

Cairaschi EA (1942) *Pentalonia nigronervosa* Coquerel (Hem. Aphididae) espèce nuisible nouvellement introduite en France. *Bulletin de la Société entomologique de France* 46: 138–140.

Carter CI, Four DF, Bartlett PW (1984) The lupin aphid's arrival land consequences. *Antennata* 8: 129–182.

Chapin E, Germain JF (2005) Un nouveau puceron des palmiers pour la côte varoise. *PHM Revue Horticole* 466: 41–45.

Cholodkovsky N (1907) On the biology of aphids on papilionaceous plants. *Russkoe èntomologicheskoe obozrienie* 2–3: 87–95.

Ciampolini M, Martelli M (1977) Appearance in Italy of the peach trunk aphid *Pterochloroides persicae* (Cholodk.). *Bolletino di Zoologia Agraria e di Bachicoltura* 14: 189–196.

Coceano PG, Petrovic-Obradovic O (2006) New Aphid species for Italy caught by suction trap. *Phytoparasitica* 34: 63–67.

Colombo M (1981) *Stomaphis mordvilkoi* Hille Ris Lambers (Aphidoidea Lachnidae) afide orientale riscontrato su noce nell'Italia del Nord. *Bollettino di Zoologia Agraria e di Bachicoltura ser. II* 16: 199–206.

Covassi M (1971) Osservazioni preliminari sulla presenza in italia di un afide nocivo ai cedri: *Cedrobium laportei* Remaud. (Homoptera, Aphidoidea, Lachnidae). *Redia* 52: 641–652

Covassi M, Binazzi A (1974) Note corologiche e morfologiche sulla *Cinara cedri* Mim. In Italia (Homoptera Aphidoidea, Lachnidae). *Redia* 55: 331–341.

Del Guercio G (1911) Intorno ad alcuni Afididi della Penisola Iberica e di altre localita, raccolti dal prof. I.S. Tavares. *Redia* 11: 296–333.

Del Guercio G (1913) Generi e specie nuove di afidi o nuovi per la fauna italiana. *Redia* 9: 169–196.

Del Guercio G (1917) Contribuzione alla conoscenza degli afidi. *Redia* 12: 197–277.

Dixon AFG (1998) *Aphid Ecology* 2nd edn. London, UK: Chapman & Hall. 300 pp.

Doncaster JP (1946) The shallot Aphis, *Myzus ascalonicus* sp. n. (Hemiptera, Aphididae). Proceeding *of the Royal Entomological Society (Lond.)* 15: 17–48.

Doncaster JP (1954) Two aphids new to Britain. *Entomologist* 87: 127–128.

Doncaster JP (1961) *Francis Walker's aphids.* London, UK: Britsih Museum (natural History). 165pp.

Dospevski S (1910) Bolesti i nepriyateli na kulturnite rasteniya za unischtozenietona koito sa iskani nastavleniya ot stantziyavata i takiva, nabyudavani v Sadovo prez 1908 godina, Godischen otchet na Durzavnata opitna zemedelska stanciya v Sadovo.

Eastop VF (1956) Thirteen aphids new to Britain and records of some other rare species. *Entomologist's Monthly Magazine* 92: 271–275.

Eastop VF (1958) The history of *Macrosiphum euphorbiae* (Thomas) in Europe; The Entomologist 91: 198–201.

Eastop VF (1962) Additions to the wild fauna and flora of the Royal Botanic Gardens, Kew. 25. A contribution to the aphid fauna. *Kew Bulletin* 16: 139–146.

Eastop VF (1971) Keys for the identification of *Acyrthosiphon* (Hemiptera: Aphididae). *Bulletin of the British Museum (Natural History) Entomology* 26: 1–115.

Eastop VF, Hille Ris Lambers D (1976) *Survey of the World's Aphids*. The Hague, Netherlands: Dr Junk W. b.v. 573 pp.

Eastop VF, Blackman RL (2005) Some new synonyms in Aphididae [Homoptera: Sternorrhyncha]. *Zootaxa* 1089: 1–36.

Emonnot P, Gayraud Y, Leclant F, Remaudière G (1967) Sur la présence en France de *Cedrobium laportei* Remaudière puceron nuisible au cèdre. *Comptes-Rendus de l'Académie d'Agriculture de France* Juin 1967: 966–972.

EUROFOR (1994) L'europe et la forêt: Les grands problèmes des forêts de l'union européenne - Dégâts occasionnés aux forêts et conséquences pour l'environnement. http://www.europarl.europa.eu/ workingpapers/agri/ch4–3_fr.htm.

Fabre JP (1976) Sur la présence en France de *Cinara cedri* (Mimeur) puceron nuisible au cédre. *Comptes-Rendus de l' Académie d'Agriculture de France* Juin 1976: 771–775.

Faust M, Timon B (1995) Origin and dissemination of peach. *Horticultural Review* 17: 331–379.

Ferguson AW (1994) Pests and plant injury on lupins in the south of England. *Crop Protection* 13: 201–210.

Foottit RG, Halbert SE, Miller GL, Maw E, Russell LM (2006) Adventive aphids (Hemiptera: Aphididae) of America north to Mexico. *Proceedings of the Entomological Society of Washington*. 108: 583–610.

Geiter O, Homma S, Kinzelbach R (2002). *Bestandsaufnahme und Bewertung von Neozoen in Deutschland*. Forschungsbericht 296. Berlin: Umweltbundesamt. Texte. 25/2002

Germain JF, Chapin E (2004) Discovery in France of the palm aphid *Cerataphis brasiliensis* (Hempel) (Hemiptera, Aphididae, Hormaphidinae). *Revue Francaise d'Entomologie (N.S.)* 26: 174.

Germain JF, Deogratias JM (2008) Confirmation de la presence en France du puceron de la violette. *PHM-revue Horticole*, 507: 42–44.

Giacalone I, Lampel G (1996) Pucerons (Homoptera, Aphidina) de la région insubrique tessinoise d'origine subméditerranéenne, méditerranéenne, esteuropéenne, asiatique et américaine. *Mittelungen der schweizeischen entomologschen Gesellschaft* 69: 229–260.

Goeze JA (1778) *Hemiptera. Entomologische Beyträge zu des ritter Linné Zwölften ausgabe des Natursystems*. Leipzig, Germany: Weidmann. 352pp.

Hales D (2005) *Aphidoidea in Australia*. 7 th International Symposium on Aphids, Freemantle, WA Australia: 2–7 October 2005.

Heie OE (1973) Tilfojelser til listen over danske bladlus (Homoptera, Aphidoidea). *Entomologiske Meddelelser* 41: 177–187.

Heie OE (1980) The Aphidoidea of Fennoscandia and Denmark. I General Part. The families Mindaridae, Hormaphididae, Thelaxidae, Anoeciidae and Pemphigidae. *Fauna Entomologica Scandinavica* 9: 1–236.

Heie OE (1982) The Aphidoidea of Fennoscandia and Denmark. II The family Drepanosiphidae. *Fauna Entomologica Scandinavica* 1I: 1–176.

Heie OE (1986) The Aphidoidea of Fennoscandia and Denmark. III The family Aphididae: subfamily Pterocommatinae, tribe Aphidini of subfamily Aphididae. *Fauna Entomologica Scandinavica* 17: 1–314.

Heie OE (1992) The Aphidoidea of Fennoscandia and Denmark. IV Family Aphididae: Part 1 of the tribe Macrosiphini of subfamily Aphidinae. *Fauna Entomologica Scandinavica* 25: 1–188.

Heie OE (1994) The Aphidoidea of Fennoscandia and Denmark. V Family Aphididae: Part 2 of the tribe Macrosiphini of subfamily Aphidinae. *Fauna Entomologica Scandinavica* 28: 1–239.

Heie OE (1995) The Aphidoidea of Fennoscandia and Denmark. VI Family Aphididae: Part 3 of tribe Macrosiphini of subfamily Aphidinae, and family Lachninae. *Fauna Entomologica Scandinavica* 31: 1–217.

Hermoso de Mendoza (1988) Primera cita en Espana de *Monellia caryella* (Fitch, 1855) (Hom., Aphidinea, callaphididae). *Boletín de la Asociación Española de Entomología* 12: 359.

Hille Ris Lambers D (1947) Neue Blattläuse aus des Schweiz II. Mitteilungen der Schweizerischen *Entomologischen Gesellschaft* 20: 649–660

Hille Ris Lambers D (1966) New and little known members of the aphid fauna of Italy (Homoptera, Aphididae). *Bolletino di Zoologia agraria e di bachicoltura, serie II* 8: 1–32.

Hille Ris Lambers D (1973) *Masonaphis lambersi* MacGillivray, 1960 (Homoptera, Aphididae), a new pest of Rhododendron in Europe. *Netherlands Journal of Plant Pathology* 79: 159–161.

Holman J (1965) Some unrecorded Middle European aphids. *Acta Faunistica Entomologica Musei Nationalis Pragae* 11: 277–283.

Holman J (1971) Taxonomy and Ecology of *Impatientinum asiaticum* Nevsky an aphid species recently introduced to Europe (Homoptera, Aphididae). *Acta Entomologica Bohemoslovaca* 68: 153–166.

Holman J (2009) Host Plant Catalog of Aphids-Palaearctic Region. New York, USA: Springer Verlag. 1216pp.

Holman J, Pintera A (1981) Übersicht der Blattläuse (Homoptera, Aphididoidea) der Rumänischen Sozialistischen Republik. Praha, Ceskoslovenska: Akademie Ved. 125 pp.

Hržič A (1996) Opazovanje naleta listnih uši (Aphididae) v letu 1994 (in Slovenian) [Observation of aphid flight in the year 1994]. *Slobodno kmetijstvo* 29: 54–56.

Hullé M, Renoust M, Turpeau E (1998) New aphid species detected by permanent aerial sampling programmes in France. In: Nieto Nafria JM, Dixon AFG (Eds) *Aphids in Natural and Managed Ecosystems*. León, Spain: Universidad de León, Secretariado de Publicaciones. 365–369.

Huntley B, Birks HJB (1983) *An Atlas of Past and Present Pollen Maps for Europe: 0–13,000 BP Years Ago*. Cambridge-London-New York-New Rochelle-Melbourne-Sydney: Cambridge University Press. 667 pp.

Ilharco FA (1960) The knowledge of aphids in Portugal. *Broteria* 29: 150–174.

Ilharco FA (1961) On an aphid collection found in the Estçap Agronomica Nacional, including a new species, *Paraschizaphis rosazevedoi*. *Agros* 44: 71–77.

Ilharco FA (1968) Algumas correcçoes e adiçoes a lista de afidios de Portugal Continental. I Parte. *Agronomia Lusitana* 29: 117–139.

Ilharco FA (1968) Algumas correcçoes e adiçoes a lista de afidios de Portugal Continental. II Parte. *Agronomia Lusitana* 29: 221–245.

Ilharco FA (1969) Algumas Correcçoes e adiçoes a lista de afidios de Portugal Continental. III Parte. *Agronomia Lusitana* 41: 313- 321.

lharco FA (1973) *Catálogo dos Afidos de Portugal Continental*. Oeiras, Portugal: Estação Agronómica National. 134 pp.

Ilharco FA (1974) List of the aphids of Madeira Island (Homoptera, Aphidoidea). *Bocagiana (Museu Municipal de Funchal- História Natural)* 35: 1–44.

Ilharco FA (1984) New records to the aphid fauna of the archpelago of madeira [Homoptera, Aphidoidea]. *Boletim do musu Municipal do Funchal* 36: 177–206.

Ilharco FA, Sousa-Silva CR, Alvarez Alvarez A (2005) First report on *Toxoptera citricidus* (Kirkaldy) in Spain and continental Portugal (Homoptera, Aphidoidea). *Agronomia Lusitana* 51: 19–21.

Jurc M, Poljakovic-pajnik L, Jurc D (2009) The first recor of Cinara curvipes (Patch, 1912) (Homoptera, Aphididae) in Slovenia and its possible economic impact. *Zbornik Gozdarstva in Leasarstva* 88: 21–29.

Kaltenbach JH (1843) Monographie der familien der Pflanzenläuse (Phytophtires) - I. Theil Die Blatt- und Erdläuse (Aphidina et Hyponomeutes). *Aachen*: 223pp.

Koch CL (1855) Die Pflanzenläuse Aphiden, getreu nach dem liben abgebildet und beschrieben Heft IX. Nüremberg, Germany. 135–236.

Laing F (1923) Aphidological Notes (Hemiptera-Homoptera). *The Entomologist's Monthly Magazine* 59: 238–247.

Laing F (1932) A new aphid pest on violets. *The Entomologist's Monthly Magazine* 68: 52–53.

Lampel G (1983) Für die neue Blattlaus-Arten (Homoptera, Aphididna). *Mitteilungen der Schweirerischen Entomologischen Gesellschaft* 56: 125–162.

Lampel G, Gonseth Y (2005) Hemiptera- Aphidina. In: Wittenberg R (Ed) *An inventory of alien species and their threat to biodiversity and economy in Switzerland*. Bern, Switzerland: Federal Office for the Environment FOEN. 157 pp.

Lawton JH, Eastop VF (1975) A bracken feeding *Macrosiphum* (Hem., Aphididae) new to Britain. *Entomologist Gazette* 26: 135–138.

Leclant F (1967) Un Aphididae americain nouveau pour la faune europeenne: *Nearctaphis bakeri* Cowen (Hom.). *Bulletin de la Société Entomologique de France* 72: 25–26.

Leclant F (1978) *Étude bioécologique des Aphides de la région méditerranéenne. Implications Agronomiques*. Montpellier, France: Université des Sciences et Techniques du Languedoc 1–43. 318 pp.

Leclant F, Renoust M (1986) Le puceron du Lagerstroemia, nouveau ravageur pour notre flore. *Phytoma Défense des cultures* Février 1986: 49–50.

Leclant F, Remaudière G (1986) Aphids new to France and Europe. *Aphidologist's Newsletter* 21: 8.

Limonta L (1990) Callaphididae (Aphidoidea) new to Italy. *Bollettino di Zoologia Agraria e di Bachicoltura, SerII* 22: 93–99.

Limonta L (2001) Heavy infestation of *Illinoia liriodendri* (Monell) (Rhynchota Aphididae) in gardens in northern Italy. *Bollettino di Zoologia Agraria e di Bachicoltura, SerII* 33: 133–136.

Lozzia GC, Binaghi P (1992) Entomofauna delle alberate cittadine e studio di un metodo di protezione integrata. *Disinfestazione* 9: 35–41.

Lucchi A, Pollini A (1995) Un nuovo fitomizo per la fauna italiana : l'afide callafidino *Tinocallis ulmiparvifoliae* Matts. (Rhynchota Homoptera). *Informatore Fitopatologico* 6: 31–32.

Macchiati L (1883) Fauna e flora degli afidi di calabria. *Bolletino della Societa Entomologica Italiana* 15: 221–287.

Malkov K (1908) Bolesti i povredi po kulturnte rastenia izprateni za izslevane v sadovskata opitna stancia prez 1907. Godishen otchet na durjavna zemlena opitna stancia v Sadovo. *Plovdiv 5* (1907): 207–274.

Mamontova VA (1955) *Dendrophilous aphids of the Ukraine.* Kiev,Ukraine: Academy des Sciences, Ukrainian SSR. 91pp.

Marchal P (1928) Etude biologique et morphologique du puceron lanigère du pommier [*Eriosoma lanigerum* (Hausmann)]. *Annales des Epiphyties* 14: 1–106.

Martin JH (2000) Two new british aphid introdcutions since 1999, in the contexte of other additions over the preceding thirty years (Sternorrhyncha: Aphidoidea). *Entomologist's Gazette* 51: 97–105.

Meier W, Schweizer C (1987) Macrosiphum albifrons, eine für die Schweiz und für Mitteleuropa neue Blattlausart auf Lupine. *Mitteilungen für die Schweizerische landwirtschaft* 87: 41–42.

Melia Masia A (1995) Novedades de la tribu Rhopalosiphina (Homoptera: Aphididae) para Europa y el este Ibérico. *Boletín de la Asociación Española de Entomología* 19: 131–139.

Meliá Masiá A (1998) Contribution to knowledge of the Macrosiphini (Aphididae) of Castellón (Spain): new records for the Spanish fauna. In: Nieto Nafría JM, Dixon AFG (Eds) *Aphids in natural and managed ecosystems*. León, Spain: Universidad de León, 379–383.

Micieli De Biase L (1988) L'*Aloephagus myersi* Essig (Homoptera-Aphididae) nuova specie per l'Italia su piante dei generi Aloe e Gasteria. *Informatore Fitopatologico* 3: 76–77.

Micieli De Biase L, Calambuca E (1979) L'*Appendiseta robiniae* (Gillette), nuova specie per l'italia su *Robinia pseudoacacia* L. *Informatore Fitopatologico* 11–12: 31–33.

Mier Durante MP, Pérez Hidalgo N (2002) Dos especies de Panaphidini (Hemiptera, Aphididae: Calaphidinae), propias de árboles ornamentales, introducidas en la Península Ibérica. *Boletim da Sociedade Portuguesa de Entomologia* 157 (Suppl. 6): 213–217.

Mifsud A (1998) A new tree dwelling aphid *Greenidea ficicola* Takahashi. *Bulletin of the Entomological Society of Malta* 1: 39–41.

Mimeur JM (1936) Aphididae (Hem.) d'Esspagne. *Boletin de la Sociedad Entomologica de Espana* 1936: 33–40.

Mordvilko AK (1914) *Insectes Hémiptères (Insecta Hemiptera). Volume I. Aphidoidea. Faune de la Russie et des pays limitrophes.* Petrograd, Russia: Musée Zoologique de l'Académie Impériale des Sciences. 236pp.

Műller FP (1974) *Aphis oenotherae*, Erstfunde in Europa und als potentieller Zierpflanzenschädling. *Entomologische Nachrichten Dresden* 18: 129–133.

Nieto Nafria JM (2007) Fauna Europaea: Aphididae. Fauna Europaea version 13. http://www.faunaeuro.org.

Nieto Nafría JM, Mier Durante MP (1998) *Fauna Ibérica. Hemiptera, Aphididae I.* Madrid, Spain: Museo Nacional de Ciencias Naturales, CSIC. 425 pp.

Nieto Nafria JM, Mier Durante MP, Remandiere G (1998) Les noms des taxa du groupe famille chez les Aphididae (Hemiptera). *Revue Française d'Entomologie* 19: 77–92.

Nobanis (2005) *European Network on Alien Invasive Species*. www.nobanis.com.

Ossiannilsson F (1959) Contributions to the knowledge of Swedish aphids. II. List of species with find records and ecological notes. *Kungl. LantbrHögsk. Annlr. Uppsala* 25: 375–527.

Paillot A (1928) Rapport sur le fonctionnement de la station entomologique de Saint Genis en laval. *Annales des Epiphyties* 14: 448.

Passerini G (1861) Additamenta ad indicem Aphidanarum quas hucusque in Italia legit. *Atti della Societa Italiana de Scienze Naturali Milano* 3: 398–401.

Patti I (1983) Nuovi reperti sulla composizione dell'afidofauna Siciliana. *Bolletino del laboratorio di Entomologia Agraria "Filippo Silvesrtri" di portici* 40: 33–53.

Pati I (1984) Un afide nocivo alla *Lagerstroemia* in Italia. *Informatore Fitopatologico*: 12, 12–14.

Pati I, Tomatore MG (1988) Utilita delle trappole ad aspirazione di tipo Rothamstead nel censimento faunistico degli Afidi. Atti XV *Congresso Nazionale Italiano* di Entomologia, L'Aquila, 925–932.

Pedro Mansilla J, Pérez R, Pérez N, Seco V, del Estal P (2001) Presencia de Tuberculatus kuricola (Hemiptera: Aphididae) spbre catasnos hibridos en Espana. *Boletin de Sanidad Vegetal: Plagas* 27: 395–400.

Pérez Hidalgo N, Gonzales Hernandez A, Seco Fernandez MV (2000) Dos especies de Cerataphis (Hemiptera, Aphididae: Hormaphidinae) introducidas en las Islas Canarias. *Boletin de Sanidad Vegetal: Plagas* 26: 425–432.

Pérez-Hidalgo N, Nieto Nafria JM (2005) Tinocallis ulmiparvifoliae Matsumura, 1919 (Hemiptera: Aphididae, calaphidinae): une nueva especie de pulgon introducida en la peninsula ibérica. *Boletin de la Asociacion espanola de Entomologia* 29: 125–127.

Pérez Hidalgo N, Pons X, Mier Durante M (2008) Detection of Drepanaphis acerifoliae (Thomas) [Hemiptera: Aphididae: Drepanosiphinae] on sugar maple trees, Acer saccharinum, in Spain. *Boletin Sociedad Entomologica Aragonesa* 43: 441–444.

Petrović O (1998) Check-list of aphids (Homoptera :Aphididae) in Serbia. *Acta entomologica serbica* 3: 9–42.

Petrović O, Milanović S (1999) [Pterochloroides persicae Choldk. – new pest of peach in Serbia] (in Serbian). *Biljni lekar* 4: 354–356.

Petrović-Obradović O, Tomanović Ž, Poljaković-Pajnik L, Vučetić A (2007) An invasive species of aphid, *Prociphilus fraxinifolii* (Hemiptera, Aphididae, Eriosomatinae), found in Serbia. *Archives of Biological Sciences, Belgrade* 59: 9–10.

Petrović-Obradović O, Tomanović Ž, Poljaković-Pajnik L, Hrnčić S, Vučetić A, Radonjić S (2010) New Invasive Species of Aphids (Hemiptera, Aphididae) in Serbia and Montenegro. *Archives of Biological Sciences, Belgrade* (in press).

Pintera A (1987) Taxonomic revision of the species of the genus *Chaitophorus* Koch in palearctis (Homoptera: Aphidoidea). *Deutsche Entomologische zeitschrift* 34: 219–340.

Piron PGM (1987) The advance of the Americal lupin aphid (*Macrosiphum albifrons* Essig) (Homoptera: Aphididae) in Europe. *Journal of Applied Entomology* 103: 111–112.

Poljaković-Pajnik L, Petrović-Obradović O (2002) Bow-legged fir aphid *Cinara curvipes* (Patch) (Aphididae, Homoptera) new pest of *Abies concolor* in Serbia. *Acta entomologica serbica* 7: 147–150.

Poljaković-Pajnik L, Petrović-Obradović O (2009) *Chaitophorus populifolii* (Aphididae : Homoptera) new species on poplars in Serbia. In: *Proceedings International Scientific Conference Forestry in achieving millennium goals*, Novi Sad, Serbia, November 2009, 379–381.

Prior RNB (1971) Some notes on new or uncommon aphids recently found in Britain. *Zoological Journal of the Linnean Society* 50: 397–430.

Prior RNB (1974) Three Japanese aphids introduced to Britain on imported «bonsai» trees. *Plant Pathology* 23: 48.

Prior RNB (1975) Three north american aphid species recently found in Britain infesting cultivated rose, *Cupressus macrocarpa* and *Poa trivialis*. *Plant Pathology* 24:123–124.

Qiao G, Zhang GX (2004) Prelimary study of aphid diversity in China: taxonomic and geographic variation. In: Simon JC, Dedryver CA, Rispe C, Hullé M (Eds) *Aphids in a new Millenium. Proceedings of the 6th International Symposium on aphids*. Rennes, France Sept. 2001, INRA Editions, 139–146.

Quednau FW (1954) Monographie der mitteleuropäischen Callaphididae (Zierläuse (Homoptera, Aphidina)) unter besonderer Berücksichtigung des ersten Jugendstadiums. I. Die Junglarven des ersten Stadiums der mitteleuropäischen Callaphididae. *Mitteilungen der Biologischen Bundesanstalt für Land- und Forstwirtschaft* 78: 1–55.

Quednau FW (1999) Atlas of the Drepanosiphine aphids of the world. Part I.: *Panaphidini* Oestlund, 1922 - *Myzocallidina* Börner, 1942 (1930) (Hemiptera: Aphididae: Calaphidinae). *Contributions of the American Entomological Institute* 31: 1–281.

Quednau FW (2003) Atlas of the drepanosiphine aphids of the world. Part II: Panaphidini Oestlund, 1922 - Panaphidina, Oestlund 1923 (Hemiptera: Aphididae: Calaphidinae). *Memoirs of the American Entomological Institute* 72: 1–301.

Rabasse JM, Coceano PG, Barbagallo S (2005) On the presence in France and North Italy of Siphonatrophia cupressi (homoptera, Aphididae), a new aphid of North American origin living on Cupressaceae. *Bolletino de Zoologia Agraria e Bachicultura* 37: 77–83.

Rabasse JM, Drescher J, Chaubet B, Limonta L, Turpeau E, Barbagallo S (2005) On the presence in Europe of two *Illinoia* aphids of North American origin (Homoptera, Aphididae). *Bolletino di Zoologia Agraria e di Bachicoltura, serie II* 37: 151–168.

Rabitsch W, Essl F (2006) Biological invasions in Austria: patterns and case studies. *Biological Invasions* 8: 295–308.

Remaudière G (1951) Contribution à l'étude des Aphidoidea de la faune française. Description de quelques Aphididae nouveaux et addition a la liste des *Myzinae* et *Dactynotinae*. *Revue de Pathologie Végétale et d'Entomologie Agricole de France* 30: 125–144.

Remaudière G (1952) Contribution à l'étude des Aphidoidea de la faune française. Description de quelques Aphididae nouveaux et addition a la liste des *Myzinae* et *Dactynotinae*. *Revue de Pathologie Végétale et d'Entomologie Agricole de France* 31: 232–263.

Remaudière G (1954) Contribution à l'étude des Aphidoidea de la faune française (7^{e} note). Deuxième addition a la liste des *Dactynotinae* et *Myzinae* (Hom. Aphidoidea) de la faune Française. *Revue de Pathologie Végétale et d'Entomologie Agricole de France* 30: 2125–144.

Remaudière G (1989) Découverte en France de l'espèce américaine *Myzocallis* (*Lineomyzocallis*) *walshii* (Monell) (Hom. Aphididae). *Annales de la Société Entomologique de France* 25: 117.

Remaudière G, Eastop VF, Autrique A (1985) Distribution des aphides de la region éthiopienne. In: Remaudière G (Ed) Contribution à l'écologie des aphides africains. Roma, Italy: Organisation des Nations Unies pour l'Alimentation et l'Agriculture, 77–93.

Remaudière G, Quednau FW, Heie OE (1988) Un nouveau Tinocallis sur Ulmus, originaire d'Asie Centrale et semblable à T. saltans (Nevsky (Homoptera; Aphididae). *The Canadian Entomologist* 120: 211–219.

Remaudière G (1989) Découverte en France de l'espèce américaine *Myzocallis (Lineomyzocallis) walshii* (Monell) (Hom.Aphididae). *Revue Francaise d'Entomologie*: 14: 172.

Remaudière G, Serain M, Trouve C, Demeester S (1992) Données nouvelles sur le genre *Trichosiphonaphis* Takahashi: cycles, hôtes, synonymies et distribution géographique (Homoptera, Aphididae). *Revue Française d'Entomologie* 14: 40–58.

Remaudière G, Munoz Viveros AL (1992) Sur la presence en France de *Myzus hemerocallis* Talahashi (Homoptera, Aphididae). *Revue Francaise d'Entomologie* 14: 172.

Remaudière G, Sorin M (1993) Two new aphids of the genus *Tuberocephalus* Shinji (Homoptera, Aphididae). *Japanese Journal of Entomology* 61: 683–690.

Remaudière G, Remaudière M (1997) Catalogue des Aphididae du monde - Catalogue of the world's Aphididae (Homoptera, Aphidoidea). Paris, France: INRA Editions. 437 pp.

Remaudière G, Ripka G (2003) Arrival in Europe (Budapest, Hungary) of American ash aphid, *Prociphilus (Meliarhizophagus) fraxinifolii* (Hemiptera, Aphididae, Eriosomatinae, Pemphigini). *Revue Francaise d'Entomologie* 25: 152.

Remaudière G, Sertkaya E, Ozdemir I (2003) Alert! Discovery in Turkey of the American aphid, *Aphis illinoisensis*, a grapevine pest (Hemiptera, Aphididae). *Revue Francaise d'Entomologie* 25: 170.

Ripka G (2001) New data to the knwoledge of the aphid fauna of Hungary (Homoptera: Aphidoidea). *Acta Phytopathologica et Enomologia Hungarica* 36: 81–87.

Roberti D (1975) Aspetti fitopatologici della mandorlicoltura puglirse: gli insetti. *Entomologica* 11: 9–20.

Scheurer S, Binazzi A (2004) Notes in bio-ecology and ethology of *Cinara curvipes* (Patch), a newly introduced species into Europe (Aphididae, Lachninae). *Redia* 87: 61–65.

Schouteden H (1906) catalogue des aphides de Belgique. *Mémoires de la Société Entomologique des Belgique* 12: 189–246.

Silvestri F (1939) Compendio di Entomologia applicata, VolI. Portici, Napoli, Italy: Tipografia Bellavista. 972pp.

Sousa-Silva CR, Ilharco FA (1995) *Afideos do Brazil e suas plantas hospedeiras;* Sao Carlos, Brazil: Editora da Univeridade de Sao Carlos. 85pp.

Stroyan HLG (1950) Recent additions to the British aphid fauna. Part. I. *Dactynotus* Rafinesque to *Rhopalosiphum* Koch C.L. *Transactions of the Royal Entomological Society (Lond.)* 101: 90–123.

Stroyan HLG (1954) A new subgenus and species of *Myzus* (Passerini, 1860). Proceeding *of the Royal Entomological Society* (Lond.) 23: 1–40.

Stroyan HLG (1956) More Merioneth aphid records. *The Entomologist* 89: 302–303.

Stroyan HLG (1964) Notes on hitherto unrecorded or overlooked british aphid species. *Transactions of the Royal Entomological Society* (Lond.) 116: 29–72.

Stroyan HLG (1971) *Masonaphis lambersi* MacGill: An introduced aphid pest of hybrid rhododendron. *Plant Pathology* 20: 196.

Stroyan HLG (1972) Additions and amendments to the check list of British aphids (Homoptera: Aphidoidea). *Transactions of the Royal Entomological Society* (Lond.) 124: 37–79.

Stroyan HLG (1977) *Homoptera. Aphididae (Part) Chaitophoridae, Callaphididae. Handbooks for the identification of British Insects Vol. 2 Part 4a*. London, UK : Royal Entomological Society of London. 130 pp.

Stroyan HLG (1981) A North American lupin aphid found in Britain. *Plant Pathology* 30: 253.

Stroyan HLG (1984) *Aphids – Pterocommatinae and Aphidinae, Homoptera. Aphididae. Handbooks for the identification of British Insects Vol. 2 Part 6*. London, UK: Royal Entomological Society of London. 232 pp.

Sűss L (1972–73) Reperti afidologici su alcune piante in serra nel Milanese. *Bollettino di Zoologia Agraria e di Bachicoltura ser. II* 11: 177–193.

Szelegiewicz H (1978) Przeglad systematyczny mszyc polski. Zeszyty problemowe postepow nauk rolniczych. *Polska Akademia Nauk* 208: 40pp.

Tambs-Lyche H, Heie O (1973) An Asian aphid suddenly appearing in large numbers on *Impatiens parviflora* in Europe. *Entomologiske Meddelelser* 41: 167–173.

Tashev D (1961) Novi listni vushki (Homoptera, Aphididae) za faunata na Bulgaria, godishnik na SU, biologo-geologo-geografski fakultet. *1-biologia* 1958/1959, 53: 157–162.

Tashev D (1964) Novi za faunata na Bulgaria listni bushki (Homoptera Aphididae), godishnik na SU biologo-geologo-geografski fakultet. *1-biologia* 1961/1962, 56: 179–190.

Tashev D (1982) A list of the aphids from Bulgaria. *Annuaire de Universite de Sofia "Kliment Ohridski" Faculte de Biologie; Livre 1 – Zoologie*: 20–35.

Tavares JS (1900) As zoocecidias Portuguesas. *Anais das Ciencias Naturaes* 7: 15–108.

Tavares JS (1905) Synopse das zoocecidias portuguesa. *Broteria* 4: 1–123.

Taylor LR, Palmer JMP (1972) Aerial sampling. In: Van Emdem HF (Ed) *Aphid Technology*. London, UK: Academic Press, 189–234.

Theobald FV (1912) A new strawberry *Aphis*. *The Entomologist* 45: 223.

Theobald FV (1913) The British species of the genus Macrosiphum pass. *Journal of Economical biology* 8: 47–94.

Theobald FV (1918) Notes on new and little known british aphides IV. *The Entomologist* 51:25–29.

Theobald FV (1926) *The plant lice or Aphididae of Great Britain, Vol I.*, London, UK: headley Brothers. 372pp.

Theobald FV (1927) *The plant lice or Aphididae of Great Britain, Vol 2.*, London, UK: headley Brothers. 411pp.

Theobald FV (1929) *The plant lice or Aphididae of Great Britain 3*. London, UK: Headley Brothers. 364 pp.

Tschorbadjiev P (1924) Konstatirani vredni nasekomi i drugi zivotinski nepriyateli po kulturnite rasteniya w Bulgaria prez 1923 g. *Svedeniya po zemedelieto* 5: 2–26.

Tsitsipis JA, Angelakis E, Margaritopoulos JT, Tsamandani K, Zarpas KD (2005) First record of the grapevine aphid *Aphis illinoisensis* in the island of Kriti, Greece. *Bulletin OEPP/EPPO* 35: 541–542.

Tsitsipis JA, Katis N, Margaritopoulos J, Lykouressis D, Avgelis A, Gargalianou I, Zarpas K, Perdikis D, Papapanayotou A (2007) A contribution to the aphid fauna of Greece. *Bulletin of Insectology* 60: 31–38.

Turpeau E, Remaudière G (1990) Découverte en France d'un puceron des pins américains du genre *Essigella* (Hom. Aphididae). *Comptes-Rendus de l'Académie d'Agriculture de France* 76: 131–132.

Van Harten A (1982) Lista anotada dos afideos (Homoptera: Aphidoidea) conhecidos das Ilhas de cabo Verde. *Agronomia lusitana* 41: 313–321.

Van Harten A, Coceano GG (1981) On some interesting species (Hemiptera Aphidoidea) trapped in Udine Province, Italy. *Bollettino del Labratorio di Entomologia Agraria "Filippo Silvestri" in Portici* 38: 29–51.

Vasilev IV (1910) Brachcevaja, ili tykvennaja tlja (*Aphis gossypii* Glover). *Trudy Byuro Entomologii* 8: 1–24.

Velimirovic V (1976) A new pest in yugoslavia *Pterochloroides persicae* (Homoptera. Aphididae) on peach trees. *Zastita Bilja* 27: 29–35.

Walker F (1848) Descriptions of aphids (2). *Annals and magazine of natural History* 1: 443–454.

Walker F (1849) Descriptions of new British aphides. *Zoologist* 7: xxxi-xl.

Ward PH (1961) A note on an aphid new to Europe. *Entomologist's Gazette* 12: 116.

Table 9.1.1. List and main characteristics of Aphididae species alien *to* Europe. Status: A: Alien *to* Europe; C: cryptogenic species. Country codes abbreviations refer to ISO 3166 (see appendix I). Habitat abbreviations refer to EUNIS (see appendix II). Only selected references are given. Last update February 2010.

Species	**Status**	**Feeding Regime**	**Native range**	**1st record in invaded areas**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Acyrthosiphon Acyrthosiphon caraganae Cholodkovsky 1908	A	phytophagous	Asia-Temperate	1907, RU	AL, AT, BG, CH, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IT, IT-SIC, LT, LV, MK, NO, NL, NO, PL, RO, RS, RU, SE, SI, SK, UA	F, I2	*Caragana.* other Fabaceae	Cholodkovsky (1907), Hržič (1996), Mordvilko (1914), Petrović (1998), Remaudière (1951), Tashev (1982)
Acyrthosiphon Acyrthosiphon kondoi Shinji, 1938	A	phytophagous	Asia-Temperate	< 2004, FR-COR	FR-COR, GR	E, I1	*Medicago*	Eastop (1971), Nieto Nafria e al. (2007), Tsitsipis et al. (2007)
Acyrthosiphon Acyrthosiphon primulae Theoblad 1913	A	phytophagous	Asia-Temperate	1913, GB	BG, CH, CZ, DK, ES, FR, DE, GB, GR, IE, IT, IT-SIC, NL, PT, SE, SK	I2, J100	*Primula*	Heie (1994), Remaudière (1952), Theobald (1913), Tsitsipis et al. (2007)
Aloephagus myersi Essig, 1950	A	phytophagous	Africa	1937, GB	ES, FR, GB, GR, IT, IT-SIC	I2, J100	*Aloe, Haworthia, Gasteria*	Eastop (1956), Leclant (1978), Micieli De Biase (1988), Tsitsipis et al. (2007)
Aphis Aphis forbesi Weed, 1889	A	phytophagous	North America	1928, FR	AL, AT, BE, BG, CH, CZ, DE, DK, EE, ES, FR, HR, HU, IT, LV, MD, PL, RO, RS, SK	I1, J100	*Fragaria*	Balachowsky (1933), Heie (1986), Paillot (1928)
Aphis Aphis gossypii Glover 1877	A	phytophagous	Tropical, subtropical	<1758 Unknown	AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, ES-BAL, ES-CAN, FI, FR, FR-COR, GB, GR, GR-CRE, HR, HU, IL, IT, IT-SAR, IT-SIC, LT, LV, MD, MK, NO, PL, PT, PT-AZO, PT-MAD, RO, RS, RU, SE, SK, UA	I2, I1, J100, E, F	Polyphagous (mainly Cucurbitaceae, Rutaceae and Malvaceae)	Blackman and Eastop (2006), Buckton (1879), Theobald (1927), Tschorbadjiev (1924), Vasilev (1910)

Species	**Status**	**Feeding Regime**	**Native range**	**1st record in invaded areas**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Aphis Aphis illinoisensis Shimer 1866	A	phyto-phagous	North America	2005, GR-CRE	GR-CRE, ME	FB	*Vitis*	Petrović-Obradović et al. (in press), Tsitsipis et al. (2005)
Aphis Aphis spiraecola Patch, 1914	A	phyto-phagous	Asia-Temperate	1961, PT	AT, BG, CH, DE, ES, ES-BAL, ES-CAN, FR, FR-COR, GB, GR, HR, IL, IT, IT-SAR, IT-SIC, MT, PT, PT-AZO, PT-MAD, RS, UA	E, I2, FA, FB, G	Polyphagous (*Citrus*, apple, *Spiraea*)	Blackman and Eastop (2000), Blackman and Eastop (2007), Ilharco (1968b)
Aphis Aphis spiraephaga F.P. Müller, 1961	A	phyto-phagous	Asia-Temperate	1955, CZ	AL, AT, CH, CZ, DE, DK, ES, FI, FR, HR, HU, IT-SIC, LT, LV, MD, MK, PL, PT, RO, RU, SE, SI, SK, UA	I2	*Spiraea*	Heie (1986), Holman (1971), Ilharco (1968b), Ilharco (1973), Tashev (1964)
Aphis Aphis spiraephila Patch, 1914	A	phyto-phagous	North America	1955 UA	UA	I2	*Spiraea*	Holman (1971), Nieto Nafria et al. (2007)
Aphis Bursaphis oenotherae oenotherae Oestlund 1887	A	phyto-phagous	North America	1972, DE	FR, DE, GB, IT-SIC, PL, RS	G3, I2	*Oenothera*	Barbagallo (1994), Műller (1974)
Aphis catalpae Mamontova, 1953	A	phyto-phagous	Asia	0	HU, UA	I2	*Catalpa*	Mamontova (1955), Petrović-Obradović et al. (in press), Ripka (2001)
Appendiseta robiniae (Gillette, 1907)	A	phyto-phagous	North America	1978, IT	BE, BG, CH, CZ, DE, ES, ES-BAL, FR, FR-COR, GB, GR, HR, HU, IT, IT-SIC, NL, RS, SK	I2, G5	*Robinia*	Arzone and Vidano (1990), Lampel (1983), Leclant and Remaudière (1986), Micieli De Biase and Calambuca (1979), Pati and Tomatore (1988), Petrović (1998)
Brachycaudus Mordvilkomemor rumexicolens (Patch, 1917)	A	phyto-phagous	North America	1953, GB	BE, CZ, DE, DK, ES, ES-CAN, FI, FR, GB, IT, IT-SAR, IT-SIC, MK, NL, NO, PL, PT, PT-MAD, RO, RU, SE, SK, UA	H5, I1	*Rumex;* other Polygonaceae	Barbagallo (1994), Barbagallo and Stroyan (1982), Heie (1973), Holman (1965), Ilharco (1974), Stroyan (1956)

Species	**Status**	**Feeding Regime**	**Native range**	**1st record in invaded areas**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Cerataphis brasiliensis (Hempel, 1901)	A	phyto-phagous	Asia-Tropical	1981, PT-MAD	ES-CAN, FR, PT-MAD	I2, J100	Palms	Chapin and Germain (2005), Germain and Chapin (2004), Ilharco (1984), Pérez Hidalgo et al. (2000)
Cerataphis lataniae (Boisduval, 1867)	A	phyto-phagous	Asia-tropical	1867, FR	CZ, ES-CAN, DE, FR, GB, IT, PL	I2, J100	*Areca, Musa*	Boisduval (1867), Chapin and Germain (2005), Pérez Hidalgo et al. (2000)
Cerataphis orchidearum (Westwood, 1879)	A	phyto-phagous	Asia-Tropical	1906, BE	BE, ES, FI, FR, GB, HU, PT-MAD, RU, SE	J100	Orchids	Germain and Chapin (2004), Heie (1980), Ilharco (1973), Ilharco (1974), Schouteden (1906)
Chaetosiphon Pentatrichopus fragaefolii (Cockerell, 1901)	A	phyto-phagous	North America	1912, GB	AT, BE, BG, CH, CZ, ES, ES-CAN, FR, DE, GB, HR, HU, IE, IL, IT-SIC, IT, LV, MK, NL, NO, PT, PT-AZO, PT-MAD, RO, RS, SI	I1, J100	*Fragaria*	Balachowsky (1933), Theobald (1912)
Chaitophorus populifolii (Essig, 1912)	A	phyto-phagous	North America	1956, DE	DE, RS	I2	*Populus*	Pintera (1987), Poljaković-Pajnik and Petrović-Obradović (2009)
Chaitophorus saliapterus quinquemaculatus Bozhko 1976	A	phyto-phagous	Asia	1953,UA	IT, UA	F9	*Salix*	Binazzi and Barbagallo (1991), Bozhko (1976), Pintera (1987)

Species	**Status**	**Feeding Regime**	**Native range**	**1st record in invaded areas**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Chromaphis juglandicola (Kaltenbach, 1843)	A	phytophagous	Asia-Temperate	< 1758 Unknown	AT, BE, BG, CH, CZ, DE, DK, ES, ES-CAN, FR, FR-COR, GB, HR, HU, IL, IT, IT-SAR, IT-SIC, MD, MK, PL, PT-AZO, PT-MAD, PT, RO, RS, SE, SI, SK, UA	I2, G5	*Juglans*	Balachowsky and Mesnil (1935), Heie (1982), Kaltenbach (1843), Schouteden (1906), Theobald (1927)
Cinara Cedrobium laportei (Remaudière, 1954)	A	phytophagous	Africa	1967, FR	ES, FR, GB, IT, IT-SAR, IT-SIC, NL, PT, SI	G3, G5, I2	*Cedrus*	Covassi (1971), Emonnot et al. (1967), Leclant (1978)
Cinara Cinara cedri Mimeur, 1936	A	phytophagous	Africa	1974,IT	BE, CH, DK, ES, FR, GB, HR, HU, IL, IT, IT-SAR, IT-SIC, RS, SI	I2, G5	*Cedrus.*	Covassi and Binazzi (1974), Fabre (1976)
Cinara Cinara curvipes (Patch, 1912)	A	phytophagous	North America	1999, GB	CZ, CH, DE, GB, RS, SK, SL	I2	*Abies*	Angst et al. (2007), Jurc et al. (2009), Martin (2000), Poljaković-Pajnik and Petrović-Obradović (2002), Scheurer and Binazzi (2004)
Drepanaphis acerifoliae (Thomas, 1878)	A	phytophagous	North America	1992, IT	IT , ES	I2	*Acer*	Lozzia and Binaghi (1992), Pérez Hidalgo et al. (2008)
Ericaphis scammelli Mason 1940	A	phytophagous	North America	1964, GB	FR, GB, IT, NL	I1, I2	*Vaccinium*	Barbagallo et al. (1999), Barbagallo et al. (1998), Prior (1971)
Ericaphis wakibae (Hottes, 1934)	A	phytophagous	North America	1963, GB	CZ, GB	I1, B3	*Fragaria*	Stroyan (1972)

Species	**Status**	**Feeding Regime**	**Native range**	**1st record in invaded areas**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Eriosoma lanigerum (Hausmann, 1802)	A	phyto-phagous	North America	1787, GB	AL, AT, BE, BG, CH, CY, CZ, DE, DK, ES, ES-CAN, FR, DE, GB, GR, HR, HU, IE, IL, IT, IT-SAR, IT-SIC, LT, LV, MD, NO, PL, PT, PT-AZO, PT-MAD, RO, RU, RS, SE, SI, SK, UA	I, I1	*Malus*; orchard trees	Balachowsky and Mesnil (1935), Marchal (1928)
Essigella Essigella californica (Essig, 1909)	A	phyto-phagous	North America	1988, FR	ES,FR, IT, IT-SAR, IT-SIC, PT-MAD	G5, I2	*Pinus radiata*, *P. pinaster*	Aguiar and Ilharco (2001), Turpeau and Remaudière (1990)
Greenidea Greenidea ficicola Takahashi 1921	A	phyto-phagous	Asia-Tropical	2004, IT	ES, IT, IT-SIC	I2	*Ficus*	Barbagallo et al. (2005a), Mifsud (1998)
Hysteroneura setariae (Thomas, 1878)	A	phyto-phagous	North America	1982, PT-MAD	ES, PT-MAD	E, I	*Prunus*, fruit trees, Graminae	Blackman and Eastop (2006), Meliá Masiá (1995), Van Harten (1982)
Idiopterus nephrelepidis Davis, 1909	A	phyto-phagous	Tropical, sub-tropical	1915, GB	BE, CH, CZ, DE, DK, ES, ES-CAN, FR, GB, GR, IE, IL, IT, IT-SIC, NL, PL, PT, PT-AZO, PT-MAD, PT, RU, SE, SI, SK	I2, J1, J100	Tropical ferns indoors	Heie (1994), Laing (1923), Theobald (1926), Tsitsipis et al. (2007)
Illinoia Illinoia andromedae (MacGillivray, 1958)]	A	phyto-phagous	North America	1960, GB	GB	I2	Asteraceae	Eastop (1962), Stroyan (1964)
Illinoia Illinoia azaleae Mason, 1925	A	phyto-phagous	North America	1950, GB	AT, CH, CZ, DK, ES, FI, FR, DE, GB, HU, IT, IT-SIC, NL, PL, PT, PT-AZO, PT-MAD, RO, RU, SE, SI	I2, J100	*Rhododendron*; Ericaceae	Biurrun and Nieto Nafría (1987), Heie (1995), Ilharco (1968b), Stroyan (1950)

Species	**Status**	**Feeding Regime**	**Native range**	**1st record in invaded areas**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Illinoia Illinoia goldamaryae (Knowlton, 1938)	A	phyto-phagous	North America	1960, GB	GB	I2, J100	Astereacae (*Aster, Erigero., Solidago*)	Eastop (1962), Stroyan (1964), Ward (1961)
Illinoia Illinoia liriodendri (Monell, 1879)	A	phyto-phagous	North America	1998, FR	DE, FR, GB, IT, SI	G5, I2	*Liriodendron*	Limonta (2001), Rabasse et al. (2005b)
Illinoia Illinoia morrisoni (Swain, 1918)	A	phyto-phagous	North America	1960, GB	FR, GB	I2	*Cupressus*	Eastop (1962), Prior (1975), Rabasse et al. (2005b) Stroyan (1964)
Illinoia Masonaphis lambersi (MacGillivray, 1960)	A	phyto-phagous	North America	1971, NL	BE, CH, CZ, DK, GB, NL, NO, PT-MAD, SK	I2	*Rhododendron, Kalmia*	Aguiar and Ilharco (2001), Heie (1995), Hille Ris Lambers (1973), Stroyan (1971), Stroyan (1972)
Illinoia Masonaphis rhododendri (Wilson, 1918)]	A	phyto-phagous	North America	1939, GB	GB, NL, SK	I2, J100	*Rhododendron*	Eastop (1956), Heie (1994), Stroyan (1950)
Impatientinum Impatientinum asiaticum Nevsky 1929	A	phyto-phagous	Asia-Temperate	1967, RU	AT, CH, CZ, DE, DK, EE, FI, FR, GB, LV, PL, RO, RU, SE, SI, SK	G, I2, X25	*Impatiens*	Heie (1994), Holman (1971), Ilharco (1968b), Tambs-Lyche and Heie (1973)
Iziphya flabella (Sanborn, 1904)	A	phyto-phagous	North America	1954, DE	DE, UA	I2	*Carex*	Quednau (1954)
Macrosiphoniella Macrosiphoniella sanborni (Gillette, 1908)	A	phyto-phagous	Asia-Temperate	1907, PT	AL, AT, BE, BG, CH, CY, CZ, DK, ES, ES-CAN, FI, FR, DE, GB, GR, HR, IE, IL, IT, IT-SIC, LT, LV, MD, NO, PL, PT, PT-AZO, PT-MAD, RO, RS, RU,SE, UA	I2, J100	*Chrysan-themum*	Balachowsky and Mesnil (1935), Del Guercio (1911), Del Guercio (1913), Holman (2009), Ilharco (1968b), Ilharco (1974), Theobald (1926)

Species	**Status**	**Feeding Regime**	**Native range**	**1st record in invaded areas**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Macrosiphum Macrosiphum albifrons Essig, 1911	A	phyto-phagous	North America	1981, GB	AT, BE, CH, DE, FR, GB, GR, IE, IT, IT-SIC, SE	I1, I2	*Lupinus, Fragaria*	Carter et al. (1984), Hullé et al. (1998), Meier and Schweizer (1987), Piron (1987), Stroyan (1981)
Macrosiphum Macrosiphum euphorbiae (Thomas, 1878)	A	phyto-phagous	North America	1917, GB	AL, AT, BE, BG, CH, CZ, DK, EE, ES, ES-CAN, FI, FR, FR-COR, DE, GB, GR, HR, HU, IS, IE, IL, IT, IT-SAR, IT-SIC, LT, LV, MD, MK, MT, NO, PL, PT, PT-AZO, PT-MAD, RO, RS, RU, SE, SI, SK, UA	E, F, I, J, J100	Polyphagous (vegetables, *Fragaria*)	Blackman and Eastop (2000), Eastop (1958)
Macrosiphum Macrosiphum ptericolens Patch, 1919	A	phyto-phagous	North America	1972, GB	GB, PL	G	*Pteridium aquilinum* (bracken)	Holman (2009), Lawton and Eastop (1975)
Megoura lespedezae (Essig & Kuwana, 1918)	A	phyto-phagous	Asia-Temperate	1994, CH	CH	I1	Polyphagous (vegetables; *Lespedeza*, Japanese clover)	Giacalone and Lampel (1996)
Melanaphis bambusae (Fullaway, 1910)	A	phyto-phagous	Asia-Temperate	1961, IT	ES, FR, GR, IT-SIC, IT, PT, PT-MAD, RS	I2	*Bambusa*	Hille Ris Lambers (1966), Nieto Nafria et al. (2007)
Melaphis rhois (Fitch, 1866)	A	phyto-phagous	North America	1902, GB	GB, SE	I2	*Rhus*	Blackman and Eastop (1994), Theobald (1918), Theobald (1929)

Species	**Status**	**Feeding Regime**	**Native range**	**1st record in invaded areas**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Monellia caryella (Fitch, 1855)	A	phyto-phagous	North America	1985, ES	IL, ES	G5	*Juglans, Carya*	Hermoso de Mendoza (1988), Nieto Nafría and Mier Durante (1998)
Monelliopsis caryae (Monell ex Riley & Monell, 1879)	A	phyto-phagous	North America	1984, FR	ES, FR, HU, IL, IT, PT	G5	*Juglans, Carya*	Hullé et al. (1998), Mier Durante and Pérez Hidalgo (2002)
Monelliopsis pecanis Bissell, 1983	A	phyto-phagous	North America	1995, PT-MAD	IT-SIC, PT-MAD	G5	*Carya*	Aguiar and Ilharco (1997), Barbagallo and Suma (1999)
Myzaphis turanica Nevsky, 1929	C	phyto-phagous	Crypto-genic	1976, ES	ES,FR, GB, IT-SIC, SE	I2	*Rosa rugosa*	Meliá Masiá (1998), Patti (1983)
Myzocallis Lineomyzocallis walshii (Monell ex Riley & Monell, 1879)	A	phyto-phagous	North America	1988, FR	BE, CH, CZ, DE, ES, FR, HU, IT, IT-SIC, RS	G, I2	*Quercus rubra*	Hullé et al. (1998), Petrović-Obradović et al. (2007), Remaudière (1989)
Myzus Myzus hemerocallis Takahashi, 1921	A	phyto-phagous	Asia-Temperate	1990, FR	FR, PT-MAD	I2	*Hemerocallis*	Aguiar and Ilharco (1997), Remaudière and Munoz Viveros (1992)
Myzus Myzus ornatus Laing, 1932	A	phyto-phagous	Asia-Temperate	1932 GB	AL, AT, BE, BG, CH, CZ, DE, DK, EE, ES, ES-CAN, FI, FR, FR-COR, GB, GR, HR, HU, IE, IT, IT-SAR, IT-SIC, LV, NO, PL, PT, PT-AZO, PT-MAD, RO, RS, RU, SE, SI, SK	I, J100, X8	Polyphagous (*Prunus cornuta-*primary host); many herbaceous plants and vegetables-secondary host)	Blackman and Eastop (2000), Ilharco (1969), Laing (1932)

Species	**Status**	**Feeding Regime**	**Native range**	**1st record in invaded areas**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Myzus Myzus varians Davidson, 1912	A	phyto-phagous	Asia-Temperate	1946, CH	AL, AT, BA, BE, BG, CH, CZ, DE, ES, FR, FR-COR, MK, DE, GB, GR, HR, HU, IT, IT-SIC, PL, RO, RS, RU, SI, SK	I2, G5	*Prunus persicae, Clematis*	Blackman and Eastop (2000), Börner (1952), Hille Ris Lambers (1947)
Myzus Nectarosiphon ascalonicus Doncaster, 1946	A	phyto-phagous	Asia-Temperate	1941, GB	AL, AT, BE, BG, CH, CZ, DE, DK, ES, ES-CAN, FI, FR, MK, DE, GB, GR, HR, IE, IS, IT, LT, LV, NL, NO, PL, PT, PT-AZO, RO, RS, RU, SE, SK	I2, E	*Fragaria, Allium*	Börner (1952), Doncaster (1946)
Myzus Nectarosiphon persicae Sulzer 1776	C	phyto-phagous	Crypto-genic	<1758 Unknown	AL, AT, BE, BG, CH, CY, CZ, DK, EE, ES, ES-BAL, ES-CAN, FI, FR, FR-COR, MK, DE, GB, GR, GR-CRE, HR, HU, IE, IT, IT-SAR, IT-SIC, LT, LV, ME, MD, MT, NO, PL, PT, PT-AZO, PT-MAD, RO, RU, RS, SE, SI, SK, UA	G5	Polyphagous	Balachowsky and Mesnil (1935), Blackman and Eastop (2000), Boisduval (1867), Buckton (1876), Koch (1855), Macchiati (1883), Schouteden (1906), Theobald (1926)
Myzus Sciamyzus cymbalariae Stroyan, 1954	C	phyto-phagous	Crypto-genic	1950, GB	BE, CH, CZ, DE, ES, FR, GB, GR, IT, PT-AZO, PT-MAD	I	Polyphagous	Blackman and Eastop (2000), Ilharco (1974), Stroyan (1954)
Nearctaphis bakeri (Cowen ex Gillette & Baker, 1895)	A	phyto-phagous	North America	1964,FR	AL, CH, ES, ES-BAL, FR, DE, GB, GR, IT, IT-SIC, PT, PT-AZO, SK UA	I, E	Maloideae (primary hosts) and Fabaceae (secondary hosts; e.g. *Trifolium*)	Heie (1992), Leclant (1967), Stroyan (1972)

Species	**Status**	**Feeding Regime**	**Native range**	**1st record in invaded areas**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Neomyzus circumflexus Buckton 1876	A	phyto-phagous	Asia	1876, GB	AL, AT, BE, BG, CH, CZ, DE, DK, EE, ES, ES-CAN, FI, FR, FR-COR, GB, HR, HU, IE, IT, IT-SIC, LT, LV, MD, NL, NO, PL, PT, PT-AZO, PT-MAD, RO, RU, SE, UA	I2, J100	Polyphagous flower crops	Blackman and Eastop (2000), Buckton (1876), Ilharco (1969)
Neophyllaphis podocarpi Takahashi, 1920	A	phyto-phagous	Asia-Temperate	1990, IT	IT	I2	*Podocarpus*	Limonta (2001)
Neotoxoptera formosana (Takahashi, 1921)	A	phyto-phagous	Asia	1994, FI	DE, FI, FR, GB, IT, NL, PT-MAD	I1, J1, J100	*Allium*	Aguiar and Ilharco (2001), Barbagallo Ciampolini (2000), Blackman and Eastop (2000)
Neotoxoptera oliveri (Essig, 1935)	A	phyto-phagous	Asia-Temperate	1959, PT	ES, FR, IT-SIC, PT-MAD, PT, RS	I1, J100	*Viola, Allium*	Ilharco (1960), Ilharco (1968b)
Neotoxoptera violae (Pergande, 1900)	A	phyto-phagous	Asia-Temperate	1939, IT	ES, ES-CAN, FR, IT IT-SIC	I2	*Viola*	Barbagallo and Coccuzza (1998), Germain and Deogratias (2008) Silvestri (1939)
Panaphis juglandis (Goeze, 1778)	A	phyto-phagous	Asia	<1758 unknown	AL, AT, BE, BA, BG, CH, CZ, DK, ES, ES-CAN, FR, FR-COR, DK, GB, GR, HR, HU, IL, IT-SIC, IT, MD, PL, PT, RO, RS, SE, SI, SK, UA	I2, G5	*Juglans*	Blanchard (1840), Goeze (1778), Ilharco (1968a), Kaltenbach (1843), Malkov (1908), Schouteden (1906), Walker (1848)
Paoliella eastopi Hille Ris Lambers, 1973	A	phyto-phagous	Africa	<2004, GB	GB	U	Passionfruit in native range (Kenya)	Nieto Nafria et al. (2007)

Species	**Status**	**Feeding Regime**	**Native range**	**1st record in invaded areas**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Pemphigus Pemphigus populitransversus Riley ex Riley & Monell, 1879	A	phytophagous	North America	1966, PT-MAD	GB, PT-AZO, PT-MAD	I2, F	*Populus*	Blackman and Eastop (1994), Ilharco (1974)
Pentalonia nigronervosa Coquerel, 1859	A	phytophagous	Tropical, subtropical	1922, GB	DK, DE, GB, IL, IT, NL, PT-AZO, ES-CAN	J100	*Musa* (preferred); Polyphagous on tropical and subtropical ornamental plants	Cairaschi (1942), Sűss (1972–73)
Periphyllus californiensis (Shinji, 1917)	A	phytophagous	Asia-Temperate	1932, GB	HR, DK, DE, GB, IT, NL, CH	I2, G5	*Acer*	Blackman and Eastop (1994), Doncaster (1954), Eastop (1956),
Prociphilus Meliarhizophagus fraxinifolii Riley ex Riley & Monell, 1879	A	phytophagous	North America	2003, HU	BG, HU, RS	G, G5	*Fraxinus*	Petrović-Obradović et al. (2007), Remaudière and Ripka (2003)
Pterochloroides persicae (Cholodkovsky, 1899)	A	phytophagous	Asia-Temperate	1975, IT	AL, BG, CY, ES, FR, GR, IT, IT-SIC, RO, RS, UA	I2, G5	*Prunus*; fruit trees (peach)	Ciampolini and Martelli (1977), Petrović and Milanović (1999), Roberti (1975), Velimirovic (1976)
Pterocomma pseudopopuleum Palmer, 1952	A	phytophagous	North America	<2004, UA	EE, UA	G	Populus	Nieto Nafria et al. (2007)
Reticulaphis distylii vand der Goot 1917	A	phytophagous	Asia-Temperate	1998, PT	ES, PT	I2, G5	Ficus	Barbagallo et al. (2005b)
Rhodobium porosum (Sanderson, 1900)	A	phytophagous	Tropical, subtropical	1934, ES	AL, AT, BA, BG, CH, CZ, DE, DK, ES, ES-CAN, FI, FR, GB, GR, HU, IL, IT, IT-SIC, LV, NL, PL, PT, PT-MAD, RO, RS, SE, SI, SK	I2, J100	*Fragaria*, *Rosa* (in greenhouses in Central Europe)	Ilharco (1969), Mimeur (1936), Tashev (1964)

Species	**Status**	**Feeding Regime**	**Native range**	**1st record in invaded areas**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Rhopalosiphoninus Rhopalosiphoninus latysiphon (Davidson, 1912)	A	phyto-phagous	North America	1921, IT	AL, AT, BE, BG, CH, CZ, DE, ES, FR, GB, GR, HR, IT, IT-SIC, NL, PL, PT, PT-AZO, PT-MAD, RO, RU	I1	*Solanum;* polyphagous on vegetables (*Beta, Fragaria, Ipomea*) and flowers (*Gladiolus*)	Blackman and Eastop (2000), Remaudière (1952), Tashev (1961)
Rhopalosiphum insertum (Walker, 1849)	A	phyto-phagous	North America	1848 GB	AL, AT, BY, BE, BG, CH, CZ, DE, DK, EE, ES, ES-CAN, FI, YU, FR, FR-COR, DE, GB, GR, HU, IE, IT, LT, LV, MD, NL, NO, PL, PT, PT-AZO, PT-MAD, RO, RU, RS, SE, SI, SK, UA	I1, E	Graminae (*Poa, Festuca, Juncus*)	Blackman and Eastop (2000), Dospevski (1910), Ilharco (1968a), Walker (1849)
Rhopalosiphum maidis (Fitch, 1856)	A	phyto-phagous	Asia	1903, IT	AL, BE, BG, CH, CY, CZ, DE, DK, ES, ES-CAN, FI, ,FR, FR-COR, GB, GR, GR-CRE, HU, IT-SAR, IT-SIC, IT, LV, MD, NL, NO, PL, PT, PT-AZO, PT-MAD, RO, RS, RU, SE, ES, SK, UA	I1, E	Maize, sorghum; other crops	Blackman and Eastop (2000), Del Guercio (1913), Del Guercio (1917), Dospevski (1910), Eastop (1956), Heie (1986), Ilharco (1961)
Rhopalosiphum rufiabdominale (Sasaki, 1899)	A	phyto-phagous	Asia-Temperate	1960 PT	BG, DK, ES, FI, FR, GR, IT, IT-SIC, PT, PT-AZO, PT-MAD, RU, UA	I1	Rice roots, Gramineae	Blackman and Eastop (2006), Heie (1986), Ilharco (1968a), Ilharco (1973)
Sipha Sipha flava (Forbes, 1884)	A	phyto-phagous	North America	1979, PT-AZO	AL, PT-AZO	I1	Sugarcane	Sousa-Silva and Ilharco (1995)

Species	**Status**	**Feeding Regime**	**Native range**	**1st record in invaded areas**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Siphonatrophia cupressi Swain, 1918	A	phyto-phagous	North America	1999, FR	FR, IT	G5, I2, FA	*Cupressus*	Rabasse et al. (2005a)
Sitobion Sitobion alopecuri (Takahashi, 1921)	A	phyto-phagous	Asia-Temperate	<2004, GB	GB, NL	I2, E	Graminae	Blackman and Eastop (2006), Nieto Nafria ei al. (2007)
Sitobion Sitobion luteum (Buckton, 1876)	C	phyto-phagous	Crypto-genic	1875 GB	BE, DE, FR, GB, PT-MAD	J100	Orchidaceae, Bromeliaceae, Araceae	Blackman and Eastop (2006), Buckton (1876), Del Guercio (1911) Schouteden (1906)
Stomaphis mordvilkoi Hille Ris Lambers, 1933	A	phyto-phagous	Asia-Tropical	1980, IT	IT	G	*Juglans*	Colombo (1981)
Takecallis arundicolens (Clarke, 1903)	A	phyto-phagous	Asia-Temperate	1923, GB	CH, DE, ES, FR, GB, IE, IT, PT	I2	Bamboos	Hille Ris Lambers (1947), Ilharco (1969), Laing (1923), Stroyan (1964), Stroyan (1977), Theobald (1927)
Takecallis arundinariae (Essig, 1917)	A	phyto-phagous	Asia-Temperate	1961, GB	CH, DE, ES, GB, GR, IT, IT-SIC, PT-MAD	I2	Bamboos	Giacalone and Lampel (1996), Pati and Tomatore (1988), Stroyan (1964), Stroyan (1977)
Takecallis taiwana (Takahashi, 1926)	A	phyto-phagous	Asia-Temperate	1923, GB	CH, DE, ES, FR, GB, HR, IT, IT-SIC	I2	Bamboos (*Phyllostachys*)	Giacalone and Lampel (1996), Limonta (1990), Stroyan (1964)
Tinocallis Sappocallis nevskyi Remaudière, Quednau & Heie, 1988	A	phyto-phagous	Asia-Temperate	1978, PL	AT, BE, CH, CZ, DE, DK, FI, GB, HU, IT, NL, PL, SE	G, G5, I2, FA	*Ulmus*	Remaudière et al. (1988), Szelegiewicz (1978), Van Harten and Coceano (1981)

Species	**Status**	**Feeding Regime**	**Native range**	**1st record in invaded areas**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Tinocallis Sappocallis saltans (Nevsky, 1929)	A	phyto-phagous	Asia-Temperate	1976,RO	ES, FR, HU, IT, IT-SIC, MD, NL, PL, RO, RU, UA	G, G5, I2	*Ulmus*	Holman and Pintera (1981), Hullé et al. (1998), Remaudière et al. (1988), Van Harten and Coceano (1981)
Tinocallis Sappocallis takachihoensis Higuchi 1972	A	phyto-phagous	Asia-Temperate	1985, FR	ES, FR, IT, IT-SIC	G, G5, I2	*Ulmus*	Hullé et al. (1998), Leclant and Renoust (1986), Leclant and Remaudière (1986)
Tinocallis Sarucallis kahawaluokalani (Kirkaldy, 1906)	A	phyto-phagous	Asia-Temperate	1984, IT	DE, ES, FR, GR, IT, IT-SIC, ME	I2, G5	*Lagerstroemia indica*	Arzone and Vidano (1990), Leclant and Renoust (1986), Ossiannilsson (1959), Pati (1984), Petrović-Obradović et al. (in press)
Tinocallis Tinocallis ulmiparvifoliae Matsumura, 1919	A	phyto-phagous	Asia-Temperate	1973, GB	ES, GB, IT	I2, J100	*Ulmus*	Lucchi and Pollini (1995), Pérez Hidalgo and Nieto Nafria (2005), Prior (1971), Stroyan (1977)
Tinocallis Tinocallis zelkowae (Takahashi, 1919)	A	phyto-phagous	Asia-Temperate	1973, GB	FR, GB	I2, J100	*Zelkova*	Prior (1971), Stroyan (1977)
Toxoptera aurantii Boyer de Fonscolombe 1841	A	phyto-phagous	Tropical, sub-tropical	1841 FR	AL, BE, CH, CY, DE, ES, ES-BAL, FR, FR-COR, GB, GR, HR, IL, IT, IT-SAR, IT-SIC, ME, MT, PT-AZO, PT-MAD, PT, RO	I, G5, J100	Polyphagous (mainly *Citrus*)	Boyer de Foscolombe (1841), Del Guercio (1917), Passerini (1861), Stroyan (1984), Tavares (1900)

Species	**Status**	**Feeding Regime**	**Native range**	**1st record in invaded areas**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Toxoptera citricidus Kirkaldy 1906	A	phyto-phagous	Tropical, sub-tropical	1994, PT-MAD	ES, PT, PT-MAD	I, G5	*Citrus*	Aguiar et al. (1994), Ilharco et al. (2005)
Trichosiphonaphis Xenomyzus polygonifoliae (Shinji, 1944)	A	phyto-phagous	Asia-Temperate	1990, FR	FR, GB, HU, IT, RS, UA	I2	*Lonicera, Polygonum*	Coceano and Petrovic-Obradovic (2006), Petrović-Obradović et al. (in press), Remaudière et al. (1992)
Tuberculatus Nippocallis kuricola (Matsumura, 1917)	A	phyto-phagous	Asia-Temperate	1981, PT-MAD	ES, PT, PT-AZO, PT-MAD	G1, I2	*Castanea, Quercus*	Ilharco (1984), Pedro Mansilla et al. (2001)
Uroleucon Lambersius erigeronense (Thomas, 1878)	A	phyto-phagous	North America	1952, FR	AT, BE, CH, CZ, DE, DK, ES, FI, FR, GB, GR, HU, IT, IT-SIC, LV, MD, NL, PL, PT-MAD, RO, RS, SE, SI, RK	J, J6	Asteraceae (*Erigeron, Coniza*)	Blackman and Eastop (2006), Heie (1995), Remaudière (1954)
Uroleucon Uroleucon pseudoambrosiae (Olive, 1963)	A	phyto-phagous	North America	<2004	PL	I	Asteraceae (Mainly *Lactuca* spp.)	Blackman and Eastop (2000), Blackman and Eastop (2006), Nieto Nafria et al. (2007)
Utamphorophora humboldti (Essig, 1941)	A	phyto-phagous	North America	1974, GB	FR, GB, GR, IE	I2	*Physocarpus*, Poaceae	Hullé et al. (1998), Prior (1975), Tsitsipis et al. (2007)
Wahlgreniella arbuti (Davidson, 1910)	A	phyto-phagous	North America	1905, PT	ES, ES-BAL, FR, FR-COR, GB, GR, IT, IT-SAR, IT-SIC, NL, PT, PT-MAD	I2, F6	*Arbutus, Arctostaphylos*	Heie (1995), Ilharco (1969), Tavares (1905), Tsitsipis et al. (2007)
Wahlgreniella nervata (Gillette, 1908)	A	phyto-phagous	North America	1973, GB	AT, BE, ES, ES-CAN, FR, GB, GR, IT-SIC	I2	*Rosa*	Blackman and Eastop (2006), Prior (1975), Tsitsipis et al. (2007)

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Scales (Hemiptera, Superfamily Coccoidea)
Chapter 9.3

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Abstract

Scale insects are frequent invaders. With 129 established species, they numerically represent one of the major group of insects alien *to* Europe. Scales are usually small insects with wingless females. Due to this small size and concealment, many species, mainly belonging to the families Diaspididae, Pseudococcidae and Pseudococcidae, have been accidentally introduced to Europe, mostly originating from tropical regions and essentially from Asia. The trade of fruit trees and ornamentals appears to be the usual pathway of introduction. At present, alien scales represent an important component of the European entomofauna, accounting for about 30% of the total scale fauna.

Keywords

Europe, Alien, scale insects

9.3.1 Introduction

Coccoidea or scale insects is a large superfamily in the order Hemiptera with a worldwide distribution. They are unusually small insects, highly specialized for plant parasitism, that have evolved different kinds of metamorphosis depending on sex and family. Scale insects are characterized by sexual dimorphism: females are wingless, usually small (from 0.5 – 10mm), with an oval or round but flat to fairly convex body

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form, sometimes bud shaped, and often protected by waxy secretions or covers. The adult females may exhibit reduction or loss of appendages, depending on family and instar, and are often sedentary or sessile. Adult males are usually winged and inconspicuous, do not feed and live a few days. Scale insect identification is mainly based upon the morphology of adult females that persist on the host plant longer than the other stages.

Females usually take three or four developmental stages to reach maturity, males usually five. Parthenogenesis is quite common. Eggs are usually laid under the female body, under the scale cover, or in waxy egg-sacs. Dispersal is carried out by first instars.

Scale insects feed on various parts of the host plant (leaves, fruits, stems, branches and roots) and are frequently introduced and acclimatized in different parts of the world. This is due to their small size (first instars are about 0.2–0.3mm; adult females usually are from 0.5 to10mm long) and their concealment using waxy secretions; beside many species live in hidden habitats (under leaf sheaths, in bark crevices or on roots) so that they can easily escape visual quarantine inspections. Once in a new territory, parthenogenesis and high fecundity favour quick colonization starting from a few females: for example, a single female *Neopulvinaria innumerabilis* may lay up to 8000 eggs (Canard 1968).

9.3.2 Taxonomy of the scale species alien *to* Europe

According to Ben-Dov et al. (2006) the superfamily Coccoidea comprises 22 families, with more than 7300 described species. In Europe, native representatives of 12 families have so far been recognized. On the basis of the best known western and central European coccoid faunas (France, Italy, Hungary) (Ben-Dov et al. 2006, Foldi 2001, Pellizzari and Russo 2004), the total number of scale insects present in Europe is likely to reach about 400–450 species. Aliens recorded in Europe up until 2007 account for 129 species which include the following eight families: Diaspididae (60 species), Pseudococcidae (37), Coccidae (23), Eriococcidae (3), Margarodidae (2), Asterolecanidae, Ortheziidae, and the alien family Phoenicococcidae, each with one species (Table 9.3.1). Unlike for other taxa, aliens represent an important component of the scale fauna currently present in Europe, i.e. near 30% (Fig. 9.3.1).

The remaining five native families (Aclerdidae, Cerococcidae, Kermesidae, Lecanodiaspididae, Micrococcidae) each have one or two species in Europe: none of them is a pest, with the exception of the family Kermesidae (8 species in Europe), in which *Kermes vermilio* and *Nidularia pulvinata* exhibit outbreaks in urban environments only.

One species, *Dactylopius coccus* Costa, representing the alien family Dactylopiidae, has been included among aliens *to* Europe, even though it is present only in Canary islands, Madeira and Azores, where it was intentionally introduced. These islands belong politically to Europe (Spain, Portugal) but biogeographically they belong to Macaronesia, a biogeographic Atlantic region quite distinct from the European continent and with a unique flora and fauna.

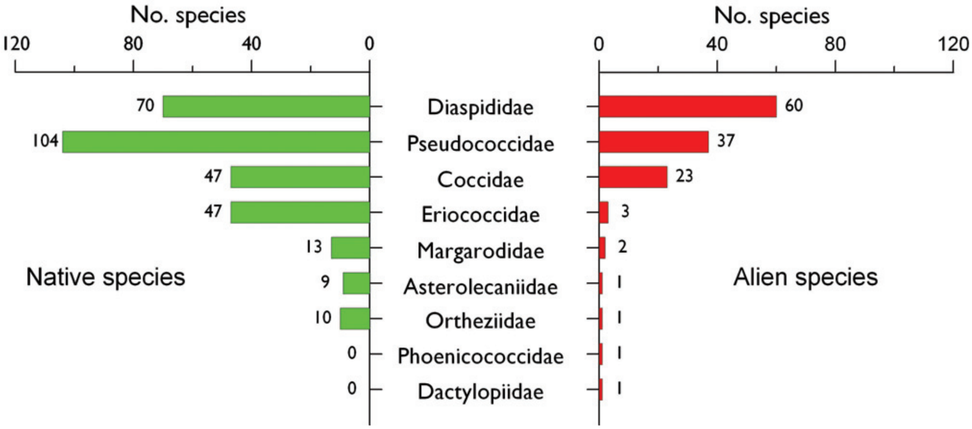

Figure 9.3.1 Taxonomic overview of the scale species alien *to* Europe compared to the native fauna. Species alien *to* Europe include cryptogenics.

Diaspididae

Armoured scale insects are the commonest alien scales incidentally introduced all over the world: this is probably due to their small dimension and camouflage. The 60 alien species account for nearly half (44.6%) of an estimated 130 species in Europe. Many notorious pests of fruit trees such as *Pseudaulacaspis pentagona* (the white peach scale- see factsheet 14.45)) and *Diaspidiotus perniciosus* (San José scale - see factsheet 14.44)) belong to this family: these species are still pests of fruit trees in spite of the introduction of specific parasitoids from their native area. The Asiatic armoured scales of *Citrus* are largely found in European *Citrus* groves and presently number 10 species. Their "invasion" started around 1850 with *Parlatoria ziziphi* and *Lepidosaphes becki* and is still going on with the arrival and establishment of *Unaspis yanonensis* (1969), *Aonidiella citrina* (1994), *Chrysomphalus aonidum* (2000). Several armoured scales commonly occur throughout European greenhouses (e.g. *Diaspis echinocacti*, *Chrysomphalus dictyospermi*, *Diaspis bromeliae*, *Abgrallaspis cyanophylli*), even if they cannot be considered as established. In some cases, species recorded only in greenhouses in northern and central Europe are established outdoors in southern countries (i.e. *Furchadaspis zamiae, Chrysomphalus aonidum*). Some armoured scales thought to be of Afrotropical origin or cryptogenic (e.g. *Aspidiotus nerii*, *Hemiberlesia lataniae, H. rapax*) are very common in natural habitats of the Mediterranean countries (including small islands).

Pseudococcidae

Mealybugs are covered with mealy or cottony wax, have a distinct segmentation and are mobile. The 37 alien mealybugs account for roughly one fourth (25.7%) of the ca. 140 European species and most of them are polyphagous. *Planococcus citri, Pseu-*

dococcus longispinus, P. viburni and *P. calceolariae* arrived and established during the 19th century and are presently the most common species on ornamental plants, both outdoors and indoors. *P. citri*, first recorded in 1813, is still a pest of *Citrus* and ornamental plants. Several mealybugs have been recorded in only one or two countries to date (e.g. *Palmicultor palmarum*, *Phenacoccus madeirensis*, *Rhizoecus americanus, Trochiscococcus speciosus*), both outdoors and in greenhouses, on ornamental plants.

Coccidae

About 70 species of soft scales are recorded in Europe. Of these, there are 23 aliens *to* Europe representing 32.8% of the fauna, and are mainly pests of fruit trees and ornamentals. Among them, the polyphagous *Coccus hesperidum* and *Saissetia oleae*, the well-known Mediterranean Black Scale, are probably the most ancient arrivals which established in the countries surrounding the Mediterranean Basin. Most recent arrivals are *Pulvinaria hydrangeae*, *P. regalis* (see factsheet 14.41), *Ceroplastes japonicus* and, in warmer places, *Protopulvinaria pyriformis*, invasive on trees and ornamental plants in urban environments. Some species, such as *Coccus pseudomagnoliarum*, after first spreading in Mediterranean *Citrus* groves, later became more localised and less common. On the other hand, the American *Pulvinaria innumerabilis* is still considered a pest of vine, more than 40 years after its arrival in European vineyards. Several species (e.g. *Saissetia coffeae*, *S. oleae, C. hesperidum*, *Eucalymnatus tessellatus, Parasaissetia nigra*) are rather common in greenhouses of central and northern Europe, while in southern Europe are outdoors pests.

Eriococcidae

European felt scales number about 50 species. Among them, only three alien felt scales have been so far recorded. The Australian *Eriococcus araucariae* is widespread on *Araucaria* trees growing in Mediterranean countries, the American *E. coccineus* is recorded on succulent plants and *Ovaticoccus agavium* is quite common on *Agave* sp. growing outdoors.

Margarodidae

European margarodids recorded up until now number 15 species. Two alien margarodids, *Icerya purchasi* (the cottony cushion scale) and *I. formicarum,* invaded Europe at very different times. The latter species is known from a single record in 2001 in Corsica and its establishment is unknown. On the other hand, the Australian *I. purchasi* has both established and caused an agricultural and environmental impact. It arrived and established in many Mediterranean countries between the end of 1800 and the first decades of 1900 and was very destructive to *Citrus* groves. The high infestations led to the introduction of the Australian coccinellid *Rodolia cardinalis*, for biological control. Presently, the cottony cushion scale is mainly a pest of ornamental plants such as *Pittosporum, Acacia* and *Mimosa*. It is also a very common species in semi-natural habitats (i.e. the Mediterranean maquis), far away from cultivated areas, where it develops on autochthonous wild plants such as *Cistus*, *Genista*, *Smilax* and *Rosmarinus*. Two other margarodids, *Marchalina hellenica* and *Matsucoccus feytaudi*, are alien *in* Europe, entirely due to deliberate introduction.

Asterolecanidae

About 10 species of asterolecanids are present in Europe. Of these, the only alien pit scale is the Asiatic *Bambusaspis bambusae*, a species associated with bamboos.

Ortheziidae

Ortheziids consist of 10 species in Europe. Among these, *Insignorthezia insignis*, a polyphagous Neotropical species, has been reported in European greenhouses since the end of 19th century. Apparently *I. insignis* is established outdoors only in Portugal and France.

Phoenicococcidae

Phoenicococcus marlatti, the Red Date Palm Scale, thought to originate in the Middle East or North Africa, is the only species currently placed in the family Phoenicococcidae. It is considered a minor pest of commercial dates, whereas in Spain, France and Italy, it infests ornamental palms (mainly *Phoenix canariensis*).

9.3.3 Temporal trends of introduction in Europe of alien scale species

Fig. 9.3.2. presents the temporal variation in the mean number of new alien species recorded per year since 1492. Serious studies of the Coccoidea began in mid 19th century. From that time, to the mid-1970s, the introduction of alien species was relatively constant, averaging 0.66 species per year. Since then, there is an apparent increase in alien introductions, up to an average of 1.15 species per year.

In interpreting this chart, account should be taken of "old" alien species, found and described in Europe, (i.e. *Aspidiotus nerii, Planococcus citri, Coccus hesperidum, Saissetia oleae*) for which the introduction date is based only on the date of their first description. In the case of the most harmful alien scales, the date of first introduc-

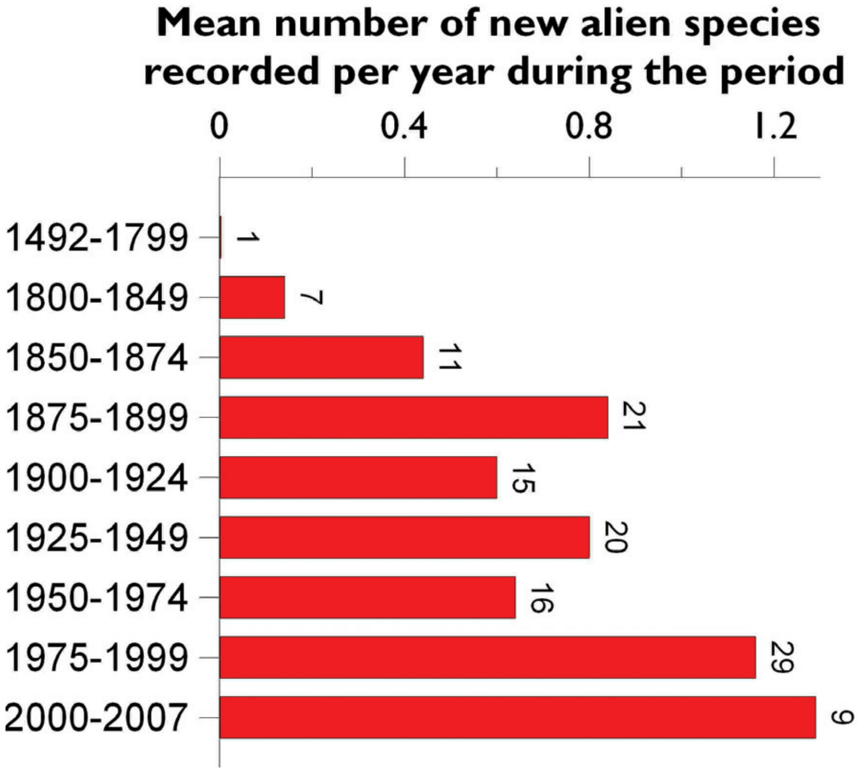

Figure 9.3.2 Temporal trends in the mean number of new records per year of scale species alien *to* Europe from 1492 to 2007. The number above the bar indicates the absolute number of species in this time period.

tion to Europe and the chronology of their invasion is known more precisely (i.e. for *Pseudaulacaspis pentagona*, *Icerya purchasi, Diaspidiotus perniciosus*). Moreover, records of alien scales depend on the presence of specialists in a given country. For instance, during the 1970–80s, advances in systematic knowledge and the increasing number of active coccidologists led to the "discovery" of several species which have probably been introduced a long time before. The great rise in the global exchanges of plants and quarantine inspections can explain the increases in subsequent years up until the present.

Among the scale insects introduced to Europe from the end of 19th century to 1960s there are several pests of fruit trees and *Citrus* (i.e. *Diaspidiotus perniciosus, Lepidosaphes gloverii, Pseudaulacaspis pentagona, Ceroplastes sinensis, Icerya purchasi*), whereas in the last 40 years the most numerous introduced scales are pest of ornamental plants, both outdoors and indoors (i.e. *Pulvinaria regalis, P. hydrangeae, Ceroplastes japonicus, Protopulvinaria pyriformis, Parassaisetia nigra, Trochiscococcus speciosus*), the main scale of agricultural importance being *Neopulvinaria innumerabilis*, a pest of vine.

9.3.4 Biogeographic patterns of the scale species alien to Europe

9.3.4.1 Origin of the alien species

The geographical origin of introduced scale insects shows a large dominance of species from tropical areas, essentially Asia, followed by southern American species (Fig. 9.3.3). The precise origin remains unknown for about one fourth of alien scales. Among the most widespread aliens to Europe are *Diaspidiotus perniciosus* of temperate Asian, *Planococcus citri* from tropical Asia, *Ceroplastes sinensis* from Central-America, *Parthenolecanium fletcheri* from Northern-America, *Saissetia oleae* from the Afrotropics, *Icerya purchasi* from Australasia, and *Lepidosaphes beckii* as cryptogenic species.

9.3.4.2 Distribution of the alien species in Europe

It should be borne in mind that, as for the other arthropod groups, the number of records of alien scales in European countries, reflects, in part, differences of study intensity and the number of local taxonomists. Moreover, the geographic position of some countries such as France, Italy and Spain, whose climatic conditions vary from high montane, continental to Mediterranean, allows establishment of species from very different geographical areas. Two countries present a particularly high number of alien species: France with 90 species and Italy with 92 species (Fig. 9.3.4). Lagging far behind are Spain, Great Britain and Portugal with 50, 43 and 41 species, respectively. The islands of the Atlantic, not represented in the figure, have respectively 51 aliens in the Canaries, 44 in Madeira and 22 in the Azores. There are 12 alien species recorded in at least 20 countries, namely *Coccus hesperidum* (28 countries), *Pulvinaria floccifera* (21), *Saissetia coffeae* (24), *S. oleae* (26), *Aspidiotus nerii* (26), *Diaspidiotus perniciosus* (26), *Pinnaspis aspidistrae* (20), *Pseudaulacaspis pentagona* (21), *Planococcus citri* (22), *Pseudococcus longispinus* (22) and *P. viburni* (26). These are all polyphagous species, with the exception of *Unaspis euonymi,* monophagous on *Euonymus* spp., recorded in 22 countries. A total of 20 species (15%) are present only in one country.

9.3.4.3 Scale species alien in Europe

With regard to scale insects alien *in* Europe, that is originating from another European area where native and introduced through human activity, only very few certain cases are known. *Marchalina hellenica* is native to Turkey and Greece and presently invasive in the small island of Ischia (Italy). It was introduced there in 1960 to study endosymbiosis, but unfortunately escaped from laboratory breeding and presently is a pest of pines (Tranfaglia and Tremblay 1984). *Matsucoccus*

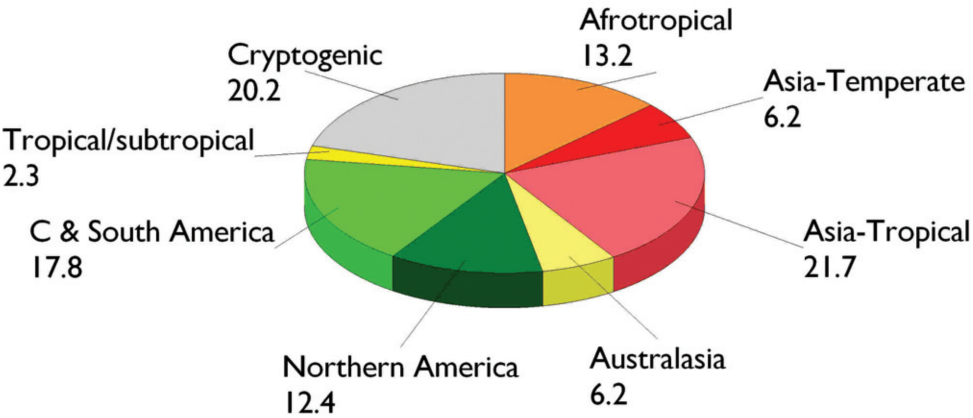

Figure 9.3.3 Geographic origin of the scale species alien *to* Europe.

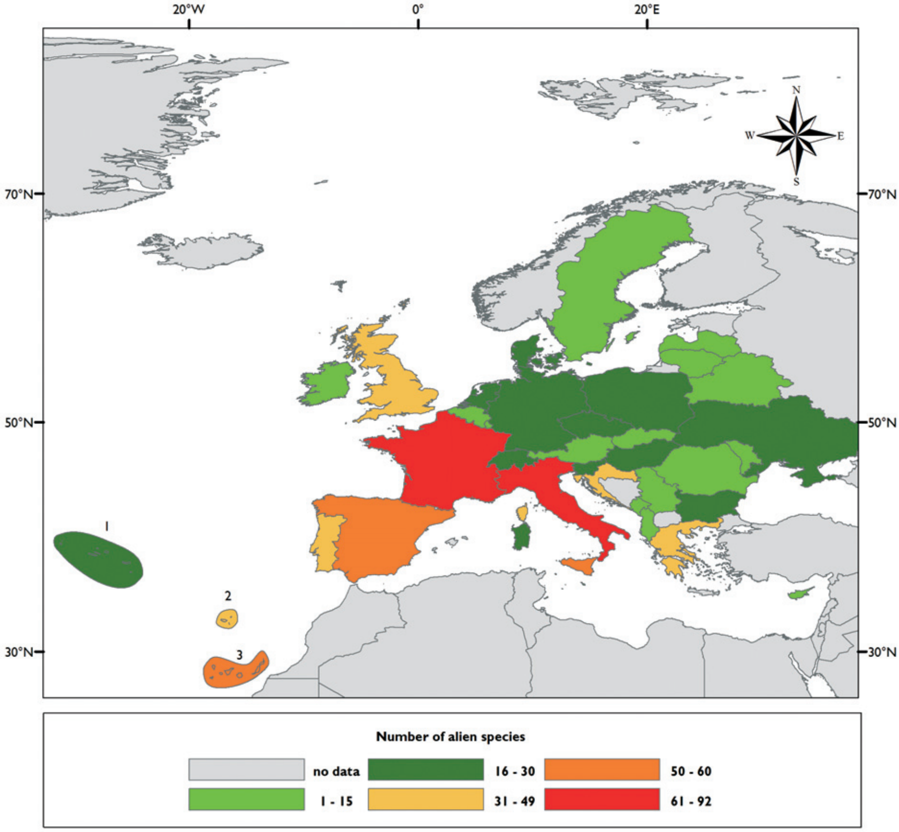

Figure 9.3.4 Numbers of established alien scale species in the European countries and main islands according to Table 9.3.1. Archipelago: **1** Azores **2** Madeira **3** Canary islands.

Figure 9.3.5 *Ceroplastes ceriferus* (Coccidae). Credit: Giuseppina Pellizzari

Figure 9.3.6 *Coccus hesperidum* (Coccidae). Credit: Giuseppina Pellizzari

feytaudi lives on *Pinus pinaster* and is native to the Atlantic regions of France, Spain and Portugal. It was introduced with its host plant in South-eastern France and from there spread towards Italy (Arzone and Vidano 1981). Both *Aonidiella lauretorum* and *A. tinerfensis* are endemic to the Atlantic islands of Canary (Spain) and Madeira (Portugal). They were introduced incidentally with their host plants

Figure 9.3.7 *Parasaissetia nigra* (Coccidae). Credit: Giuseppina.

Figure 9.3.8 *Protopulvinaria pyriformis* (Coccidae). Credit: Giuseppina Pellizzari.

in the Botanic gardens of Sintra and Lisbon (Portugal), where they still persist (Balachowsky 1948).

9.3.6 Pathways of introduction in Europe of alien scale species

Scale insects are highly specialized, sedentary, plant-parasitic insects and the only pathway of introduction is the horticultural and ornamental trade: importation and trade

Figure 9.3.9 *Pulvinaria hydrangeae* (Coccidae). Credit: Nico Schneider

Figure 9.3.10 *Pulvinaria floccifera* (Coccidae). Credit: Nico Schneider

of fruit and *Citrus* trees, ornamental trees and bushes, bulbs and corms, has led to incidental introduction and subsequent spread of scale insects. More recently, the "fashion" of succulent plant cultivation and the subsequent increase in plant importation and plant exchanges among collectors is responsible for the introduction and spread of several species such as *Delottococcus euphorbiae*, *Hypogeococcus pungens, Trochiscococcus speciosus, Vryburgia rimariae, Spilococcus mamillariae* and *Eriococcus coccineus.* Importation of bonsais from Asia could allow the introduction and spread of *Rhizoecus hibisci*, a mealybug living on roots and recently intercepted several times by European quarantine services.

Figure 9.3.11 *Chrysomphalus aonidum* (Diaspididae). Credit: Giuseppina Pellizzari.

Figure 9.3.12 *Unaspis yanonensis* (Diaspididae). Credit: Giuseppina Pellizzari.

9.3.7 Ecosystems and habitats invaded in Europe by alien scale species

Alien, established scale insects colonize strongly anthropogenic habitats such as cultivated agricultural lands, horticultural and domestic habitats, urban environments, gardens and parks, botanic gardens, nurseries and greenhouses, but they have also spread to natural habitats. Mediterranean *Citrus* groves host a large community of alien scales: 18 different species have been so far recorded. These are: *Icerya purchasi Planococcus citri, Pseudococcus calceolariae, P. longispinus, Ceroplastes sinensis, Coccus hesperidum, C. pseudomagnoliarum, Saissetia oleae, Aonidiella aurantii, A. citrina, As-*

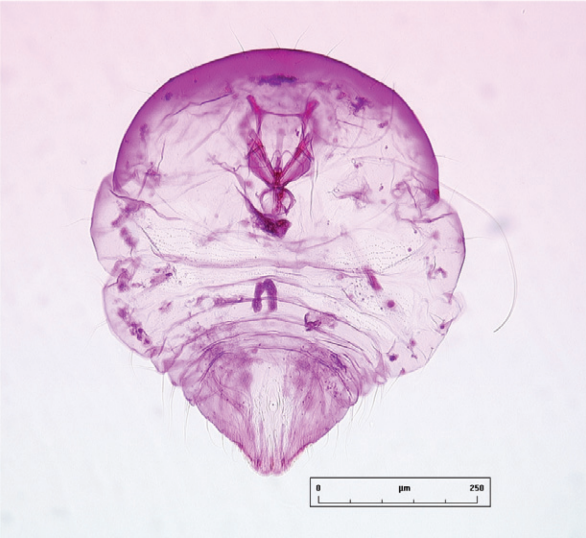

Figure 9.3.13 *Comstockiella sabalis* (Diaspididae). Credit: Jean Francois Germain

Figure 9.3.14 *Ovaticoccus agavium* (Eriococcidae). Credit: Giuseppina Pellizzari

pidiotus nerii, *Chrysomphalus dictyospermi, C. aonidum, Lepidosaphes beckii, L. gloverii, Parlatoria pergandii, P. ziziphi* and *Unaspis yanonensis.* Some polyphagous scales are urban pests, largely distributed in urban parks and gardens, on trees and ornamentals (i.e. *Pulvinaria regalis*, *P. hydrangeae*, *Ceroplastes japonicus*), whereas they are absent or very rare in the countryside. A few monophagous species are only known in Botanical gardens, where they persist outdoors, at a low population levels, on exotic plants

Figure 9.3.15 *Pseudococcus comstocki* (Pseudococcidae). Credit: Giuseppina Pellizzari

Figure 9.3.16 *Pseudococcus longispinus* (Pseudococcidae). Credit: Giuseppina Pellizzari

introduced over there a long before (i.e. *Aonidiella tinerfensis, Pseudaonidia paeoniae* or *Bambusaspis bambusae*).

Several other monophagous species remain strictly associated to their original, exotic ornamental plants, and have a correspondingly wide distribution in Europe (i.e. *Parthenolecanium fletcheri, Pulvinaria mesembryanthemi, Eriococcus araucariae*). On the other hand, some polyphagous species (i.e. *Diaspidiotus perniciosus*, *Pseudaulacaspis pentagona, Pulvinaria floccifera*) have spread from cultivated areas to natural woodland and forest habitats (Balachowsky 1932b, Balachowsky 1936). Others (*Antonina graminis*,

Figure 9.3.17 *Pseudococcus calceolariae* (Pseudococcidae). Credit: Jean Francois Germain

Chorizococcus rostellum and *Trionymus angustifrons*) can be found in grasslands. In natural habitats of Mediterranean countries (including small islands), species such as the armoured scales *Aspidiotus nerii* (see factsheet 14.43), *Hemiberlesia lataniae, H. rapax*, the mealybug *Planococcus citri,* the wax scale *Ceroplastes sinensis* and the Australian *I. purchasi* are quite common on wild autochthonous plants, growing far away from cultivated plants. Their transfer from cultivated plants to authochtonous ones in natural environments confirms that they have fully acclimatized.

9.3.8 Impact of alien scale species

Scale insects are plant pests, especially of fruit trees, woody ornamentals, forest trees and greenhouse plants. They cause damage to plants by sap sucking. Moreover, except for Diaspididae and Asterolecaniidae, they excrete honeydew that covers leaves and fruits and allows the development of sooty mould. This black sooty mould can reduce photosynthesis by 70%, leading to early senescence, with smaller and premature fruits, and loss of aesthetic value (Mibey 1997). Moreover, Coccidae and Pseudococcidae are vectors of closteroviruses. For example, *Planococcus citri* and *Pulvinaria innumerabilis* may transmit the Grapevine Leafroller-associated Virus (GLRaV-1, GLRaV-3) and the Corky Bark disease (GVA, GVB) (Sforza et al. 2003, Zorloni et al. 2006). Diaspididae cause discolouration on leaves, red or black spots on fruits, and twig dieback. Pesticides are commonly applied to control scale insects in fruit orchards and *Citrus* groves. Infestations of alien scales in orchards have led to the introduction to Europe, from their native area, of many natural enemies for biological control purposes.

References

Anagnou–Veroniki M, Papaioannou–Souliotis P, Karanastasi E, Giannopolitis CN (2008) New records of plant pests and weeds in Greece, 1990–2007. *Hellenic Plant Protection Journal* 1: 55–78.

Arzone A, Vidano C (1981) *Matsucoccus feytaudi* Duc. (Homoptera, Margarodidae) fitomizo letale su *Pinus pinaster* in Italia. *Informatore Fitopatologico* 10: 3–10.

Baeta Neves CM (1954) A entomafauna "exoticas" em Portugal. *Portugaliae Acta Biologica* 4: 191–196.

Balachowsky AS (1930) Contribution à l'étude des Coccides de France (3ème note). Coccides nouveaux ou peu connus de la faune de France. *Bulletin de la Société entomologique de France* 178–184.

Balachowsky AS (1932a) *Etude biologique des coccides du basin occidental de la Méditerranée-Encyclopédie Entomologique* XV. Paris : P. Lechevalier & Fils. 214pp.

Balachowsky AS (1932b) La théorie des "places vides" et le peuplement des végétaux par les Coccides *Bulletin de la Société entomologique de France.* Livre du Centenaire:517–522.

Balachowsky AS (1936) La cochenille floconneuse est-elle indigène dans les forêts de France ? *Revue Pathologie Végétale et Entomologie Agricole de France* 23: 307–31.

Balachowsky AS (1938) Les cochenilles de Madère (seconde partie) II Lecaniinae, Eriococcidae, Dactylopinae, Ortheziinae, Margarodidae. *Revue de Pathologie Végétale et d'Entomologie Agricole de France* 4: 255–272.

Balachowsky AS (1948) Les cochenilles de France d'Europe, du Nord de l'Afrique, et du bassin Méditerranéen IV - Monographie des Coccoidea; Diaspidinae-IV, Odonaspidini-Parlatorini. *Actualités Scientifiques et Industrielles* 1054: 243–394.

Balachowsky AS (1953) Les cochenilles de France d'Europe, du Nord de l'Afrique, et du bassin Méditerranéen VII - Monographie des Coccoidea; Diaspidinae-IV, Odonaspidini-Parlatorini. *Actualités Scientifiques et Industrielles* 1202: 725–929.

Balachowsky AS (1954) *Les cochenilles Paléarctiques de la tribu des Diaspidini*. Paris : Mémoires Scientifiques de l'Institut Pasteur. 450 pp.

Barbagallo S (1974) Notizie sulla presenza in Sicilia di una nuova cocciniglia degli agrumi *Coccus pseudomagnoliarum* (Kuwana) (Homoptera, Coccidae) osservazioni biologiche preliminari. *Entomologica Bari* 10: 121–139.

Bénassy C (1969) The biological control against coccids of citrus in the country of the French zone. In: Chapman HD (Ed) *Proceedings of the First International Citrus Symposium Vol 2*. Riverside, CA: University of California, 793–799.

Ben-Dov Y (1994) *A systematic catalogue of the mealybugs of the world (Insecta: Homoptera: Coccoidea: Pseudococcidae and Putoidae) with data on geographical distribution, host plants, biology and economic importance.* Andover, England: Intercept Publications Ltd. 686 pp.

Ben-Dov Y, Miller DR, Gibson GAP (2006) ScaleNet: a database of the scale insects of the world. http://www.selbarc.usda.gov/scalenet/scalenet.htm.

Berlese A, Leonardi G (1896) Diagnosi di cocciniglie nuove (Cont.). *Rivista di Patologia Vegetale Firenze* 4: 345–352.

Berlese A, Leonardi G (1899) Cocciniglie che minacciano la Frutticultura Europea: 4 Storia della scoperta e diffusione. *Rivista di Patologia Vegetale Firenze* 7: 253–273.

Blanchard R (1883) Les Coccides utiles. *Bulletin de la Société Zoologique de France* 8: 217–328.

Bouché PF (1851) Neue Arten der Schildlausfamilie. *Entomologische Zeitung, Stettin* 12: 110–112.

Canard M (1968) Un nouveau *Pulvinaria* (Hom Coccoidea) nuisible aux arbres d'alignement dans la région Parisienne. *Annales de la Société Entomologique de France (NS)* 4: 951–958.

Chapin E, Germain JF (2005) Des ravageurs des palmiers en France, espèces établies, introduites ou interceptées. In: *Proceedings du 2éme CIAC et de la 7éme CIRA* (N° ISBN: 21–905550–02–3, AFPP Octobre 2005), 9 pp.

Costa OG (1829) (1835) *Fauna del regno di napoli, famiglia de coccinigliferi, o de gallinsetti*. Napoli: Emmiteri. 23 pp.

Del Guercio G (1900) Osservazioni intorno ad una nuova cocciniglia nociva agli agrumi in Italia ed al modo di immunizzare la parte legnosa delle,piante contro la puntura delle coccinglie in generale e di distruggerle. *Nuove Relazione della R. Stazione di Entomologia Agraria Firenze* 3: 3–26.

Douglas JW (1887) Note on some British Coccidae (N°6). *Entomologist's Monthly Magazine* 23: 239–243.

Douglas JW (1888) Notes on some British and exotic Coccidae (N°12). *Entomologist's Monthly Magazine* 25: 150–153.

Douglas JW (1889) The spreading of *Orthezia insignis* in England. *Entomologist's Monthly Magazine* 25: 270.

Fernandes IM 1992 (1990) Contribuiçaos para o conhecimento de Coccoidea (Homoptera) de Portugal I Lista anotada de cochenilhas do jardin do Centro de Zoologia Garcia de Orta. *Serie de zoologia, Lisboa* 17: 53–63.

Foldi I (2001) Liste des cochenilles de France (Hemiptera, Coccoidea). *Bulletin de la société entomologique de France* 103: 303–308.

Germain JF, Matile-Ferrero D, Picart JL, Delvare G, Piron M (2002) Inventory of scale insects in tropical green houses in France and knowledge of their parasitic Hymenoptera, previous to development of biological control. In: Sixième Conférence Internationale sur les Ravageurs en Agriculture Tome 1 AGRO, Montpellier, 253–260.

Germain JF, Matile-Ferrero D (2006) *Comstockiella sabalis* (Comstock), *Crisicoccus pini Kuwana* and *Phenacoccus defectus* Ferris, scales new to France (Hem, Diaspididae and Pseudococcidae). Bulletin de la Société Entomologique de France 111: 395–401.

Gómez-Menor Ortega J (1946) Adiciones a los "Cóccidos de Espana" (la nota). *Eos* 22: 59–106.

Gómez-Menor Ortega J (1957) Adiciones a los cóccidos de Espana (4a nota). *Eos* 33: 39–86.

Goux L (1937) Notes sur les coccides (Hem) de la France (18ème note) Six espèces nouvelles pour la France et remarques sur le genre *Lecanopsis*, *Exaeretopus* et *Luzulaspis. Bulletin de la Société entomologique de France* 42: 93–96.

Green EE (1915) Observations on British Coccidae in 1914, with descriptions of new species. *Entomologist's Monthly Magazine* 51: 175–185.

Green EE (1917) Observations on British Coccidae: with descriptions of new species. *Entomologist's Monthly Magazine* 53: 201–210, 260–269.

Green EE (1920) Observations on British Coccidae No V. *Entomologist's Monthly Magazine* 56: 114–130.

Green EE (1921a) Observations on British Coccidae with descriptions of new species No VI. *Entomologist's Monthly Magazine* 57: 146–152, 189–200.

Green EE (1921b) Observations on British Coccidae: with descriptions of new species-VII. *Entomologist's Monthly Magazine* 57: 257–259.

Green EE (1923) Observations on the Coccidae of the Madeira island. *Bulletin of Entomological Research* 14: 87–99.

Green EE (1928) Observations on British Coccidae - XI With descriptions of new species. *Entomologist's Monthly Magazine* 64: 20–31.

Hodgson CJ (1994) *The scale insect family Coccidae: an identification manual to genera*. Wallingford, Oxon, UK: CAB International. 639 pp.

Jactel H, Meinassieu P, Burban C (1996) Découverte en Corse de *Matsucoccus feytaudi* Duc (Homoptera: Margarodidae), cochenille du pin maritime. *Annales des Sciences Forestières* 53: 145–152.

Jansen MGM (1995) Scale insects (Homoptera: Coccinea) from import interceptions and greenhouses in the Netherlands. *Israel Journal of Entomology* 29: 131–146.

Kawecki Z (1935) Czerwce (Coccidae) województwa krakowskiego I kieleckiego zebrane w latach 1933–1934 (Die schildläuse (Coccidae) der wojewodschaften Kraków und kielce die in den jahren 1933–1934 gesammelt wurden) Sprawozdanie Komisji Fizjograficznej Polskiej Akad Umiejetnosci . *Annual Report of the Physiographical Commission of Polish Academy of Sciences & Letters* 68: 73–90.

Koteja J, Zak-Ogaza B (1966) Investigations on scale insects (Homoptera, Coccoidea) of the Pieniny Klippen Belt. *Acta Zoologica Cracoviensia* 11: 305–332.

Kozár F, Tzalev M, Viktorin RA, Horváth J (1979) New data to the knowledge of the scale insects of Bulgaria (Homoptera: Coccoidea). *Folia Entomologica Hungarica* 32: 129–132.

Kozarzhevskaya E, Reitzel J (1975) The scale insects (Homoptera: Coccoidea) of Denmark. *Statens Forsogsvirksomhed I Plantkultur Beretning Copenhagen* 1226: 1–40.

Leonardi G (1897) Monografia de genere *Aspidiotus* (nota preventiva). *Rivista di patologia Vegetale Firenze* 5: 283–286.

Leonardi G (1898) Generi e specie di diaspi Saggio di sistematica degli *Aspidiotus*. *Rivista di patologia Vegetale Firenze* 6: 48–78.

Leonardi G (1899) Sopra una Cocciniglia che danneggia la *Araucaria excelsa. Bollettino di Entomologia Agraria e Patologia Vegetale* 6: 53–55.

Leonardi G (1903) (1904) Generi e specie di dispini Saggio di sistematica delle parlatoriae. *Annali della Regia Scuolo di Agricoltura di Portici* 5: 1–59.

Leonardi G (1906) (1905) Diagnosi di cocciniglie nuove. *Redia* 3: 1–7.

Leonardi G (1913) Nuove specie di cocciniglie raccolte in Italia. *Bollettino del Laboratorio di Zoologia Generale e e Agraria della Regia Scuola Superiore Agricoltura di Portici* 7: 59–65.

Leonardi G (1918) Terza contribuzione alla conoscenza delle cocciniglie Italiane. *Bollettino del R Laboratorio di Entomologia Agraria di portici* 12: 188–216.

Leonardi G (1920) *Monografia delle cocciniglie Italiane*. Portici: Della Torre 555 pp.

Lindinger L (1908) (1907) Ein neuer Orchideen-schädling, *Leucodiaspis cockerelli* (de Charm). *Green Jahrbuch der Hamburgischen Wissenschaftlichen Anstalten Hamburg* 3: 121–124.

Longo S, Mazzeo G, Russo A, Siscaro G (1994) *Aonidiella citrina* (Coquillet) nuovo parassita degli agrumi in Italia. *Informatore Fitopatologico*, 12, 19–23.

Lucas H (1853) *Coccus ziziphi*. *Annales de la Société Entomologique de France* 1: 28–29.

Lupo V (1938) Revisione delle cocciniglie italiane II *Howardia*, *Adiscodiaspis*, *Chionaspis*, *Pinnaspis*, *Fiorinia*, *Kuwanaspis*. *Bollettino del Laboratorio di zoologia generale ed agraria di Portici* 29: 255–322.

Lupo V (1948) Revisione delle cocciniglie Italiane. V. (*Pseudoparlatoria, Parlatoria*). Bollettino del R. Laboratorio di Entomologia Agraria. Portici 8: 33–79.

Malumphy CP (2005) *Eulecanium excrescens* (Ferris) (Hemiptera: Coccidae), an Asian pest of woody ornamentals and fruit trees, new to Britain. *British Journal of Entomology and Natural History* 18: 45–49.

Marchal P (1907) La cochenille floconneuse. *Bulletin de la Société Naturelle d'Acclimatation* 186–199.

Marotta S (1987) I Coccidi (Homoptera: Coccoidea: Coccidae) segnalati in Italia, con riferimenti bibliografici sulla tassonomia, geonomia, biologia e piante ospiti. *Bollettino del Laboratorio di Entomologia Agraria 'Filippo Silvestri'* 44: 97–119.

Marotta S (1992) Ricerche su pseudococcidi (Homoptera: Coccoidea) dell'Italia centro-meridiionale. *Bollettino del Laboratorio di Entomologia Agraria 'Filippo Silvestri'* 47: 63–111.

Marotta S (1995) Due *Rhizoecus* Kunckel d'Herculais, 1878 (Homoptera Coccoidea Pseudococcidae) nuovi per la fauna italiana. Bollettino di Zoologia Agrari e di Bachicoltura (Milano) Ser II 27: 117–121.

Marotta S, Garonna AP (1991) Homoptera Coccoidea nuovi e poco conosciuti delle piante grasse in Italia. Atti Congn nza It Ent, Bari-martina (TA), 23–28: 741–746.

Marotta S, Tranfaglia A (1990) New and little known species of Italian scale insects (Homoptera: Coccoidae). In: *Proceedings of the 6th International Symposium of Scale Insect Studies, part II. Kraków, Poland, August 1990.* Kraków: Agricultural University Press, 107–112.

Mazzeo G, Russo A, Suma P (1999) Phenacoccus solani Ferris (Homoptera Coccoidea) on ornamental in Italy. Bollettino di Zoologia Agraria e di Bachicoltura *(Milano)* 31: 31–35.

Melis A (1943) Contributo alla conoscenza dell'*Aspidiotus pernicious*. *Redia* 29: 1–170.

Menozzi C (1933) Contributo alla conoscenza delle cocciniglie (Hemip Coccidae) d'Italia (prima nota). *Bollettino della Società Entomologica Italiana Firenze* 65: 41–47.

Mibey RK (1997) Sooty Moulds. In: Ben-Dov Y, Hodgson CJ (Eds) *World Crop Pests Soft Scale Insects, Their Biology, Natural Enemies and Control,* vol. 7A. Amsterdam: Elsevier, 275–288.

Mori N, Pellizzari G, Tosi L (2001) *Ceroplastes ceriferus* (Fabricius) (Hemiptera; Coccoidea): new pest of ornamentals in Europe? *Bollettino di Zoologia Agraria e di Bachicoltura (Milano)* 33: 331–336.

Morrison H (1939) Taxonomy of some scale insects of the genus *Parlatoria* encountered in plant quarantine inspection work. *United States Department of Agriculture, Miscellaneous Publications* 344: 1–34.

Newstead R (1898) Observations on Coccidae (N°7). *Entomologist's Monthly Magazine* 34: 92–99.

Olivier GA (1791) Cochenille. *Coccus.* Genre d'insectes de la première section de l'ordre des Hémiptères. In: Olivier GA (Ed.), Encyclopédie méthodique, Paris, 85–100.

Pegazzano F (1949) Un diaspino nuovo per la fauna Paleartica: *Pseudaonidia poeoniae* Cockll (Hemiptera, Coccidae). *Redia* 34: 233–235.

Pellizzari G (1993) Homoptera Coccoidea nuovi o poco noti per la fauna italiana. *Bollettino di Zoologia Agraria e di Bachicoltura* 25 (1): 49–55.

Pellizzari G, Camporese P (1994) The *Ceroplastes* species (Homoptera: Coccoidea) of the Mediterranean basin with emphasis on *C japonicus* Green. *Annales de la Societe entomologique de France (NS)* 30: 175–192.

Pellizzari G, Russo, A (2004) List of the scale insects (Hemiptera, Coccoidea) of Italy. In Proceedings of the 10th International Symposium on Scale Insects Studies, Adana, April 2004, 167–183.

Porcelli E (1990) Cocciniglie nuove per l'Italia. *Frustula entomologica NS* 26: 31–38.

Risso A (1813) mémoire sur l'histoire naturelle des oranges, bigaradiers, limettiers, cédratiers, limoniers ou citronniers, cultivés dans le département des Alpes-Maritimes. *Annales du Muséum National d'Histoire naturelle Paris* 20: 169–212, 401–431.

Ruiz Castro A (1944) Un Coccido ampelofago nuevo en espana (*Aspidiotus uvae* Comstock). Boletín *de* Patologia *Vegétal* y *Entomologia Agricola* 13: 55–73.

Russell L (1941) A classification of the scale genus *Asterolecanium*. *United States Department of agriculture, Miscellaneous Publications* 424: 1–319.

Russo A, Mazzeo G (1992) *Rhizoecus americanus* (Hambleton) e *Pseudaulacaspis cockerelli* (Cooley) (Homptera Coccoidea) dannosi alle painte ornamentali in Italia. *Bollettino di Zoologia agraria e di bachicoltura Ser II* 24: 215–221.

Russo A, Mazzeo G (1996) *Dactylopius coccus* Costa (Homoptera, Coccoidea): la cocciniglia del carminio. *Informatore Fitopatologico* 4: 10–13.

Russo A, Mazzeo G, Suma P (1999) Sulla presenza di *Entaspidiotus lounsburyi* (Marlatt, 1908) su Mesembryanthemaceae in Italia (Homoptera, Coccoidea). *Redia* 82: 83–87.

Seabra AF de (1942) Contribuiçoes para o inventario da fauna Lusitânica Insecta: Homoptera (Coccidae). *Aditamento Memorias y Estudos do Museo Zoologico da Universidade de Coimbra* 128: 1–2.

Sforza R, Boudon-Padieu E, Greif C (2003) New mealybug species vectoring Grapevine leafroll-associated viruses-1 and-3 (GLRaV-1 and –3). *European Journal of Plant Pathology* 109: 975–981.

Signoret V (1869a) Essai sur les cochenilles ou gallinsectes (Homoptères - Coccides), 4ème partie. *Annales de la Société Entomologique de France* 9: 109–138.

Signoret V (1869b) Essai sur les cochenilles ou gallinsectes (Homoptères - Coccides), 5ème partie. *Annales de la Société Entomologique de France* 9: 431–452.

Signoret V (1875) Essai sur les cochenilles ou gallinsectes (Homoptères - Coccides), 15e partie. *Annales de la Société Entomologique de France* (série 5) 5: 305–352.

Süss L, Trematerra P (1986) *Hypogeococcus festerianus* (Lizer y Trelles), nocivo alle Cactacee ormamentali in Liguria. *Informatore Fitopatologico* 10: 43–46.

Targioni Tozzetti A (1884) Relazione intorno ai lavori della R Stazione di Entomologia Agraria di Firenze per gli anni 1879–80 article V-omotteri. *Annali di Agricoltura (Ministero di Agricoltura, Industria e commercio) Firenze, Roma*: 383–414.

Targioni Tozzetti A (1867) Studii sulle Cocciniglie. *Memorie della Società Italiana di Scineze Naturali Milano* 3: 1–87.

Targioni Tozzetti A (1886) (1885) Sull'insetto che danneggia I gelsi. *Rivista di bachicoltura* 18: 1–3

Tranfaglia A (1976) Studi sugli Homoptera Coccoidea IV Su alcune Cocciniglie nuovo o poco conosciute per l'Italia (Coccidae, Eriococcidae, Pseudococcidae). *Bollettino del laboratorio di entomologia Agraria 'Filippo Silvestri' Portici* 33: 128–143.

Tranfaglia A (1981) Studi sugli Homoptera Coccoidea V Notizie morfo-sistematiche su alcune specie di Cocciniglie con descrizione di tre nuove specie di Pseudococcidi. *Bollettini del Laboratorio di Entomologia Agraria 'Filippo Sivestri' Portici* 38: 3–28.

Tranfaglia A, Tremblay E (1984) Faunistic and systematic studies on Italian scale insects. In *Verhandlungen des Zehnten Internationalen Symposiums über Entomofaunistik Mitteleuropas (*SIEEC X), August 1983, Budapest (1984), 372–374.

Tranfaglia A, Viggiani G (1988) Cocciniglie di importanza economica in Italia e loro controllo. Benevento, Regione Campania, Italy: Assessorato Agricoltura, Servizio Sperimentazione Abete Grafica 30pp.

Williams DJ (1985) Scale insects (Homoptera: Coccoidea) of Tresco, isles of Sicily. *Entomologist's Gazette* 36: 135–144.

Williams DJ, Pellizzari G (1997) Two species of mealybugs (Homoptera Pseudococcidae) on the roots of Aloaceae in greenhouses in England and Italy. *Bollettino di Zoologia agraria e di Bachicoltura ser II* 29: 157–166.

Zahradnik J (1990) Die Schildläuse (Coccinea) auf Gewächshaus- un Zimmerpflanzen in den Tschechischen Ländern. *Acta Universitatis Carolinae Biologica* 34: 1–160.

Zorloni A, Prati S, Chiesa S, Bianco PA (2006) Transmission of grapevine leafroll associated virus 3 by the soft scale insect *Neopulvinaria innumerabilis* Rathvon. In *Abstracts* of the *13th Congresso Nazionale* della Società Italiana di Patologia Vegetale *September, 2006*, Foggia, 17.

Pellizzari G, Danzig E (2007) The bamboo mealybugs *Balanococcus kwoni* n. sp. and *Palmicultor lumpurensis* (Takahashi) (Hemiptera, Pseudococcidae) Zootaxa 1583: 65–68.

Table 9.3.1. List and main characteristics of the scale species alien to Europe. Status: A: Alien to Europe; C: cryptogenic species. Country codes abbreviations refer to ISO 3166 (see appendix I). Habitat abbreviations refer to EUNIS (see appendix II). Only selected references are given. Last update 29/05/200

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Asterolecaniidae								
Bambusaspis bambusae (Boisduval, 1869)	A	Phyto-phagous	Asia-Tropical	1941, IT-SIC	DK, ES, FR, GB, IT, IT-SIC, PT, PT-MAD	I2, J100	*Bambusa*	Russell (1941)
Coccidae								
Ceroplastes ceriferus (Fabricius, 1798)	A	Phyto-phagous	Central-America	1921, IT	IT, ES-CAN, GB	I2	Polyphagous	Green (1921b), Mori et al. (2001)
Ceroplastes floridensis Comstock, 1881	A	Phyto-phagous	South-America	1930, FR	CY, FR, GR, IL, MT, PT-AZO, PT-MAD	I2	Polyphagous	Balachowsky (1930)
Ceroplastes japonicus Green, 1921	A	Phyto-phagous	Asia-Tropical	1930, FR	FR, IT, HR, SI	I2	Polyphagous	Pellizzari and Camporese (1994)
Ceroplastes sinensis Del Guercio 1900	A	Phyto-phagous	Central-America	1890, IT	AL, ES, ES-CAN, FR, FR-COR, GR,HR, IT, IT-SIC, MT, ME, PT, PT-AZO, PT-MAD, RO	I2	Polyphagous	Del Guercio (1900)
Coccus hesperidum Linnaeus, 1758	A	Phyto-phagous	Tropical/ subtropical	1829, IT	BE, BG, CH, CY, DE, DK, ES, ES-CAN, FR, FR-COR, GB, GR, HU, HR, IT, IT-SIC, IT-SAR, LV, NL, ME, MT, PT, PT-AZO, PT-MAD, SK, SI, RS, RO, UA	I2	Polyphagous	Costa (1829)
Coccus longulus (Douglas, 1887)	A	Phyto-phagous	Tropical/ subtropical	2001, FR	FR, ES-CAN	I2	Polyphagous	Foldi (2001)
Coccus pseudohesperidum (Cockerell, 1895)	A	Phyto-phagous	Southern-America	1920, GB	GB, LV, UA	I2	Polyphagous	Green (1921a)

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Coccus pseudomagnoliarum (Kuwana, 1914)	A	Phyto-phagous	Asia-Tropical	1974, GR, IT	FR, GR, HR, IT, IT-SIC,ME, SI	I2	*Citrus*	Barbagallo (1974)
Eucalymnatus tessellatus (Signoret, 1873)	A	Phyto-phagous	Southern-America	1932, FR	BG, DK, DE, ES, ES-CAN, FR, IL, PT-MAD, PL, UA	I2, J100	*Livistona* ., Palms	Balachowsky (1954)
Eulecanium excresens Ferris, 1920	A	Phyto-phagous	Northern-America	1998, GB	GB	I2	*Juglans*, *Wisteria*	Malumphy (2005)
Cryptinglisia lounsburyi (Cockerell, 1900)	A	Phyto-phagous	Afrotropical	1982, IT	IT	I2	*Pelargonium*	Marotta (1987)
Neopulvinaria innumerabilis (Rathvon, 1880)	A	Phyto-phagous	Northern-America	1961, FR	FR, HR, IT, SI	I2	*Vitis*, polyphagous	Hodgson (1994)
Parasaissetia nigra (Nietner, 1861)	A	Phyto-phagous	Afrotropical	1900, IT	AL, ES, ES-CAN,FR, FR-COR, IT, IT-SIC, MT, PT, PT-AZO, PT-MAD, PL, RO	I2	Polyphagous	Marotta (1987)
Parthenolecanium fletcheri (Cockerell, 1893)	A	Phyto-phagous	Northern-America	1935, PL	AT, BG, CH, CZ, DE, FR, HU, HR, LV, NL, PL, RO, S	I2	*Cupressus*, *Thuya*	Kawecki (1935)
Protopulvinaria pyriformis (Cockerell, 1894)	A	Phyto-phagous	Asia-Tropical	1991, IT	AL, ES, ES-CAN, FR, GR, IT, IT-SIC, PT, PT-AZO, PT-MAD	I2	Polyphagous	Marotta and Tranfaglia (1990)
Pulvinaria floccifera (Westwood, 1870)	A	Phyto-phagous	Asia-Temperate	1889, FR	CH, CY, CZ, DE, ES, ES-CAN, FR, FR-COR, GB, GR, HU, HR, IT, IT-SAR, IT-SIC, NL,PT, PT-MAD, SE, SI, RO, RU	I2	*Ilex aquifolium*, *Taxus baccata*	Marchal (1907)

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Pulvinaria horii Kuwana, 1902	A	Phyto-phagous	Asia-Temperate/ Japan	2001, FR, GR	FR, GR, HR, IT, IT-SIC,ME, SI	F, G	*Aesculus, Acer, Ficus*	Foldi (2001)
Pulvinaria hydrangeae (Steinweden, 1946)	A	Phyto-phagous	Northern-America	2001, FR	CH, DE, FR, GB, HR, IT, LU, NL, SI	I2	Polyphagous	Foldi (2001)
Pulvinaria psidii Maskell, 1893	A	Phyto-phagous	Tropical/ subtropical	1928, GB	GB, ES-CAN	I2	Polyphagous	Green (1928)
Pulvinaria regalis Canard, 1968	A	Phyto-phagous	Asia-temperate	1968, FR	AT, BE, CH, DE, FR, GB, IRL, LU, NL	I2	Polyphagous	Canard (1968)
Pulvinariella mesembryanthemi (Vallot, 1830)	A	Phyto-phagous	Afrotropical/ South Africa	1829, FR	ES, ES-CAN,FR, GB, GR, IT, IT-SAR, IT-SIC, MT, PT-MAD, SI	I2	Aizoaceae	Balachowsky (1932a)
Saissetia coffeae (Walker, 1852)	A	Phyto-phagous	Afrotropical	1867, IT	BG, CH, DK, ES, ES-CAN, FR, FR-COR, GB, GR, HR, HU, IT, IT-SAR, IT-SIC, LV, MT, NL, PT, PT-AZO, PT-MAD, PL, RO, S, UA	I2, J100	Polyphagous	Leonardi (1920)
Saissetia oleae (Olivier, 1791)	A	Phyto-phagous	Afrotropical	1791, FR, IT	AL, AT, BG, CH, CY,DK, ES, ES-CAN, FR, FR-COR, GB, GR, HR, IT, IT-SAR, IT-SIC, ME, PT, PT-AZO, PT-MAD, NL, RO, SK, SI, RS, UA	I, I2	*Olea europea, Nerium oleander,* polyphagous	Olivier (1791)
Dactylopiidae								
Dactylopius coccus Costa, 1829	A	Phyto-phagous	Central-America	1827, ES-CAN	ES-CAN, PT-AZO, PT-MAD	I	Cactaceae	Russo and Mazzeo (1996)

Family *Species*	Status	Regime	Native range	1st record in Europe	Invaded countries	Habitat	Hosts	References
Diaspididae								
Abgrallaspis cyanophylli (Signoret, 1869)	C	Phyto-phagous	Cryptogenic	1868, FR	BG, CZ, DK, ES-CAN, FR, FR-COR, IT, IT-SAR, IT-SIC, PL	I2	Polyphagous	Signoret (1869a)
Aonidiella aurantii (Maskell, 1879)	A	Phyto-phagous	Asia-Tropical/ China	1881, IT	CY, ES, ES-CAN, FR, FR-COR, GR, IT, IT-SAR, IT-SIC, PT-MAD	I, I2	*Citrus*, Polyphagous	Leonardi (1918)
Aonidiella citrina (Coquillett, 1891)	A	Phyto-phagous	Asia-tropical	1994, IT	CY, FR, FR-COR, IT	I, I2	*Citrus*, Polyphagous	Longo et al. (1994)
Aonidiella taxus Leonardi 1906	A	Phyto-phagous	Asia-tropical	1906, IT	ES, FR, IT, IT-SIC	I2	*Taxus*	Leonardi (1906)
Aonidiella tinerfensis (Lindinger, 1911)	A	Phyto-phagous	Africa/ Canary Islands	1936, PT	PT	I2	*Dracaena*	Fernandes (1992)
Aspidiotus destructor Signoret 1869	C	Phyto-phagous	cryptogenic	1898, IT	FR, IT	J100	Palms, Polyphagous	Leonardi (1898)
Aspidiotus nerii (Bouché, 1833)	A	Phyto-phagous	Afrotropical	1829, IT	AL, CH, CY, CZ, DE, DK, ES, ES-CAN, FR, FR-COR, GB, GR, HU, HR, IT, IT-SAR, IT-SIC, MT, PT, PT-AZO, PT-MAD, PL, RO, RS, SE, SI	I, I2	*Nerium oleander*, Polyphagous	Leonardi (1920)
Aulacaspis tubercularis Newstead, 1906	C	Phyto-phagous	Cryptogenic	1990, IT	IT, IT-SIC, PT	I2	*Mangifera*	Porcelli (1990)
Chrysomphalus aonidum (Linnaeus, 1758)	A	Phyto-phagous	Southern-America	1895, IT	BE, DE, DK, ES, ES-CAN, FR, FR-COR, GB, GR, HR, IT, PT-MAD, PL, RS	I2	*Citrus*, Polyphagous	Leonardi (1920)

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Chrysomphalus dictyopsermi (Morgan, 1889)	A	Phyto-phagous	Asia-Tropical	1896, IT	CZ,DK, ES, ES-CAN, FR, FR-COR, GB, GR, HR, IT, PT, PL,PT-AZO, PT-MAD, PL, RO, RS	I2, J100	*Citrus*, Polyphagous	Berlese and Leonardi (1896)
Chrysomphalus pinnulifer (Maskell, 1891)	C	Phyto-phagous	Cryptogenic	1957, ES	ES, ES-CAN, PT-MAD	I2	Polyphagous	Gómez-Menor Ortega (1957)
Comstockiella sabalis (Comstock, 1883)	A	Phyto-phagous	Northern-America	2005, FR	FR	I2	Palms	Germain and Matile-Ferrero (2006)
Diaspidiotus osborni (Newell & Cockerell, 1898)	A	Phyto-phagous	Northern-America	1979, BG	BG, CH, IT, IT-SIC	I2	*Platanus*	Kozár et al. (1979)
Diaspidiotus perniciosus (Comstock, 1881)	A	Phyto-phagous	Asia-temperate/ China	1928, HU	AT, BG, CH, CZ, DE, DK, ES, ES-CAN, FR, FR-COR, GB, GR, HU, HR, IT, IT-SAR, IT-SIC, MD, NL, PT, PT-MAD, PL, RO, SE, SI, UA	G, I	Fruit trees, Polyphagous	Melis (1943)
Diaspidiotus uvae (Comstock 1881)	A	Phyto-phagous	Northern-America	1944, ES	ES, ES-CAN	I	Polyphagous	Ruiz Castro (1944)
Diaspis boisduvalii Signoret 1869	A	Phyto-phagous	Southern-America	1868, FR	BG, DE, DK, ES, ES-CAN, FR, FR-COR, GB, GR, IT, IT-SIC, PT, PT-MAD, SE	I2, J100	Polyphagous	Signoret (1869b)
Diaspis bromeliae (Kerner, 1778)	A	Phyto-phagous	Southern-America	1868, FR	A, B, BG, CH, CZ, DE, DK, ES, ES-CAN FR, GB, HU, IT, IT-SIC, MT, NL, PT-AZO, PT-MAD, PL, SE	I2, J100	Bromeliaceae	Signoret (1869b)

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Diaspis echinocacti (Bouché, 1833)	A	Phytophagous	Central-America	1827, IT	DE, DK, ES, ES-CAN, FR, FR-COR, GB, GR, HU, HR, IT, IT-SAR, IT-SIC, LU, LT, PT, PT-MAD	I2, J100	Cactaceae	Leonardi (1920)
Entaspidiotus lounsburyi (Marlatt, 1908)	A	Phytophagous	Afrotropical/ South Africa	1999, IT, IT-SIC	IT, IT-SIC	I2	Aizoaceae	Russo et al. (1999)
Eulepidosaphes pyriformis (Maskell, 1897)	A	Phytophagous	Afrotropical/ South Africa	1985, GB	GB	I2	Polyphagous	Williams (1985)
Fiorinia fioriniae (Targioni Tozzetti, 1867)	A	Phytophagous	Asia-Tropical	1867, IT	ES-CAN, FR, GR, IT, IT-SIC, MT, PT-MAD	I2	Polyphagous	Targioni Tozzetti (1886), (1885)
Fiorinia pinicola Maskell, 1897	A	Phytophagous	Asia-Tropical	1952, PT	IT, PT	I2	Polyphagous	Baeta Neves (1954)
Furchadaspis zamiae (Morgan, 1890)	A	Phytophagous	Afrotropical	1895, IT	CH, CZ, DE, DK, ES, ES-CAN, FR, GB, IT, IT-SAR, IT-SIC, PT, PT-AZO, PT-MAD, PL, SE, UA	I2, J100	Cycadaceae, Zamiaceae	Berlese and Leonardi (1896)
Gymnaspis aechmeae Newstead, 1898	C	Phytophagous	Cryptogenic	1898, GB	BE, BG, CH, CZ, DE, ES, FR, IT, IRL, Pl, RO, S	I2, J100	Bromeliaceae	Newstead (1898)
Hemiberlesia lataniae (Signoret, 1869)	C	Phytophagous	Cryptogenic	1869, FR	AT, BE, BG, CY, CZ, DE, ES, ES-CAN, FR, FR-COR, GB, GR, IT, IT-SIC, PT, PT-MAD, PL, RO	I2, J100	Polyphagous	Signoret (1869a)
Hemiberlesia palmae (Cockerell, 1892)	A	Phytophagous	Southern-America	1920, GB	CY, GB, PT, PT-MAD	I2, J100	Palms	Green (1920)

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Hemiberlesia rapax (Comstock, 1881)	C	Phyto-phagous	Cryptogenic	1881, IT	CZ, ES, ES-CAN, FR, GR, IT, IT-SAR, IT-SIC, MA, PT, PT-AZO, PT-MAD, PL	I2, J100	Polyphagous	Leonardi (1920)
Howardia biclavis (Comstock, 1883)	C	Phyto-phagous	Cryptogenic	1896, IT	FR, IT	I2, J100	Polyphagous	Berlese and Leonardi (1896)
Ischnaspis longirostris (Signoret, 1882)	C	Phyto-phagous	Cryptogenic	1954, FR	CZ, DK, ES-CAN, F	I2, J100	Polyphagous	Balachowsky (1954)
Kuwanaspis pseudoleucaspis Kuwana, 1923	A	Phyto-phagous	Asia-temperate/ China Japan	1900, IT	AL,FR, HR, IT, PL, SI, UA	I2	Bamboos	Lupo (1938)
Lepidosaphes beckii (Newman, 1869)	C	Phyto-phagous	Cryptogenic	1850, DE	BG, CY, ES, ES-CAN, FR, FR-COR, GB, GR, HR, IT, IT-SAR, IT-SIC, MA, PT, PT-AZO, PT-MAD	I2	Polyphagous	Bouché (1851)
Lepidosaphes gloverii (Packard, 1869)	C	Phyto-phagous	Cryptogenic	1884, IT	ES, FR, FR-COR, HR, IT, IT-SAR, IT-SIC, GR, P	I2	*Citrus*, Polyphagous	Targioni Tozzetti (1884)
Leucaspis podocarpi (Green, 1929)	A	Phyto-phagous	Australasia/ New-Zealand	1985, GB	GB	I2	Podocarpus	Williams (1985)
Lindingaspis rossi (Maskell, 1891)	A	Phyto-phagous	Australasia/ Australia	1942, PT	ES, FR, IT, IT-SIC, PT, PT-MAD	F, G, I2	Polyphagous	Seabra de (1942)
Lopholeucaspis cockerelli (Grandpré & Charmoy, 1899)	C	Phyto-phagous	Cryptogenic	1908, DE	DE, GB, GR	J100	Orchidaceae	Lindinger (1908)
Oceanaspidiotus spinosus (Comstock, 1883)	C	Phyto-phagous	Cryptogenic	1890, IT-SIC	ES, ES-CAN, GB, IT, IT-SIC, PT, PT-AZO, PT-MAD	I2, J100	Polyphagous	Leonardi (1897)
Odonaspis greenii (Cockerell, 1902)	A	Phyto-phagous	Asia-Tropical	1963, CZ	CZ, ES, IT	I2, J100	Bamboos	Zahradnik (1990)

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Odonaspis secreta (Cockerell, 1896)	A	Phyto-phagous	Asia-Tropical	1929, FR	FR	I2	Bamboos	Balachowsky (1930)
Opuntaspis philococcus (Cockerell, 1893)	A	Phyto-phagous	Southern-America	1929, FR	FR	I2	Opuntia	Balachowsky (1932a)
Parlatoria blanchardi Targioni Tozzetti, 1883	A	Phyto-phagous	Arabian peninsula	1947, IT	ES, FR, IT, PT	I2	Palms	Lupo (1948)
Parlatoria camelliae Comstock, 1883	A	Phyto-phagous	Asia-Tropical	1903, IT	ES, FR, IT, IT-SIC, PT, PT-MAD	I2	*Camellia*, Polyphagous	Leonardi (1903)
Parlatoria crotonis Douglas, 1867	C	Phyto-phagous	Cryptogenic	1887, GB	FR, GB, IT, HU	I2	*Croton*	Douglas (1887)
Parlatoria pergandii Comstock 1881	C	Phyto-phagous	Cryptogenic	Last 1899, IT	CY, DE, ES, ES-CAN, FR, FR-COR, GR, HR, IT, IT-SAR, IT-SIC, MT, PT, PT-MAD	I2, J100	*Citrus*, Polyphagous	Berlese and Leonardi (1899)
Parlatoria proteus (Curtis, 1843)	C	Phyto-phagous	Cryptogenic	1939, FR	BG, CZ, DE, DK, FR, PL, UA	I2, J100	Palms, orchids, Polyphagous	Morrison (1939)
Parlatoria theae Cockerell, 1896	C	Phyto-phagous	Cryptogenic	1953, FR	ES, FR, PT-MAD, PL, UA	I2	Polyphagous	Balachowsky (1953)
Parlatoria ziziphi (Lucas, 1853)	A	Phyto-phagous	Asia-Tropical	1853, FR	BG, CY, ES, ES-CAN, FR, FR-COR, GR, HR, IT, IT-SAR, IT-SIC, PT, UA	I2	*Citrus*, Rutaceae	Lucas (1853)
Pinnaspis aspidistrae (Signoret, 1869)	A	Phyto-phagous	Asia-Tropical	1868, FR	B, BG, CZ, DE, ES, ES-CAN, FR, FR-COR, GB, HU, IT,IT-SIC, IE, MT, NL, PT, PT-MAD, PL, S, UA	J100	Polyphagous	Signoret (1869b)
Pinnaspis buxi (Bouché, 1851)	C	Phyto-phagous	Cryptogenic	1851, DE	DE, DK, FR, IT	J100	Polyphagous	Balachowsky (1938)

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Pinnaspis strachani (Cooley, 1899)	C	Phyto-phagous	Cryptogenic	1988, IT	DE, ES-CAN, FR, GB, IT, PL	J100	Polyphagous	Tranfaglia and Viggiani (1988)
Poliaspis cycadis Comstock, 1833		Phyto-phagous	Asia-tropical	2007, GR	GR	J100	Cycadaceae, Ericaceae	Anagnou–Veroniki et al. (2008)
Pseudaonidia paeoniae (Cockerell, 1899)	A	Phyto-phagous	Asia-Tropical	1949, IT	IT	J100	*Camellia*	Pegazzano (1949)
Pseudaulacaspis cockerelli (Cooley, 1897)	A	Phyto-phagous	Asia-Tropical	1992, IT	FR, FR-COR, IT, IT-SIC, SI	J100	Polyphagous	Russo and Mazzeo (1992)
Pseudaulacaspis pentagona (Targioni Tozzetti, 1886)	A	Phyto-phagous	Asia-Tropical?	1886, IT	AT, BG, CH, DE, ES, ES-CAN, FR, FR-COR, GB, GR, HU, HR, IT, IT-SAR, IT-SIC, MA, NL, PT, PT-MAD, SI, UA	G, J, I	Fruit trees, Polyphagous	Targioni Tozzetti (1867)
Pseudoparlatoria parlatorioides (Comstock, 1883)	C	Phyto-phagous	Cryptogenic	1918, IT	CZ, DE, ES, FR, IT, PT-MAD	I2, J100	Polyphagous	Leonardi (1918)
Pseudoparlatoria ostreata Cockerell, 1892	C	Phyto-phagous	Cryptogenic	1954, FR	FR	I2	Polyphagous	Balachowsky (1954)
Rutherfordia major (Cockerell, 1894)	C	Phyto-phagous	Cryptogenic	2002, FR	FR	I2, J100	Polyphagous	Germain et al. (2002)
Selenaspidus albus McKenzie, 1953	A	Phyto-phagous	Afrotropical/ South Africa	1991, IT	IT	I2	Euphorbiaceae	Marotta and Garonna (1991)
Umbaspis regularis (Newstead, 1911)	A	Phyto-phagous	Afrotropical	1990, IT	IT	I2	Polyphagous	Pellizzari (1993)
Unaspis euonymi (Comstock, 1881)	A	Phyto-phagous	Asia-Temperate/ Eastern Asia	1884, IT	AT, BG, CH, DE, ES, ES-CAN, FR, FR-COR, GB, GR, HU, HR, IT, IT-SAR, IT-SIC, MT, NL, PL, PT, RO, SI, UA	I2	*Euonymus*	Targioni Tozzetti (1884)

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Unaspis yanonensis (Kuwana, 1923)	A	Phytophagous	Asia-Tropical	1969, FR	ES, FR, FR-COR, IT	I, I2	*Citrus*	Bénassy (1969)
Eriococcidae								
Eriococcus araucariae Maskell, 1879	A	Phytophagous	Australasia/ Australia	1895?, IT	ES, ES-CAN, FR, FR-COR, GR, HR, IT, IT-SAR, IT-SIC, PT, PT-AZO, PT-MAD	I2	*Araucaria*	Leonardi (1899)
Eriococcus coccineus Cockerell, 1894	A	Phytophagous	Northern-America	1930, FR	FR,FR-COR, GR, HR, IT, IT-SIC	I2, J100	Cactaceae	Balachowsky (1932a)
Ovaticoccus agavium (Douglas, 1888)	A	Phytophagous	Northern-America	1888, GB	FR, FR-COR, IT, IT-SIC, UA	I2, J100	Agavaceae	Green (1915)
Margarodidae								
Icerya formicarum Newsteadt, 1897	A	Phytophagous	Asia-Tropical	2001, FR	FR	I2	Polyphagous	Foldi (2001)
Icerya purchasi (Maskell, 1879)	A	Phytophagous	Australasia/ Australia	1900, IT	AL, CH, CY, ES, ES-CAN, FR, FR-COR, GR, HR, IT, IT-SAR, IT-SIC, MT, PT, PT-AZO, PT-MAD, RO, SI	I, I2	Polyphagous	Leonardi (1920)
Ortheziidae								
Insignorthezia insignis (Browne, 1997)	A	Phytophagous	Southerrn-America	1887, GB	AT, CH, CZ, DE, DK, ES-CAN, FR, GB, HU, HR, PT, PT-AZO, PT-MAD	I2, J100	Polyphagous	Douglas (1889)
Phoenicoccocidae								
Phoenicococcus marlatti (Cockerell, 1899)	A	Phytophagous	North Africa	1930, FR	ES, FR, FR-COR, IT, IT-SIC, PT-MAD	I2	Palms	Balachowsky (1930)
Pseudococcidae								
Antonina crawi Cockerell, 1900	A	Phytophagous	Asia-Tropical	1937, FR	ES, FR, GB, HR, UA	I2	Poaceae	Goux (1937)

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Antonina graminis (Maskell, 1897)	A	Phyto-phagous	Asia-Tropical	1992, IT	FR, IT	E, I2	Poaceae	Marotta (1992)
Balanococcus diminutus (Leonardi, 1918)	A	Phyto-phagous	Australasia/ Australia	1918, IT	FR, GB, IT, UA	J100	*Phormium*	Leonardi (1918)
Balanococcus kwoni Pellizzari & Danzig 2007	A	Phyto-phagous	Asia	Last 2007,IT	IT	I2	Bamboos	Pellizzari and Danzig (2007)
Chaetococcus bambusae (Maskell, 1892)	A	Phyto-phagous	Asia-Tropical	1990, IT	IT	I2	Bamboos	Porcelli (1990)
Chorizococcus rostellum (Lobdell, 1930)	A	Phyto-phagous	Northern-America	1979, GR	FR, GR, HU, IT, IT-SAR	E, I	Agavaceae, Gramineae	Tranfaglia (1981)
Delottococcus euphorbiae (Ezzat & McConnell, 1956)	A	Phyto-phagous	Afrotropical/ South Africa	1977, IT	FR, IT, IT-SIC	I2	Polyphagous	Tranfaglia (1981)
Dysmicoccus boninsis (Kuwana, 1909)	C	Phyto-phagous	Cryptogenic	Last 1938 PT-MAD	PT-MAD	I	Polyphagous	Balachowsky (1938)
Dysmicoccus brevipes (Cockerell, 1893)	A	Phyto-phagous	Central-America	1933, NL	ES-CAN, IT, IT-SIC,NL, PT-AZO, PT-MAD	J100	Polyphagous	Jansen (1995)
Dysmicoccus grassii (Leonardi, 1913)	A	Phyto-phagous	Central-America	Last 1913 ES-CAN	ES-CAN, FR	I, J100	Polyphagous	Leonardi (1913)
Dysmicoccus mackienziei Beardsley 1965	A	Phyto-phagous	Southern-America/ Mexico	1989, IT	IT	I2	Bromeliaceae	Marotta (1992)
Dysmicoccus neobrevipes Beardsley 1959	A	Phyto-phagous	Southern-America	1988, NL	IT, IT-SIC, NL	I2	Polyphagous	Jansen (1995)
Ferrisia virgata (Cockerell, 1893)	A	Phyto-phagous	Southern-America	1994, NL	FR, NL	I2, J100	Polyphagous	Jansen (1995)
Geococcus coffeae Green, 1933	A	Phyto-phagous	Asia-Tropical	1967, NL	DK, FR, NL	I2, J100	Polyphagous	Jansen (1995)

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Hypogeococcus pungens Granara de Willink, 1981	A	Phytophagous	Southern-America	1986, IT	FR, FR-COR, GR, IT, IT-SIC	I2	Cactaceae	Süss and Trematerra (1986)
Nipaecoccus nipae (Maskell, 1893)	A	Phytophagous	Central-America	1917, GB	ES, ES-CAN, GB, IT-SIC, PT-MAD	I2, J100	Polyphagous	Green (1917)
Palmicultor palmarum (Ehrhorn, 1916)	C	Phytophagous	Cryptogenic	2004, FR	ES-CAN, F	J100	Palms	Chapin and Germain (2005)
Peliococcus serratus (Ferris, 1925)	A	Phytophagous	Northern-America	1976, IT	IT	G, I2	*Corylus*	Tranfaglia (1976)
Phenacoccus gossypii Townsend & Cockerell, 1898	A	Phytophagous	Northern-America	1946, ES	ES, ES-CAN	I2	Polyphagous	Gómez-Menor Ortega (1946)
Phenacoccus madeirensis Green, 1923	A	Phytophagous	Southern-America	1923, PT-MAD	FR, IT, IT-SIC, PT-MAD	I2	Polyphagous	Green (1923)
Phenacoccus solani Ferris, 1918	A	Phytophagous	Northern-America	1999, IT, IT-SIC	AL, IT, IT-SIC	I2	Polyphagous	Mazzeo et al. (1999)
Planococcus citri (Risso, 1813)	A	Phytophagous	Asia-Tropical	1813, FR	BG, CH, CY, CZ, ES, ES-CAN, FR, FR-COR, GB,GR, HU, HR, IT, IT-SAR, IT-SIC, NL, PL, PT, PT-AZO, PT-MAD, SI, UA	I2, J100	Polyphagous	Risso (1813)
Planococcus halli Ezzat & McConnel, 1956	C	Phytophagous	Cryptogenic	1989, IT	IT	I2	*Nerium oleander*, Polyphagous	Marotta (1992)
Pseudococcus calceolariae (Maskell, 1879)	A	Phytophagous	Australasia/ Australia	1914, GB	BG, CZ, ES, ES-CAN, FR, FR-COR, GB, HR, IT, IT-SAR, IT-SIC, PT, PT-AZO, UA	I2, J100	Polyphagous	Green (1915)

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Pseudococcus cosmtocki (Kuwana, 1902)	A	Phyto-phagous	Asia-Temperate	last 1989, MD	ES-CAN,FR, IT, MD, PT-MAD	I, I2	Polyphagous	Ben-Dov (1994)
Pseudococcus longispinus (Targioni TozzettIT, 1868)	A	Phyto-phagous	Australasia/ Australia	1867, IT	BG, CZ, DK, ES, ES-CAN, FR, FR-COR, GB, GR, HU, HR, IT, IT-SAR, IT-SIC, LV, MT, PT, PT-AZO, PT-MAD, PL, SI, UA	I2, J100	Polyphagous	Targioni Tozzetti (1886), (1885)
Pseudococcus viburni (Signoret, 1875)	A	Phyto-phagous	Northern-America	1875, FR	B, BG, DE, DK, CZ, ES, ES-CAN, FR, FR-COR, GB, GR, HU, HR, IT, IT-SAR, IT-SIC, MT, NL, PT, PT-AZO, PT-MAD, PL, SI, SK, RS, UA	I, I2	Polyphagous	Signoret (1875)
Rhizoecus americanus (Hambleton, 1946)	A	Phyto-phagous	Northern-America	1992, IT, IT-SIC	IT, IT-SIC	I2	Polyphagous	Russo and Mazzeo (1992)
Rhizoecus cacticans (Hambleton, 1946)	A	Phyto-phagous	Southern-America	1961, NL	BY, CZ, DK, ES-CAN, IT, IT-SIC, NL, PL	I2	Polyphagous	Jansen (1995)
Rhizoecus dianthi Green, 1926	A	Phyto-phagous	Australasia/ Australia	1961, NL	CZ, DK, FR, IT, NL, PL	I2	Polyphagous	Jansen (1995)
Rhizoecus latus (Hambleton, 1946)	A	Phyto-phagous	Southern-America	1995, IT	IT	I2	Polyphagous	Marotta (1995)
Spilococcus mamillariae (Bouché, 1844)	A	Phyto-phagous	Northern-America	1979, IT	CZ, DE, DK, FR, GB, HU, IT, IT-SIC	I2, J100	Cactaceae	Tranfaglia (1981)
Trionymus angustifrons Hall, 1926	A	Phyto-phagous	Arabian peninsula	1966, PL	CH, FR, PL	E, I2	Compositae, *Tamarix*, *Urtica*	Koteja and Zak-Ogaza (1966)
Trochiscococcus speciosus (De Lotto, 1961)	A	Phyto-phagous	Afrotropical	1990, IT	FR,IT	J100	Liliaceae	Williams and Pellizzari (1997)

Family *Species*	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Vryburgia amaryllidis (Bouché, 1837)	A	Phyto-phagous	Afrotropical	1933, IT	BG, DE, ES, FR,GR, IT, NL, P	I2	Polyphagous	Menozzi (1933)
Vryburgia brevicruris (McKenzie, 1960)	A	Phyto-phagous	Afrotropical	1975, DK	BE, DK, GB	I2	Polyphagous	Kozarzhevskaya and Reitzel (1975)
Vryburgia rimariae Tranfaglia, 1981	A	Phyto-phagous	Afrotropical/ South Africa	1975, IT	FR, IT, IT-SIC	I2	Crassulaceae	Tranfaglia (1981)

Table 9.3.2. List and main characteristics of the scale species alien *in* Europe. Country codes abbreviations refer to ISO 3166 (see appendix I). Habitat abbreviations refer to EUNIS (see appendix II). Only selected references are given. Last update 29/05/2009

Family *Species*	**Regime**	**Native range**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Diaspididae						
Aonidiella tinerfensis Lindinger (1911)	Phytophagous	Canary Islands	PT	I2	*Dracaena*	Balachowsky (1948), Fernandes (1992), (1990)
Aonidiella lauretorum (Lindinger, 1911)	Phytophagous	Canary Islands, Madeira	PT	I2	Polyphagous	Balachowsky (1948)
Margarodidae						
Marchalina hellenica (Gennadius, 1883)	Phytophagous	Greece, Turkey	IT	G	*Pinus*	Tranfaglia and Tremblay (1984)
Matsucoccus feytaudi Ducasse 1941	Phytophagous	France, Spain, Portugal	IT, FR-COR	G	*Pinus pinaster*	Arzone and Vidano (1981), Jactel et al. (1996)

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Other Hemiptera Sternorrhyncha (Aleyrodidae, Phylloxeroidea, and Psylloidea) and Hemiptera Auchenorrhyncha

Chapter 9.4

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Abstract

Apart from aphids and scales, 52 additional Sternorrhyncha hemipteran species alien to Europe have been identified within Aleyrodidae (27 whitefly species), Phylloxeroidea (9 adelgids, 2 phylloxerans) and Psylloidea (14 species of jumping plant-lice) in addition to 12 Auchenorrhyncha species (mostly Cicadellidae- 8 species). At present, the alien species represent 39% of the total whitefly fauna and 36% of the total adelgid fauna occuring in Europe. The proportion is insignificant in the other groups. The arrival of alien phylloxerans and adelgids appeared to peak during the first part of the 20th century. In contrast, the mean number of new records per year of alien aleyrodids, psylloids and Auchenorrhyncha increased regularly after the 1950s. For these three groups, an average of 0.5–0.6 new alien species has been recorded per year in Europe since 2000. The region of origin of the alien species largely differs between the different groups. Alien aleyrodids and psylloids mainly originated from tropical regions whilst the adelgids and phylloxerans came equally from North America and Asia. A major part of the alien Auchenorrhyncha originated

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from North American. Most of these alien species are presently observed in man-made habitats, especially in parks and gardens but alien adelgids are mainly observed in forests because of their association with conifer trees used for afforestation.

Keywords
alien, Europe, Adelgidae, Aleyrodidae, Cicadellidae, Psyllidae, Phylloxeridae, Auchenorrhyncha

9.4.1. Introduction

This chapter will consider the hemipteran species alien to Europe belonging to the Sternorrhyncha superfamilies other than Aphidoidea and Coccoidea (i.e., Aleyrodoidea, and superfamilies Phylloxeroidea and Psylloidea) and to the Auchenorrhyncha (Cicadomorpha and Fulgoromorpha suborders). We will mainly follow the higher classification used in Fauna Europaea (Asche and Hoch 2004, Nieto Nafria and Binazzi 2005).

Both **Aleyrodoidae** (whiteflies) and **Psylloidea** (jumping plant-lice or psylloids) are distributed throughout the major zoogeographical regions of the World, with their greatest diversity in tropical and south temperate regions. They are all sap-sucking insects and most of them are narrowly host-plant specific. This is particularly true for the psylloids were such specificity may also be present at higher taxonomic levels and not just at species level. Both adult whiteflies and psylloids possess a feeding rostrum, two pairs of flying wings and are fully mobile. Reproduction in both groups is generally sexual with some rare cases of *parthenogenetic** development. The eggs in both groups are laid directly onto the host-plant surface.

Whiteflies comprise a relatively small group of insects in a unique family Aleyrodidae, and we will later us only this family name. Whiteflies are the least speciose among the four groups of sternorrhynchous Hemiptera (whiteflies, aphids, jumping plant-lice and scale insects) with only 1,556 described species accommodated in 161 genera (Martin and Mound 2008). Adult whiteflies are very small insects, most measuring between 1–3 mm in body length. Life-cycles of whiteflies are somewhat unusual. The first-instar larvae are able to walk around (crawler) short distances on the host plant until a suitable feeding site is found; then, the remaining three larval instars are sessile. The final whitefly larval stage is usually termed as a *puparium** where feeding goes on during the first part of this stage. It is also this stage which is used for almost all whitefly taxonomy and systematic with adults being identified only rarely. All whitefly species are free living during their larval stages.

Jumping-plant lice (Psylloidea) comprise some 3,000 described species accommodated in the six currently recognized families. Adults range from 1–12 mm in body length. Life-cycles of psylloids are very straightforward with eggs laid singly or in clusters on the host plant, the immatures undergoing five larval instars (being all mobile unless gall-dwelling) and after these adults emerge. In jumping-plant lice, both adults and nymphal stages are used for species identifications. More than three-quarters of psylloid species are free-living during their larval stages, but some are gall-inducing and others live under protective scales or lerps (waxy constructions covering the body).

The feeding activity of whiteflies and psylloids may negatively affect the host-plant by rendering weakness and thus more susceptibility to other diseases. The feeding activity of these insects (especially in whiteflies) may produce copious honeydew which may cover underlying leaves and fruits/flowers of the host-plant. Usually, this honeydew is immediately covered by black sooty mould which impairs photosynthesis and/or renders unmarketable plant parts such as flowers and fruits. Notorious pest species in both groups (adults) are vectors of a number of plant pathogens such as viruses and phytoplasmas.

Phylloxeroidea (adelgids and phylloxerans) is a closely related superfamily, which include some of the most destructive introduced plant pests in the World. They include minute insects (1–2 mm in body length), which are highly host specific but with a simple morphology. The two groups are distinguished from typical aphids (Aphididae) by the complete absence of *siphunculi** and the retention of the ancestral trait of oviparity in all generations. Phylloxerans feed on angiosperms, particularly hickories and ashes (Juglandaceae), oaks and beeches (Fagaceae) and grapes (Vitaceae) but adelgids only develop on certain genera of the Pinaceae family, retaining their ancestral relationships with gymnosperms. Such as their host plants, adelgids are endemic to the Northern Hemisphere in boreal and temperate habitats. Despite the broad geographical distribution of these host plants, there are less than 70 and ca. 75 species of known adelgids and phylloxerans, respectively (Havill and Foottit 2007). However, there is considerable taxonomic uncertainty in both groups since several described species may not represent unique taxa but are actually different morphological forms of the same species found on different host plants. Both groups exhibit cyclical parthenogenesis and possess complex, multigenerational, polymorphic life cycles. Five generations make up the typical two- year adelgid *holocycle**, three produced on the primary host, *Picea* spp. (noticed as -I- in Table 9.4.1) where sexual reproduction and gall formation occurs, and the last two are produced on a secondary host (*Abies*, *Larix*, *Pseudotsuga*, *Tsuga*, or *Pinus,* noticed as -II- in Table 9.4.1) which supports a series of asexual generations. Adelgids that are *anholocyclic** complete their entire life cycle on either *Picea* or on a secondary host genus. Some anholocyclic species may in fact be holocyclic, but forms on the alternate host have not been described. Typically, sexual reproduction and host alternation nymphs and galls are formed in spring. Winged *gallicolae** can disperse or can stay to lay eggs near the gall from which they emerged.

Auchenorrhyncha, with some 42,000 described species worldwide is probably paraphyletic but composed of two well supported monophyletic groups, **Fulgoromorpha** (planthoppers) and **Cicadomorpha** (leafhoppers, froghoppers, treehoppers and cicadas). Hemipteran phylogeny is still controversial (Cryan 2005, Yoshizawa and Saigusa 2001) although Sternorrhyncha, Fulgoromorpha, Cicadomorpha, Coleorrhyncha and Heteroptera are considered monophyletic by most authors (Bourgoin and Campbell 2002, Dietrich 2002, Nielson 1985). Auchenorrhyncha usually feed on plant sap, either on phloem, xylem or parenchyma, and they occur therefore in almost all habitats colonized by vascular plants. Many are of economic importance due to the transmission of phytopathogenic organisms causing plant diseases such as phytoplasmas and virus diseases (Bourgoin and Campbell 2002, Carver et al. 1991, Dietrich 2005, Kristensen 1991, Nielson 1985). Most Auchenorrhyncha have a bisexual reproduction. Eggs are usually laid into plant tissue and there are 5 nymphal instars. While some species are good flyers and can be carried by wind over relatively long distances (Della Giustina and Balasse 1999), most of the translocations are considered due to anthropogenic causes. All the species introduced from North American and east Asiatic are assumed to have been imported with plants, either as eggs in the tissue or as nymphs or adults feeding on the host plants.

Planthoppers (Fulgoromorpha) with 21 families and some 12,000 described species occur worldwide but are most diverse in the tropics. Only the widely distributed families Cixiidae and Delphacidae occur also in colder regions such as Northern Europe. In Europe, ca. 750 species of Fulgoromorpha are expected to occur (Asche and Hoch 2004). They can be distinguished by the following characters: pedicel of antenna bulbous or enlarged; presence of *tegulae** on the mesothorax; bases of mid-coxae widely separated. The body size varies from 2–114 mm but most species are small (O'Brien and Wilson 1985).

Cicadomorpha are characterised by following characters: antennal pedicel small; tegulae absent; meso-coxae small and narrowly separated. To date, 30,000 species of Cicadomorpha have been described in over than 5,000 genera and 13 families. Dietrich (Dietrich 2002) estimated that about 6–10% of plant-feeding insects belong to the Cicadomorpha. Despite their economic importance, there are surprisingly still many gaps in the knowledge on the taxonomy, phylogeny, life history and biology of Auchenorrhyncha.

9.4.2. Taxonomy and invasion history of the Aleyrodidae, Psylloidea, Phylloxeroidea, and Auchenorrhyncha alien *to* Europe

The literature about alien species of Aleyrodidae, Psylloidea, Phylloxeroidea, and Auchenorrhyncha in Europe is relatively scattered, most of the studies dealing with alien pests of economic importance such as *Bemisia tabaci* and *Trialeurodes vaporarium* (Bedford et al. 1994, Martin et al. 2000) for Aleyrodidae or *Metcalfa pruinosa* and *Scaphoideus titanus* (Arzone et al. 1987, Dlabola 1981) for Auchenorrhyncha. Indeed, comprehensive data on alien species were available for only a few European countries. i.e., Albania, Bulgaria and Macedonia (Tomov et al. 2009), Austria (Essl and Rabitsch 2002), the Czech Republic (Šefrová and Laštùvka 2005), Germany (Geiter et al. 2002), Great Britain (Hill et al. 2005), Slovenia (Seljak 2002) and Switzerland (Kenis 2005). The 'Handbook of alien species in Europe' (DAISIE 2009), generated by the DAISIE project, listed a number of species alien to Europe (i.e, of exotic origin or cryptogenic) and alien in Europe (introduced by man from a European region to another where the species is not native) but the status of some of these species also needed to be reviewed. At the end of each group, we provide information on the species of this group we excluded from the alien list either because of confusion in their actual status or of misidentifications. Apart from the established species, the alien lists of Aleyrodidae, Phylloxeroidea and Psylloidea will also include species which were observed only in greenhouses and for which no data is available on their establishment in the wild in the mentioned territory. In contrast, the list of alien Auchenorrhyncha will only include established species in the wild.

9.4.2.1 Aleyrodidae

A total of 27 species alien *to* Europe were recorded. Although the family Aleyrodidae include three subfamilies only two of these are represented in both the alien and the native European fauna. At present, the alien species represent 39% of the total whitefly fauna observed in Europe (Figure 9.4.1). Twenty alien species belong to Aleyrodinae, which is the most widespread and largest subfamily with over 1,400 described species. Seven species belong to the subfamily Aleurodicinae, which is mainly confined to South America, plus very few species in South-Eastern Asia and other geographical regions (121 described species) (Martin 1996). It is usually regarded as being more primitive than Aleyrodinae. In general, Aleurodicinae represent much larger species than typical whitefly, their additional wing venation being possibly a functional necessity associated with their large size. The pupal cases of the Aleurodicinae are generally more complex than those of the Aleyrodinae, bearing large compound wax-secreting pores on the dorsal surface. Species of whiteflies intercepted in greenhouses (occasionally or once) are rather few. Such species were included in the list because additional introductions as well as establishment in the wild are not to be excluded especially under global change conditions. These species include *Filicaleyrodes williamsi*, a species whose origin remains obscure; *Aleuropteridis filicicola,* an African species found on ferns; *Aleurotulus nephrolepidis*, a specialist fern feeder often found in greenhouses which is already known to occur in the wild in Macaronesia (Martin et al. 2000); *Ceraleurodicus varus*, an Aleurodicinae species which was found to colonize orchids in 1939- 1940 in an orchid house at the Budapest Botanical Garden, but was never intercepted again or recorded in other European countries; *Aleurodicus destructor* of which a single specimen was collected from *Olea* at a Garden Festival in Liverpool, UK, but which is occasionally intercepted by quarantine inspections in Europe (Martin 1996); a neotropical whitefly, *Aleurotrachelus trachoides* was intercepted in Great Britain on sweet potato leaves imported from Gambia (Malumphy 2005); and, *Pealius azaleae*. This latter species is often regarded as a minor pest of ornamental azaleas (*Rhododendron* spp.). It was originally described from Belgian material intercepted by quarantine officials in the United States but its origin is likely Eastern Asia. The occurrence of this species in Europe is very sporadic and records often reflect newly introduced populations with azalea hosts being kept indoors, in greenhouses or in very sheltered places.

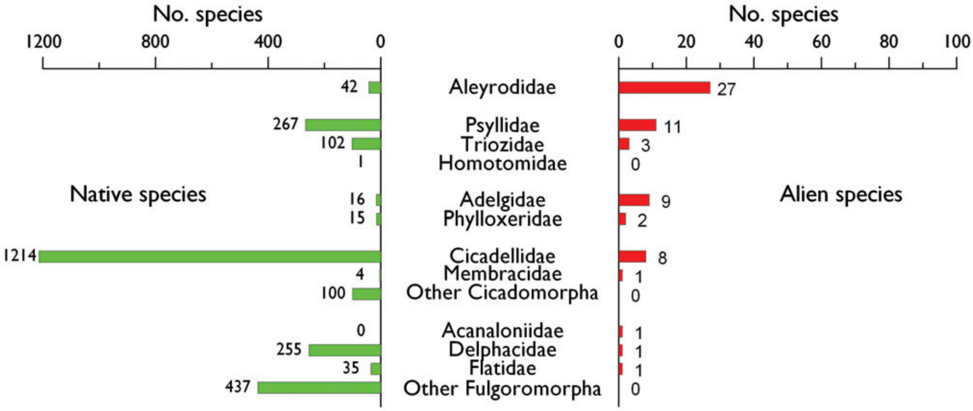

Figure 9.4.1. Comparison of the relative importance of Aleyrodidae, Psylloidea, Phylloxeroidea, and Auchenorrhyncha in the alien and native entomofauna in Europe. The number right to the bar indicates the number of species per family.

An emergent whitefly pest in Europe is *Alerocanthus spiniferus*, commonly known as the Orange Spiny Whitefly. This species is listed as a quarantine threat to Europe and is included in the EPPO A1-List of species recommended for regulation as quarantine pests and in the EU Annex II/A1 under: "Pests known not to occur in the EU, whose introduction into, and/or whose spread within, all EU Member States is prohibited, with reference to specific plants or plant products". The accidental introduction, acclimatization and spreading of this species in southern Italy (Porcelli 2008) is thus of concern to all the European Union. As pointed out by Porcelli (Porcelli 2008), the origin of the infestation of this species is still unknown, and the species has already spread in the Apulia Region to make its eradication impossible. *A. spiniferus* is a widespread tropical species, occasionally a pest on *Annona* and *Citrus*, but it is also recorded from woody hosts of more than 15 plant families (Martin 1996). *Aleuroclava aucubae*, a species described from Japan and most likely of Oriental origin, was recently recorded from Italy (Pellizari and Šimala 2007) and may also prove to be a potential pest in Europe. It is known to occur on more than 15 plant families (Mound and Halsey 1978) and in the Veneto region, the species was found on both greenhouse plants (*Citrus x limon* (L.) Osb., *Ficus sycomorus* L.) and outdoor host plants (*Pittosporum tobira* (Thunb.) Aiton , *Prunus armeniaca* L., *Photinia*).

Some whitefly species not native to Europe have been found in Macaronesia and some of these are also penetrating into Europe. *Aleuroplatus perseaphagus* is a species of Neotropical origin, but was first described from Madeira. The species is common on avocado. *Aleurotrachelus atratus* is also a species of Neotropical origin, but was found in the Canary Islands (Martin et al. 2000) and is now being recorded on several endangered palm species on various islands in the south-western Indian Ocean and in glasshouses in Paris (Borowiec et al. 2010). *Acaudaleyrodes rachipora* was described from India and is probably native to Asia but the species is also known from the Canary islands (Martin et al. 2000). *Crenidorsum aroidephagus*, introduced in Madeira, is a native of New World, colonising several plant species of the Araceae family in Central and South America, southern USA, and the Pacific Region. It is is also reported as a minor pest for growers of ornamental-foliage plants (Martin et al. 2001)·

Massilieurodes chittendeni is most probably a species originating from northern Asia, from where its host plant, rhododendrons, mainly originate. This species was described on material collected in England in 1928 (Laing 1928). Klasa et al. (2003) reported the introduction of this species to central Poland, the Czech Republic, Germany and the Netherlands. Two whitefly species with an uncertain area of origin include *Dialeurodes kirkaldyi* and *Singiella citrifolii* both potential pests of *Citrus*-plantations. *D. kirkaldyi* was originally described from Hawaii and later reported in several states in North America (Russell 1964). The species is also known from Africa and Asia. In Europe it was so far found in Cyprus and Portugal. *S. citrifolii* was originally described from the United States. It is known from the Oriental Regions and from the Neotropics and the Nearctic Region. In Europe the species is known from Madeira (Aguiar 1998) and recently it was reported from the Mediterranean Region (Lebanon) (Martin 2000). *Parabemisia myricae*, commonly known as the Japanese bayberry whitefly, is probably native to Japan. It arrived in the Mediterranean Basin and Southern Europe in the mid 1980s and in a very short time it invaded most of the Mediterranean countries with considerable damage to citrus plantations (Rapisarda et al. 1990).

Some alien whitefly species show little dispersion in Europe. *Trialeurodes packardi*, a species native to the Nearctic Region where it is extremely polyphagous, was only noted in Hungary (Kozár et al. 1987) as a pest on strawberries. *T. packardi* is closely related to *T. vaporariorum*, and the two species can only be distinguished via microscopic examination of pupal cases, and this may also be a reason why the species was not recorded elsewhere in Europe.

A highly polyphagous Neotropical species is *Aleurodicus dispersus*, commonly known as the Spiralling Whitefly. This species is occasionally detected in northern Europe on plants imported from the Far East (Martin 1996). In the 1970s this species began a rapid expansion of its range, westwards from the New World, and crossed the Pacific to the Philippines by 1983, and in 1990 its arrival in the Malay Peninsula was noted. Since then its spread continued into Thailand, Sri Lanka, southern India, the Maldive Islands, and Western Africa (Martin 1996). Its establishment in the Canaries dates back to the early 1960s, but the species is also known from Macaronesia where it is common on trees and shrubs in the open and seems to be a well established species. A species which co-exists with *A. dispersus* in the Canary Island is *Lecanoides floccissimus*, a second Neotropical species which is particularly damaging to numerous unrelated host-plants due to direct feeding and by the enormous populations depriving plants of sap and thus inhibiting growth. The species is also known to secrete copious honeydew on which sooty mould immediately grows and a final effect to people living in the area where this species is abundant, is the fluffy white “wool” secreted by the larval stages, which blows from trees, sticks to clothing and garden furniture, and even causes allergic reactions (Martin et al. 1997). The genus *Paraleyrodes*, also native to the

Neotropical Region, is represented in the West Palaearctic by three species. *Paraleyrodes* species are all very small, comparable in size to members of the Aleyrodinae, and similarly having their fore wing venation reduced to a single unbranched main vein. However, the larval instars all possess wax-producing pores of compound structure, claws on the puparial legs and a quadrisetose *ligula**, all being diagnostic characteristics for the Aleurodicinae. *P. bondari*, is well established in Madeira with material collected on several host-plants since 1995 and likelwise, *P. citricolus,* established on the same island at least since 1994 and is common on both *Citrus* spp. and *Persea americana* Miller (Martin 1996). *P. minei*, although originally described from Syria, is native to the Neotropics. This species has been established in Spain since the early 1990s where it provokes substantial damage on citrus plantations (Garcia Garcia et al. 1992). A fourth species, *P. pseudonaranjae* Martin has become established in Florida, Hawaii, Bermuda and Hong Kong and seems to be rapidly extending its native geographical range (Martin 2001). This species is polyphagous with *Citrus* included in its host-plant records and Europe should be alerted with respect to the high risk of introducing this species.

With regard to the DAISIE list of alien Aleyrodidae published in the 'Handbook of alien species in Europe'(DAISIE 2009), the identification of *Aleuroclava guyavae* by Pellizari and Šimala (Pellizari and Šimala 2007) was incorrect and should refer to *A. aucubae*, a closely related species (Martin, J. pers. comm., 2010). *Bemisis afer* (Priesner & Hosny) was not included as an alien species to Europe in this work as this group is in need of taxonomic revision. Several samples from Britain do however come from glasshouses and its status in Britain was reviewed by Malumphy (2003). Besides, several forms are known from Macaronesia, and before a proper revision of the group is done to define species boundaries no account on European material is included. *Aleurolobus marlatti* (Quaintance) was also removed from the list of alien species in Europe. The species has a very wide geographical distribution with native records from Southern Europe (Sicily and Malta). We also excluded *Aleurolobus olivinus* (Silvestri), a species which is widely found in Europe and wherever its preferred host-plant (olive tree) grows. Finally, *Dialeurodes formosensis* Takahashi was also excluded because the unconfirmed record to species level of Iaccarino (1985) was incorrect and should refer to *Dialeurodes setiger* (Goux), a species native of the Mediterranean area.

9.4.2.2 Psylloidea

Jumping plant-lice alien *to* Europe include 14 species belonging to two families, Psyllidae (11 species) and Triozidae (3 species) (Figure 9.4.1). The Psyllidae family is the largest family of jumping lant-lice with a cosmopolitan distribution and some 1,800 described species accommodated in more than 150 genera. As presently constituted this family is difficult to define as, effectively, it comprises all those species that do not belong in any other of the five psylloid families. The family has a wide range of host-plants with many species utilising woody legumes. Some species are gall-inducers and all of the solitary lerp-forming species belong to this family. The genus *Acizzia* currently accommodates more than 30 described species of psylloids mainly found in Australia, New Zealand, the Old World tropics and extending through North Africa and the Middle East to the Mediterranean Basin (Hodkinson and Hollis 1987). Among other characteristics, male adults of this genus have a *proctiger** with a conspicuous posterior lobe, forewing with a tapered pterostigma and distinct costal break, basal metatarsus with 1 or 2 black spures and apical segment of aedeagus often complex. Species feed on mimosoid legumes, particularly *Acacia* and *Albizia*. In Europe, four species are considered alien introductions. *Acizzia hollisi* was described from Saudi Arabia and Israel (Burckhardt 1981) on *Acacia raddiana* Savi and was found on the island of Lampedusa in 1987 (Conci and Tamanini 1989). *Acizzia acaciaebaileyanae* and *A. uncatoides* were originally described from Australia and New Zealand, respectively. Both species have been introduced and established in several European locations; *A. acaciaebaileyanae* in France (Malausa et al. 1997), Italy (Fauna Italia, Rapisarda 1985) and Slovenia (Seljak et al. 2004) whereas *A. uncatoides* in France, Italy, Portugal (Hodkinson and Hollis 1987), Montenegro (Lauterer 1993), Malta (Mifsud 2010) and the Canary Islands. Within this psylloid group, the latest arrival in Europe was *Acizzia jamatonica*, originally described from Asia. This species was first noted in Italy (Zandigiacomo et al. 2002), and it was later recorded from a number of European countries including France and Corsica (Chapin and Cocquempot 2005), Slovenia (Seljak 2003), Switzerland (Kenis 2005), Croatia (Seljak et al. 2004), and Hungary (Redel and Penzes 2006). Since 2006, this species was also introduced in the Nearctic Region and its occurrence in the south-eastern United States was surveyed (Wheeler Jr and Richard Hoebeke 2009).

Another group of psylloids which are being accidentally introduced and established in Europe are those associated with eucalyptus plantations. The psylloid subfamily Spondyliaspidinae represents a group of insects associated with Myrtaceae, in particular with eucalyptus. Eucalypts, native to Australia, are planted for a variety of uses in many warmer regions throughout the Old and the New World. The commercial value of selected species for the production of ornamental foliage used in the cut flower industry and/or for pulp timber production has resulted in the widespread planting of *Eucalyptus* trees. Psylloids associated with such host-plants, have become established outside their native range and are sometimes responsible for severe damage to such plantations (Burckhardt and Elgueta 2000). One such psylloid is *Blastopsylla occidentalis* described from Australia, New Zealand and California, and subsequently reported from Mexico, Brazil and Chile (Burckhardt and Lauterer 1997). The species was recently reported in Italy (Laudonia 2006) and most likely this psylloid is already established in other Mediterranean countries. *Glycaspis brimblecombei,* commonly known as the Redgum Lerp Psyllid, originally described from Brisbane in Australia, is also expanding its range with records from Mauritius and California (late 1990s), and it has recently been intercepted in Spain and Portugal (Valente and Hodkinson 2008). The Redgum Lerp Psyllid is becoming a major ornamental pest of Red Gum Eucalyptus, but also occurs on Sugar Gum, Glue Gum and other *Eucalyptus* spp. Three species of *Ctenarytaina* also established in Europe, the first being *C. eucalypti*, commonly known as the Eucalyptus psyllid. Originally described from specimens collected on blue gum in New Zealand, this species was first introduced into southern England, northern France and South Africa as early as the 1920s (Laing 1922, Mercier and Poisson 1926, Pettey 1925). This psylloid pest expanded and its current distribution includes France, Germany, Italy, Portugal, Madeira, the Azores, Spain, the Canary Islands, Switzerland and Great Britain (Hodkinson 1999, Wittenberg 2005). The two other species of *Ctenarytaina* have been introduced more recently. *C. spatulata* was first reported from France and Italy (Costanzi et al. 2003) and later from Portugal (Valente et al. 2004) and Spain (Mansilla et al. 2004), whereas C. *peregrina* was first intercepted and described from England (Hodkinson 2007) and recently reported from France and Italy (Cocquempot and Constanzi (Unpubl.)).

The genus *Cacopsylla* includes more than 100 described species distributed mainly in the Holarctic Region, with species that penetrate the Oriental, Afrotropical and Neotropical Regions. Cocquempot and Germain (Cocquempot and Germain 2000) recorded *Cacopsylla fulguralis*, a species native to western Asia, for the first time from France and subsequently the species was found in Belgium (Baugnée 2003), Italy (Süss and Salvodelli 2003), Spain (Cocquempot 2008), Switzerland (Cantiani 1968) and the United Kingdom (Malumphy and Halstead 2003). *Cacopsylla pulchella*, a species strictly associated with the Juda's tree (*Cercis siliquastrum* L.) is probably native to the Eastern Mediterranean basin but since the 1960s the species was found in various localities in Central and Northern Europe (Cantiani 1968, Hodkinson and White 1979b).

The family Triozidae is the second largest family of Psylloidea with some 1,000 described species accommodated in 50 poorly diagnosed genera (Hollis 1984) with a worldwide tropical/temperate distribution. Species utilise host plants in a wide variety of families but never on legumes and many species produce characteristic galls on their host-plants. Four species are recorded as alien for Europe. *Trioza neglecta* was introduced to Europe from south-western and Central Asia, the area of its origin, with its host plant, *Elaeagnus angustifolia* L. grown as an ornamental shrub in parks and along roads. It is now widely distributed from Georgia, Armenia, Azerbaijan, Iran and Anatolia through Russia, Ukraine, Moldavia, Bulgaria, the former Yugoslavia and Romania to Central Europe (Hungary, Slovakia, the Czech Republic, Austria) (Lauterer and Malenovský 2002b). The other two introduced triozid psylloids include *T. erytreae* and *T. vitreoradiata*, both of economic importance and which are treated in detail under section 9.4.8. An additional triozid species, *Bactericera tremblayi* (Wagner), was included in the list of aliens of the DAISIE 'Handbook of alien species in Europe' (DAISIE 2009) but was removed from the present list. This species was abundant in Southern Italy and caused problems on onions since the late 1950s. However, around 1980 the populations of this species declined and now the species seems to be rare and localised. According to Tremblay (1988) the species could have been a recent introduction in Italy from the former USSR. There is not much to sustain such a statement given the fact that apart from Italy, the species is known to occur in Switzerland, France, Turkey, Iran and questionably from Syria and also because the species is polyphagous on herbaceous plants (Burckhardt and Mühlethaler 2003, Lauterer et al. in prep).

In addition, several other psylloid species can be considered as alien *in* Europe. One is a species from the small Homotomidae family, which includes 80 described species in the world, accommodated in 11 genera. Host plants all belong to the Moraceae family, and mainly to the genus *Ficus*. Most known larvae are free-living, although some live in colonies under communal lerps and very few species are gall-inducers. Most species have a pan-tropical distribution but *Homotoma ficus* (L.), a native of Central-Southern Europe and the Middle East feeding on *Ficus carica* L., has been introduced in Southern England where it seems to be confined (Hodkinson and White 1979a). It is alien to North America (Hollis and Broomfield 1989).

In the same category of alien *in* Europe are two Psyllidae species. *Calophya rhois* (Löw), a southern-European species, was reported as introduced in Britain on the basis of a single record from Scalpay in the Hebrides (Hodkinson and White 1979a). The genus *Calophya* is species-poor and distributed in the Neotropical, Holarctic and Oriental Regions with jumping plant-lice associated mainly with Anacardiaceae. *Livilla variegata* (Löw), is probably native to Eastern Europe. The species is known from France, Italy, Switzerland, Bosnia, Romania, Spain, Great Britain, Hungary, Germany, Austria and the Czech Republic (Hodkinson and White 1979b, Lauterer and Malenovský 2002b). This species is strictly oligophagous on *Laburnum anagyroides* Medik. and *L.. alpinum* (Mill.) Bercht. & Presl., and it is already a widespread element in Central Europe, where it colonises its host plant, *L. anagyroides*, an introduced Mediterranean ornamental tree commonly planted in parks and gardens, towns and villages and on roadsides. The introduction and spread of *L. variegata* in Central Europe escaped the notice of entomologists, similar to what happened in England, where it was collected for the first time in 1978 (Hollis 1978), but by which time it was already widespread in that country. A last species, *Trioza alacris* Flor, is most likely of Mediterranean origin but was introduced throughout central and Northern Europe (only in greenhouses or on laurels placed temporarily outside during summer) on cultivated bay laurel. It mostly develops on Laurel (*Laurus nobilis* L.) but is also reported on *L. azoricus* Seub., producing characteristic large leaf galls by rolling the leaf margins down to the lower leaf surface. Most probably the earliest record in Central Europe was that of Schaefer (1949) with material collected from Switzerland in 1917. The species was also introduced in USA (California and New Jersey), Brazil, Chile and Argentina (Conci and Tamanini 1985).

9.4.2.3. Phylloxeroidea

– Adelgidae

Following the 2007 revision by Havill and Footit (2007), a total of 9 adelgid species were identified as alien *to* Europe, including 6 species in the genus *Adelges* (subgenera *Cholodovskaya*, *Dreyfusia*, and *Gilletteella*) and 3 species in the genus *Pineus* (subgenera *Pineus* and *Eopineus)*. At present, these alien species represent 36% of the total adelgid fauna observed in Europe (Figure 9.4.1). Most of them were introduced during the late 19th century- early 20th century alongside with their exotic conifer host trees which were massively used at that time for afforestation in Europe, e.g. Douglas-fir (*Pseudotsuga menziesii* Mirb. (Franco)) for *Adelges cooleyi* (Chrystal 1922) and *A. coweni* (Roversi and Binazzi 1996), Caucasian fir (*Abies nordmanianna* Spach.) for *Adelges (Dreyfusia) nordmanianna* (Marchal 1913) , *A. prelli* (Eichhorn 1967) and *A. merkeri* (Binazzi and Covassi 1988), and oriental spruce, *Picea orientalis* (L.) Link., for *Pineus orientalis*. Some other species were introduced along with ornamental trees originating from North America such as *Pineus* (*Eopineus*) *strobi* with the eastern white pine, *Pinus strobus* (Steffan 1972), and *Pineus similis* with Sitka spruce, *Picea sitchensis* (Bong.) Carrière (Carter 1975, Carter 1975). A majority (five out of nine) of the alien species are holocyclic, one is anholocyclic of first type developing entirely on *Picea* (*Pineus similis*) and three anholocyclic of second type developing entirely on *Pseudotsuga* (*Adelges coweni*), *Larix* (*A. viridula*) or *Pinus strobus* (*Pineus strobi*).

In addition, several adelgid species native of the Alps and/or Central Europe can be considered as alien *in* Europe. Their primary host is mostly spruce (*Picea*), and then larch (*Larix*), fir (*Abies*), or pine (*Pinus*). They include *Adelges (Adelges) laricis* Vallot, which accompanied the plantations of larch in the lowlands (Glavendekić et al. 2007, Hill et al. 2005), and several species introduced from continental Europe to Great Britain, i.e. *Adelges (Adelges) piceae* Ratzeburg, *A. (Sacchiphantes) abietis* L. , *A. (Sacchiphantes) viridis* Ratzeburg , and *Pineus pineoides* Cholodkovsky (Hill et al. 2005). Similarly, the alpine *Pineus cembrae* (Cholodokovsky) colonized the Faroe islands with Swiss stone pine, *Pinus cembra* L. *Adelges (Aphrastasia) pectinatae* (Cholodkovsky), a species which develops on spruce and fir was first considered as an alien in Europe (DAISIE 2009) having established in Central and Northern Europe, including the Baltic countries (Gederaas et al. 2007, Holman and Pintera 1977). However, its origin is difficult to be ascertained since Havill and Footit (2007) indicated 'Europe, China and Japan'.

– *Phylloxeridae*

There are two species of phylloxerans alien *to* Europe with regard to 15 native species (Figure 9.4.1). *Moritziella corticalis* is of unknown origin (cryptogenic) and was first reported as introduced in Britain (Barson and Carter 1972). The genus *Moritziella* accommodates two species living on Fagaceae. They are distinguished from Palaearctic species of *Phylloxera* by the absence of abdominal spiracles on segment 2–5 and by the presence of numerous well-developed, pigmented dorsal tubercles. Generic distinction between North American species of *Phylloxera* and *Moritziella* is however not satisfactory.

The other species is the well-known 'Phylloxera', *Viteus vitifoliae* (=*Dactylosphaera vitifoliae*) which has devastated the European vineyards at the end of 19th century. The genus *Viteus* is a monotypic genus, the *alatae** of which have paler abdominal *stigmal** plates and a shorter distal *sensorium** on the third antennal segment than the common

European *Quercus*-feeding *Phylloxera*. *Viteus vitifoliae* typically goes through a two-year cycle involving a sexual phase and leaf-galling and root-feeding stages on American vines. On European vines it normally lives continuously on the roots, reproducing parthenogenetically. Leaf-galls occur in Europe on cultivars derived from hybrids between *Vitis vinifera* L. and American vines. The economic significance of this species is discussed in some detail under section 9.4.8.

9.4.2.4. Auchenorrhyncha

A total of 12 species alien *to* Europe have been considered (Figure 9.4.1). Not surprisingly most of them belong to the species- rich family of Cicadellidae (17,000–20,000 worldwide; 1,236 species in Europe). Other families are represented only by a single species in each.

Within Cicadomorpha, the Cicadellidae (leafhoppers) is the largest family with 50 subfamilies and 17,000–20,000 described species. Leafhoppers live in all zoogeographical regions and feed on a wide range of host plants, though individual species have often trophically and geographically restricted ranges (Dolling 1991, Nielson 1985). Cicadellidae varies in body length from 2–30 mm. Leafhoppers feed on a large range of plants (grasses, herbaceous plants, trees and shrubs). The majority of leafhoppers feed on phloem, some on xylem (especially the subfamily Cicadellinae), and only members of the subfamiliy Typhlocybinae are specialised parenchyma-feeder. Leafhoppers are well known vectors of plant diseases and of economic importance worldwide. For some leafhopper species migratory behaviour is documented (Della Giustina 2002). Eight leafhopper species are certainly alien to Europe. Probably most famous is the Rhododendron leafhopper, *Graphocephala fennahi*, a native to North America. The species was first reported from southern England in the 1930s but it crossed the Channel only after 1960, to the Netherlands from where it spread rapidly within continental Europe. Two other North American species, *Scaphoideus titanus* and *Erythroneura vulnerata*, are pest species on grapes. Especially *Scaphoideus titanus* has become an important pest since it is the vector of 'flavescence dorée' phytoplasma to grapevine. The Neartic leafhopper *Kyboasca maligna* does not seem to be problematic as an alien species to Europe for the time being. From Eastern Asia four cicadellid species have been introduced: *Japananus hyalinus*, *Macropsis elaeagni*, *Orientus ishidae* and *Igutettix oculatus*. None of them have yet been found to transmit plant diseases in Europe and are therefore not of economic importance. *O. ishidae* was only recently reported new to Europe (Günthart et al. 2004) but is spreading rapidly in Europe (Switzerland, Italy, Germany, Slovenia, France, Austria, Czech Republic). *I. oculatus* (=*Vilbasteana oculata* (Lindberg)) is originally an eastern Palaearctic species which was first found in Moscow in 1984 and is now spreading to the west (Finland (Söderman 2005)). It lives on *Syringa*.

With around 3,200 described species Membracidae is the largest family of treehoppers. Membracids are widespread worldwide but only few species occur in Europe. This family is most diverse in the Neotropics and North America. Characteristic is the enlarged pronotum with sometimes bizarre shaped extensions and elongations. They are medium sized with a body length of 2–24 mm. As with other members of Cicadomorpha, Membracidae lay their eggs into living plant tissue. If populations are too big this can cause serious damages to the host plant and therefore can be regarded as crop pests (e.g. apple trees, see e.g. (Arzone et al. 1987)). Only four species are native to Europe. One species (*Stictocephala bisonia*) was introduced from North America.

The Fulgoromorpha group yet contributed for only three species alien to Europe, with one per family Delphacidae, Flatidae and Acanaloniidae, to be compared to 727 species native in Europe. Delphacidae are characterized by a moveable spur on the hind tibia. Species are generally small (2–6 mm) and are widely distributed also in colder regions. Worldwide around 1,500 delphacid species are described. They feed on monocotyledons and are economically important as pest species on rice, maize, wheat and sugarcane. *Nilaparvata lugens* (Stål) for example is a serious pest of rice in Asia (O'Brien 2002, Wilson and Claridge 1991). In Europe there are some 260 species. Only one alien delphacid has established in Europe, *Prokelisia marginata*, which was first found on the Algarve (Portugal) in 1994 and in Spain in 1998 (unpublished data M.R. Wilson). In Slovenia a well established population was found in 2004 (Seljak 2004). New, unpublished records are from southern England (2008) and France (2009). It is very likely that this planthopper is expanding its range rapidly along the European coasts.

Species of the family Flatidae have often colourful opaque wings and can be distinguished from other Fulgoromorpha by the numerous parallel crossveins along the costal margin of the forewing and a single spine at each side of the second tarsomere of the hind leg. The body size varies between 4.5–32.0 mm. Flatids feed on different shrubs, trees and herbs (O'Brien 2002). The North American *Metcalfa pruinosa* has been introduced to Europe probably in plant material and was first recorded in Italy in 1983. From there it is spreading rapidly to the rest of southern Europe (France, Slovenia, Switzerland, Austria, the Czech Republic) causing damages on grapes (Della Giustina 1986, Dlabola 1981, Holzinger et al. 1996, Lauterer and Malenovský 2002a, Mani and Baroffio 1997, Seljak 2002).

The Acanaloniidae is a small family of Fulgoromorpha with c. 80 described species accommodated in 14 genera. In general they resemble flatid planthoppers. This family is not native to Europe and the north American species *Acanalonia conica* was only recently introduced into northern Italy (D'Urso and Uliana 2006). *A. conica* has a similar biology to *Metcalfa pruinosa* and can often be found in mixed nymphal feeding groupings with the latter (Wilson and MacPherson 1981). Therefore this species could potentially be another pest insect for European vineyards.

Tropiduchidae is a small family within the Fulgoromorpha with some 400 described species worldwide. Body size varies between 5–13 mm; the mesonotum with its apical angle is separated by a transverse groove. They feed on ferns, palms, grasses and Dicotyledonae (O'Brien 2002). *Ommatissus lybicus* Bergevin, the dubas bug, was for a long time regarded as a variety of *O. binotatus* Fieber (but see Asche and Wilson 1989). *O. lybicus* is a severe pest of date palms in the Middle East causing the death of trees. *O. binotatus* was described from Spain and feeds on *Chamaerops humilis* L. It was also found in Sicily and Portugal and is a native European species and should be deleted from the DAISIE list.

Species with an Eurosiberian or a Holarctic distribution, *Edwardsiana ishidai* Matsumura and *Kyboasca bipunctata* (Oshanin), have been excluded from Table 9.4.1. Other leafhopper species with a doubtful alien status include: *Cicadulina bipunctata* (Melichar), a North African species which occurs also in the eastern Mediterranean; *Empoasca punjabensis* Singh-Pruthi, originally described from India but is also reported from the southern parts of European Russia , Ukraine, Bulgaria, Serbia and Greece; *Jacobiasca lybica* (Bergevin & Zanon), another North African species which is reported from other Mediterranean regions (Sicily, Sardinia and Greece); *Melillaia desbrochersi* (Lethierry), a North African species also reported from Greece, Sicily and Corsica; *Psammotettix saxatilis* Emeljanov, described from Kazakhstan and found in France but possibly conspecific with *P. sierranevadae* Dlabola from Spain.

There are some papers reporting mainly records of Mediterranean Auchenorrhyncha new to Northern European regions (Maczey and Wilson 2004, Nickel and Holzinger 2006, Wilson 1981). Due to lack of sufficient historical information on the distribution of most Auchenorrhyncha species it is difficult to determine if anthropogenic factors and/or climatic influence are the main causes of range extension. There are for example some southern European *Eupteryx* species, which appear to have become in the last decades more common in central Europe or even extended their range to northern latitudes such as Denmark and the UK. These species may exploit certain man made habitats, e.g. in greenhouses where herbal plants are cultivated (such as Lamiaceae e.g. *Melissa*, *Oreganum*, etc.) but may also build up localised 'wild' populations. Such populations may be stable over years under good environmental conditions but can also easily break down depending on several conditions including weather, pressure of predators, parasites and others. Continental European Auchenorrhyncha species introduced to European islands are also excluded of this overview. Thus, five Cicadellidae species (*Empoasca pteridis* (Dahlbom), *Grypotes puncticollis* (Herrich-Schaffer), *Iassus scutellaris* (Fieber), *Placotettix taeniatifrons* (Kirschbaum) and *Wagneripteryx germari* (Zetterstedt)) are reported to be alien in the UK (Stewart 1993). On the other hand it is very likely that *Philaenus spumarius* L. (Aphrophoridae) was introduced into Iceland in the late 1970s.

9.4.3 Temporal trends of introduction in Europe of alien species of Aleyrodidae, Psylloidea, Phylloxeroidea, and Auchenorrhyncha

The first records in Europe are approximately known for 60 of the 64 species considered here. Dates given are relatively imprecise, as most of these tiny species have probably been introduced several years before they were reported.

The number of new records per time period largely differed among Aleyrodidae, Psylloidea, Phylloxeroidea and Auchenorrhyncha (Figure 9.4.2.). The arrival of alien phylloxerans and adelgids appeared to peak during the first part of the 20th century. Some species such as the Grape Phylloxera, *Viteus vinifoliae*, and the silver fir adelgid, *Adelges nordmannianae*, arrived earlier in the 19th century but most species, especially the ones associated with Douglas-fir (*Adelges cooleyi* and *A. coweni*) were probably introduced in the early 1900s. Only one new species having been introduced later (*Pineus simi*lis in 1971), and apparently none during the last ten years.

In contrast, the mean number of new records per year of Aleyrodids, Psylloids and Auchenorrhyncha increased regularly from the 1950s. For these three groups, an average of 0.5–0.6 new alien species has been recorded per year in Europe since 2000. The first documented introduced alien Auchenorrhycha to Europe was *Stictocephala bisonia* (at that time under the name *Ceresa bubalus*) in eastern Europe (former Austro-Hungarian Empire) in 1912 (Horvaáth 1912). This treehopper was probably introduced with fruit tree cuttings and is now widespread all over Europe except the northern regions. It was followed by another North American species, *Graphocephala fennahi*, which was first found on rhododendrons in southern England in 1933. Since then other Auchenorrhyncha species from North America or East Asia have been introduced mainly to Central or Southern Europe benefiting from international trade of plants. In the case of *Scaphoideus titanus* it seems that this species had a first ancient introduction followed by multiple colonization events (Bertin et al. 2007).

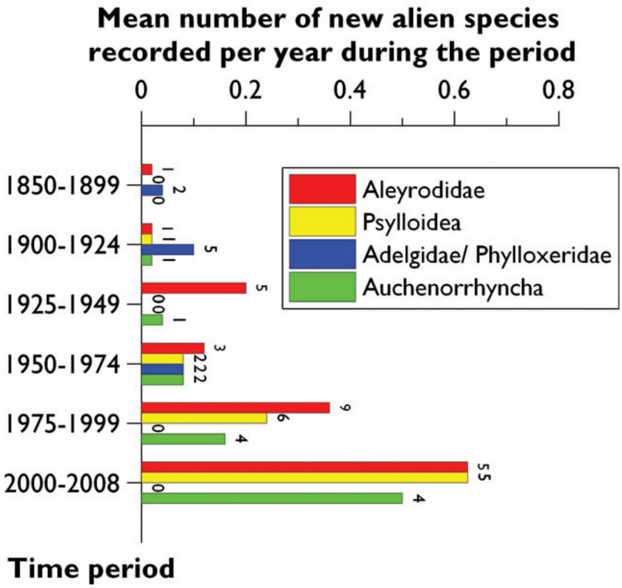

Figure 9.4.2. Temporal changes in the mean number of new records per year of Aleyrodidae, Psylloidea, Phylloxeroidea (Adelgidae/ Phylloxeridae) and Auchenorrhyncha alien *to* Europe from 1800 to 2009. The number right to the bar indicates the total number of species recorded per time period.

9.4.4 Biogeographic patterns of the Aleyrodidae, Psylloidea, Phylloxeroidea, and Auchenorrhyncha alien to Europe

9.4.4.1 Origin of alien species

The region of origin of the alien species largely differs between groups (Figure 9.4.3). Aleyrodids and psylloids mainly originated from tropical regions, the Neotropics and Australasia, respectively. Adelgids and phylloxerans came equally from North America and Asia, mostly because a number of adelgids were introduced from the Caucasus Mountains together with their conifer hosts. In contrast, most of the alien Auchenorrhyncha have a North American origin. For a few species, the area of origin remains uncertain.

9.4.4.2 Distribution of alien species in the European countries

For whiteflies and psylloids, the distribution of alien species to Europe or to certain parts of Europe has been highlighted and documented in 9.4.2 and is also presented in Table 9.4.1. Most of the alien species of aleyrodids, psylloids, phylloxerans and adelgids did not spread largely within Europe yet. Indeed, 31 species out of 52 (i.e., 60%) have colonized less than five European countries. Only 4 species, two aleyrodids (*Bemisia ta-*

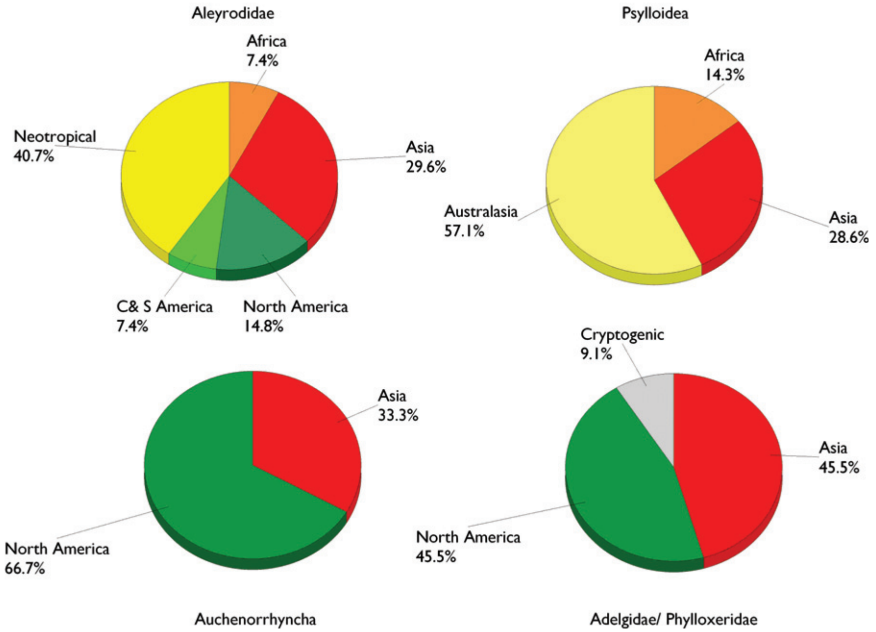

Figure 9.4.3. Comparative origin of the Aleyrodidae, Psylloidea, Phylloxeroidea (Adelgidae/ Phylloxeridae) and Auchenorrhyncha species alien *to* Europe

baci and *Trialeurodes vaporariorum*), one phyloxeran (*Viteus vinifoliae*) and one adelgid (*Adelges nordmannianae*) have colonized more than 20 countries (Table 9.4.1).

Due to the lack of comprehensive data we cannot give appropriate information on the distribution of alien Auchenorrhyncha in Europe. However three species (*Scaphoideus titanus*, *Metcalfa pruinosa* and recently *Acanalonia conica*) could have first established in the Mediterranean region from where they spread northbound. Other species expanded their range from eastern Europe (*Stictocephala bisonia*, *Macropsis eleagni*) or central Europe (*Japananus hyalinus*, *Orientus ishidae*), one species started from the UK (*Graphocephala fennahi*). It is also possible that some of the alien species had multiple introductions (*Scaphoideus titanus*, *Prokelisia marginata*). Generally the introduced species could spread easily as long as the environmental conditions are appropriate for them (climate, host plants, etc.). Five out of the 12 alien species spread in more than 10 countries, with *Stictocephala bisonia* having expanded in 26 countries and islands (Table 9.4.1).

9.4.5 Pathways of introduction to Europe of the alien species of Aleyrodidae, Psylloidea, Phylloxeroidea, and Auchenorrhyncha

Most alien species of whiteflies, psylloids, phylloxerids and adelgids were accidentally introduced with their host plant. In most circumstances such introductions occurred via trade of the host plant or of parts of the host plants such as fruit or cut flowers.

It is reported that Auchenorrhyncha can migrate. Usually they are short-distance migrants to leave non-permanent habitats but some species are able to migrate over long distances (Della Giustina 2002). The probably most amazing example is the cicadellid *Balclutha pauxilla* Lindberg which invaded in swarms the Ascension Island in the Atlantic Ocean (about half way between South America and Africa) in 1976. The specimens must have flown more than 2,000 km over the sea probably coming from Africa (Ghauri 1983).

Despite of the fact of possible migration, alien Auchenorrhyncha certainly profit of the worldwide trade of fruit trees, vine cuttings and ornamental plants. Especially eggs in the plant tissue can survive the transport even over long distances and time. Once arrived, the nymphs hatch and without their specific parasites they can build up strong populations. Not surprisingly some alien Auchenorrhyncha were first found around harbours (e.g. *Prokelisia marginata*) or cities (*Orientus ishidae*), an unmistakable trace of their pathway of introduction.

9.4.6 Ecosystems and habitats invaded in Europe by the alien species of Aleyrodidae, Psylloidea, Phylloxeroidea, and Auchenorrhyncha

Apart from those species so far intercepted only in greenhouses and of which no reports exist of their establishment in Europe, the other introduced species of the five groups treated in this account are often confined to few related host plants. For example, several species of whiteflies which in their area of origin are highly polyphagous have shown to be strictly oligophagous in their new territories, occurring mainly on Citrus and some other woody hosts.

Thus, the major part of these alien species is presently observed in man-made habitats, especially in parks and gardens where a number of exotic plants have been planted (Figure 9.4.4). Natural and semi-natural habitats are yet little colonized by alien Auchenorrhyncha and psylloids (<20%) and quite none by aleyrodids. A noticeable exception concerns adelgids because of their association with conifer trees used for afforestation. More than 60% of the alien adelgids are thus found in forest habitats together with fir, spruce and larch trees.

Interestingly so far only one grassland species (*Prokelisia marginata*) was introduced to Europe. This species lives originally in salt marshes along the East-Coast of North America and is associated with *Spartina* grasses. All other alien Auchenorrhyncha colonize mainly anthropogenic habitats (vine yards, orchards, gardens, parks). Some of them are polyphagous and can therefore also be found in natural environments (e.g. *Stictocephala bisonia* in dry habitats or *Orientus ishidae* on willows and birch trees).

9.4.7 Ecological and economic impact of the alien species of Aleyrodidae, Psylloidea, Phylloxeroidea, and Auchenorrhyncha

In terms of economic losses, the two most important whiteflies in Europe are *Trialeurodes vaporariorum*, commonly known as the glasshouse or greenhouse whitefly and *Bemisia tabaci,* commonly known as the Cotton Whitefly. *T. vaporariorum* is a member of a North American species-group. It was however described in 1856 from England, at which time the species was an already widespread and established pest. *B. tabaci*,

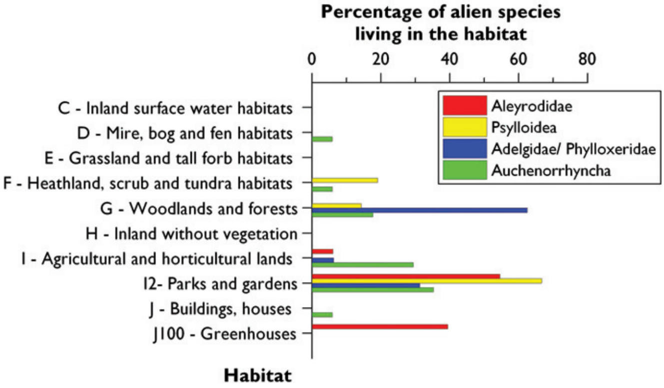

Figure 9.4.4. Main European habitats colonized by the established alien species of Aleyrodidae, Psylloidea, Phylloxeroidea (Adelgidae/ Phylloxeridae) and Auchenorrhyncha. The number over each bar indicates the absolute number of alien species recorded per habitat. Note that a species may have colonized several habitats.

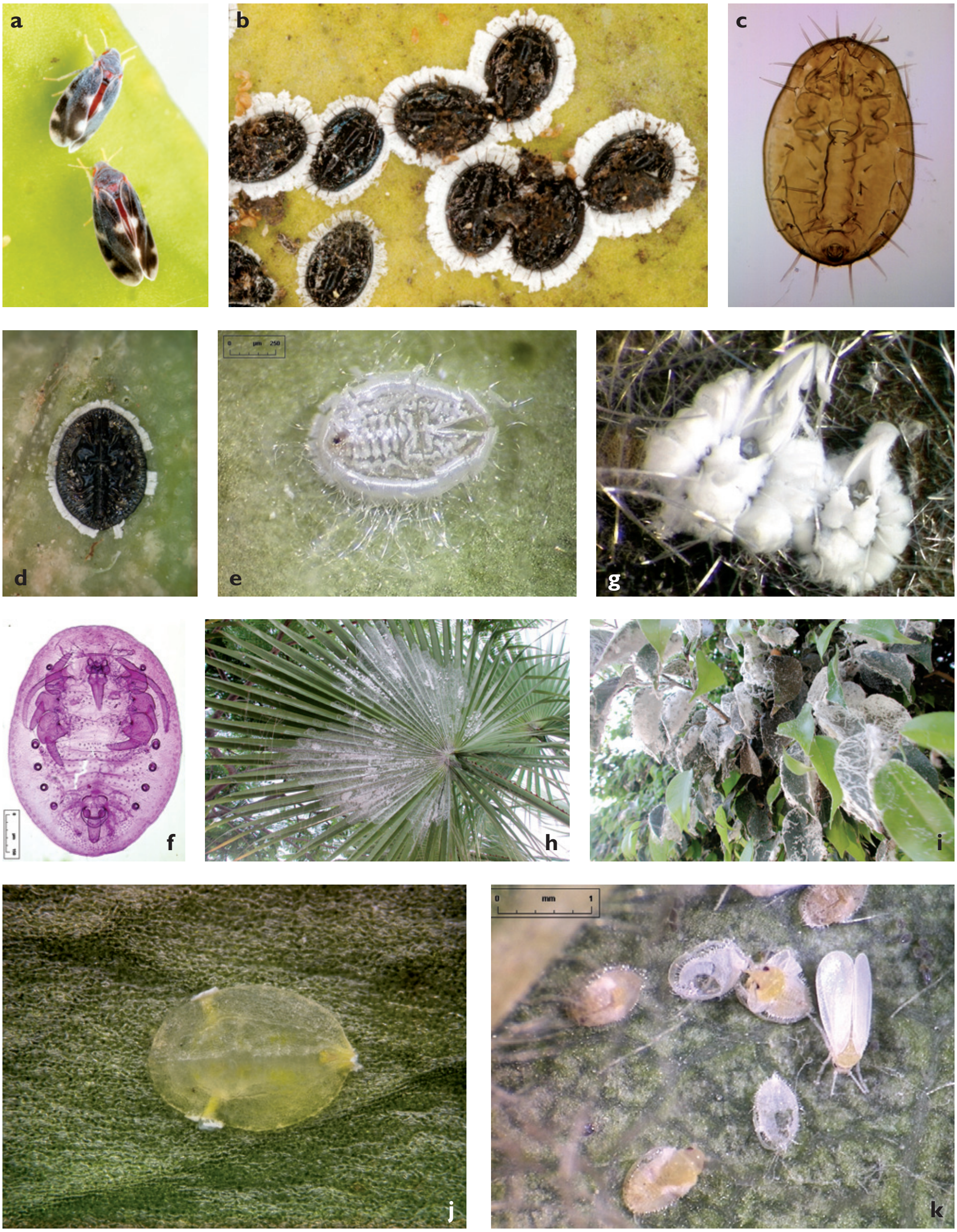

Figure 9.4.5. Aleyrodid species alien *to* Europe. **a** *Aleurocanthus spiniferus* adult **b** *Aleurocanthus spiniferus* puparium **c** *Aleurocanthus spiniferus* puparium from palm leaf (East-Timor) **d** *Acaudaleyrodes rachipora* puparium on leaf of *Argania* (Agadir, Morocco) **e** *Aleurothrixus floccosus* puparium on leaf of *Citrus reticulata* (France) **f** *Aleurodicus dispersus* puparium from leaf of *Psidium gajava* (Martinique) **g** *Aleurodicus dispersus* puparium on leaf of *Psidium gajava* (Martinique) **h** *Aleurodicus dispersus* damage on palm leaf **i** *Aleurodicus dispersus* damage on leaf **j** *Bemisia tabaci* from Thailand intercepted at Roissy airport, France on leaf of *Eryngium foetidum* **k** *Trialeurodes vaporariorum* adults and puparium on leaf of *Fragaria* (France). (Credit: **a, b, h, i** - Francesco Porcelli; **c, d, e, f, g, j, k** - LNPV Montpellier).

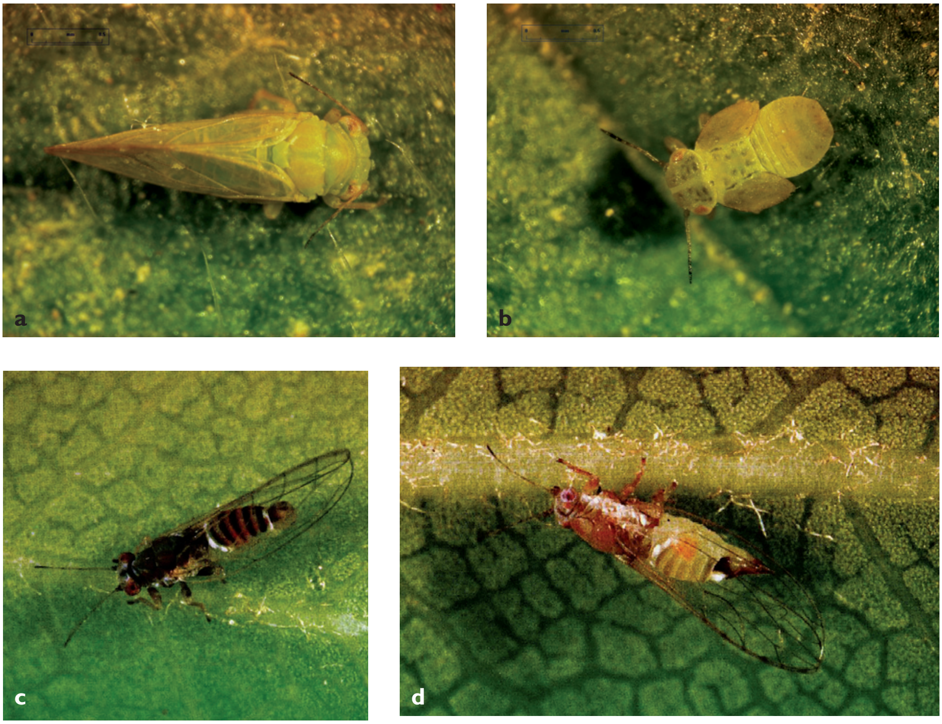

Figure 9.4.6. Psylloid species alien *to* Europe. **a** *Acizzia jamatonica* adult on leaf of *Albizia* (Bordeaux, France) **b** *Acizzia jamatonica* immature on leaf of *Albizia* (Bordeaux, France) **d** *Trioza vitreoradiata* male under a leaf of *Pittosporum tobira* **e** *Trioza vitreoradiata* female. (Credits: **a, b** - LNPV Montpellier; **c, d** - Jean-Marie Ramel and Christian Cocquempot).

probably of Asian origin, is now virtually cosmopolitan, usually found under glass in areas with continental climates. Several biotopes of this species are known (De Barro et al. 1998) and this taxon is known to transmit geminiviruses to cultivated plants of various unrelated groups (Bedford et al. 1994) and is a serious pest of both open-air and protected cropping. Some of the "emerging" whitefly pests in Europe may also prove to be of high economic impact to European agriculture and within this group the most promising species seems to be *Aleurocanthus spiniferus*.

One of the most important species of psylloid in terms of economic losses is *Trioza erytrea*, a native to the Afrotropical Region. This species is a major pest of citrus plantations, but in its native range is also known to develop on *Vepris undulata* (Thunb.) Verdoorn & C.A. Sm. *Zanthoxylum* (=*Fagara*) *capense* (Thunb.) Harvey and *Clausena anisata* (Willd.) Hook. f. ex Benth. (Hollis 1984). The main economic importance of *T. erytreae* is as vector of the citrus disease caused by citrus greening bacterium (also transmitted by the psylloid, *Diaphorina citri* Kuwayana). Both psylloids are listed as A1 quarantine pests by EPPO and other phytosanitary organisations. Isolated outbreaks of this species were first noted in Europe in Madeira in 1994 and it seems that the species is now established on both the Canary Islands and Madeira (Borges et al. 2008, Gonzalez

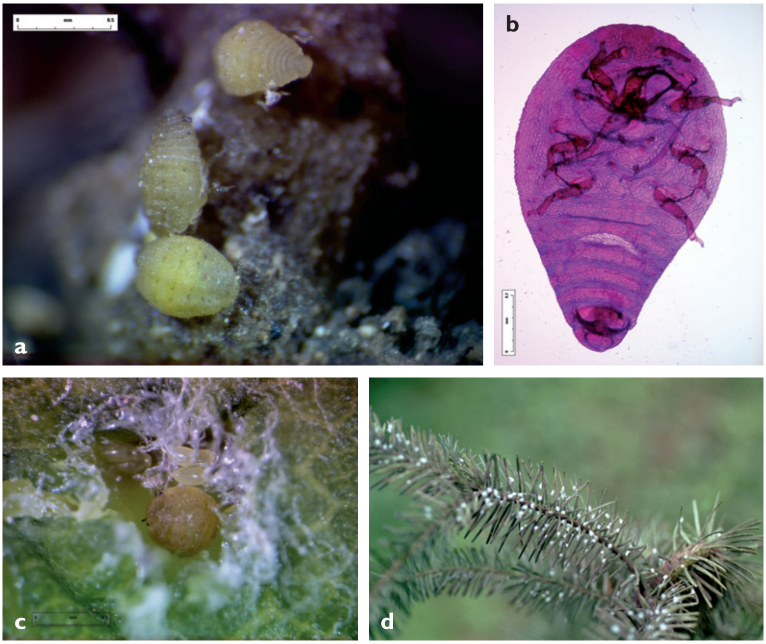

Figure 9.4.7. Adelgid and phylloxeran species alien alien *to* Europe. **a, b** - *Viteus vitifoliae* on roots of *Vitis vinifera* (France) **c** *V. vitifoliae* from galls on leaf of *V.vinifera* (France) (Credit: LNPV Montpellier) **d** *Adelges cooleyi* on needles of Douglas-fir (France) (Credit: A. Roques).

2003). *T. erytrea* is also a species of considerable taxonomic interest as it is part of a complex of species, all of which are difficult to define morphologically, but which have discrete host plant preferences (Hollis 1984). Another important psylloid of economic significance is *Trioza vitreoradiata*, a species native to New Zealand but recently established in Britain (Martin and Malumphy 1995), Ireland (O'Connor et al. 2004), and France (Cocquempot 2008). This psylloid is specific to *Pittosporum* where apart from direct loss by the plant in the form of sap depletion caused by the feeding activity of the psylloid, shallow pit galls are formed on young leaves, which remain visible for the life of the leaf. Sooty mould is also very common due to the large amounts of honeydew droppings on underlying leafs. The galling and presence of such sooty moulds make unmarketable ornamental plants of *Pittosporum tenuifolium* Gaertner, which are often grown for the cut-flower industry and also harvested for its foliage (Martin and Malumphy 1995).

Two of the introduced Auchenorrhyncha are of high economical importance. Both are regarded as pest species of vine. *Scaphoideus titanus* is a vector of 'flavescence dorée', a phytoplasma disease (grape vine yellows), which can cause big crop losses. *Metcalfa pruinosa* affects the plants directly. Strong populations can weaken the plant by sucking and the excreted honeydew is medium for fungi, which can cause reduction in the quality of the fruits.

The only phylloxerid of devastating economic significance and which was the cause of much trouble for the wine industry in Europe was the Grape Phylloxera, *Viteus vitifoliae*. This serious pest of grapes originated in North America where the local

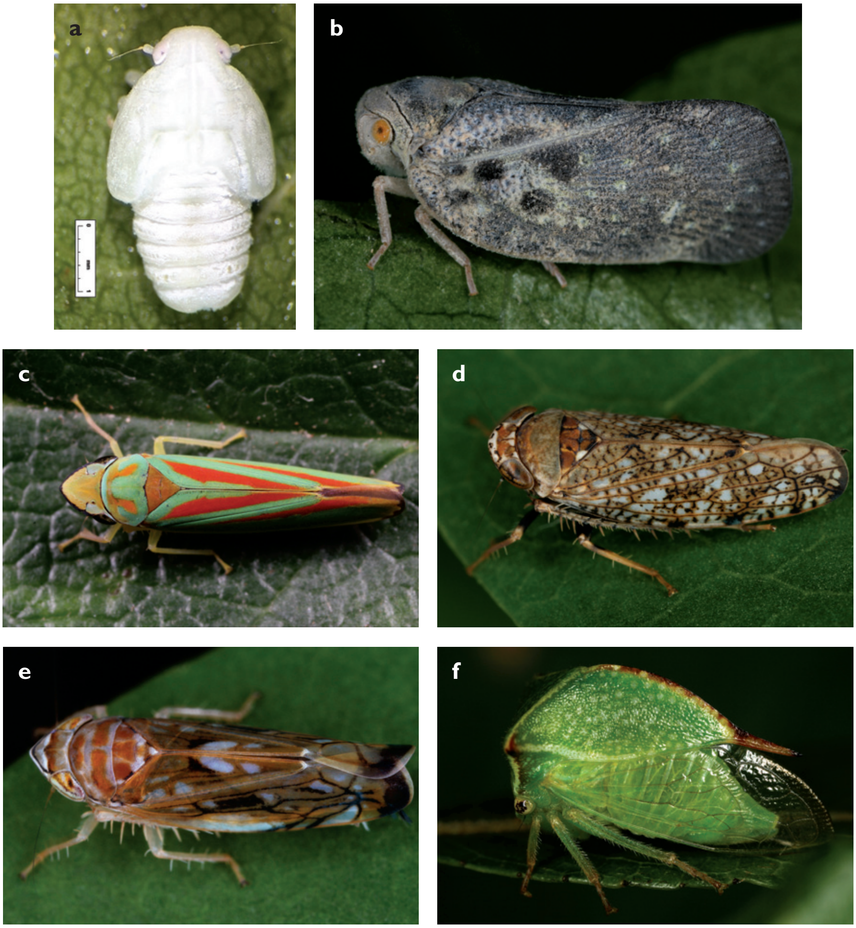

Figure 9.4.8. Auchenorrhyncha species alien *to* Europe. **a** *Metcalfa pruinosa* larvae **b** *Metcalfa pruinosa* adult **c** *Graphocephala fennahi* adult **d** *Orientus ishidae* adult **e** *Scaphoideus titanus* adult **f** *Stictocephala bisonia* adult. (Credit: **a** - LNPV Montpellier; **b–f** - Gernot Kunz)

vines evolved with it and are not severely damaged by its feeding activity. The species was accidentally introduced to Europe around 1860. In Italy, the species was first reported in 1879 and one year later it was also found in Sicily. In certain countries, possibly due to strict quarantine notices of this new pest, several years passed by before its introduction (e.g. in Malta, Grape Phylloxera was introduced in 1919 (Mifsud and Watson 1999)) but eventually the species was introduced everywhere. It invaded the Mediterranean Region, the Middle East, Africa, Korea, Australia, New Zealand and parts of South America. Grape Phylloxera feeds on species of *Vitis* including grape vines. Foliar attack does not seem to be unduly damaging, but asexual forms attacking roots all year round can kill plants that did not originate from North America. Grafting European vines onto North American rootstocks has successfully solved this problem in the past, but concern has increased in recent years because this resistance is being broken in some parts of the World as new biotypes of Grape Phylloxera are evolving (King and Rilling 1985).

9.4.8. Conclusion

Only few European countries produced comprehensive lists of alien Aleyrodidae, Psylloidea, Phylloxeroidea and Auchenorrhyncha. Most of these alien insects were probably introduced by plant material and once established could spread quickly into other European countries. Fortunately, only few species (*Trioza erythrea*, *Trioza vitreoradiata*, *Scaphoideus titanus*, *Metcalfa pruinosas* and *Stictocephala bisonia*) have to be regarded as pest or potential pest species so far. However, recent introductions (*Acanalonia conica*, *Orientus ishidae*, *Prokelisia marginata*) show that trade is the main factor of introduction and that at any time new problematic species can occur.

On the other hand we have still not sufficient information on the migration of Auchenorrhyncha within European regions. Several observations indicate that in the last decades Mediterranean species expanded their distribution to the North but it is not clear if they can establish wild populations or not. Usually these species profit from anthropogenic habitats (e.g. agricultural areas and parks) and can cause problems. Therefore we need to monitor species migration carefully.

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References

Aguiar AMF (1998) New records of whiteflies (Homoptera : Aleyrodidae) from Madeira Island with some taxonomic notes. *Boletim do Museu Municipal do Funchal* Suplemento 5: 9–26.

Aloi A. (1898) Un nuovo e serio pericolo per l'odierna viticoltura. *Agricoltore calabro-siculo*, 23: 229–230.

Anonymous (1894) Đrazprostranenie na filoksernata zaraza u nas. *Oralo* 1, 29–30, 234–236.

Arzone A, Vidano C, Alma A (1987) Auchenorrhyncha introduced into Europe from the Nearctic region: taxonomic and phytopathological problems. In Wilson MR, Nault LR (eds) *Proceedings of the 2nd International Workshop on leafhoppers and Planthoppers of Economic Importance*. London: CIE, 3–17.

Asche M, Hoch H (2004) *Fauna Europaea: Cicadomorpha*. Fauna Europaea version 1.1, available at http://www.faunaeur.org [accessed at 05.02.2010].

Asche M, Wilson M R (1989) The palm-feeding planthopper genus *Ommatissus* (Homoptera: Fulgoroidea: Tropiduchidae). *Systematic Entomology* 14: 127–147.

Barson G, Carter CI (1972) A species of Phylloxeridae, *Moritziella corticalis* (Kalt.) (Homoptera) new to Britain, and a key to the British oak-feeding Phylloxeridae. *Entomologist* 105: 130–134.

Baudyš E (1935) *Hospodářská fytopathologie.* [Economic phythopathology]. Brno, 630 pp.

Baugnée JY (2003) Sur la présence en Belgique du Cicadellidae *Kyboasca maligna* (Walsh, 1862) et du Psyllidae *Cacopsylla fulguralis* (Kuwayama, 1907) (Hemiptera Homoptera). *Bulletin de la Société royale belge d'Entomologie* 139: 72–73.

Bayer E (1914) *Moravské hálky (Zoocecidia).* Pokorný a spol., Brno, 181 pp.

Bayer E (1920) *Synopsis zoocecidií středoevropských se zřetelem k zemím českým* [Synopsis of the Central-European galls with regard to the Czech country] Brno: Moravy Muzeum Zemské. 237 pp.

Bedford ID, Briddon RW, Brown JK, Rosell RC, Markham PG (1994) Geminivirus transmission and biological characterisation of Bemisia tabaci (Gennadius) biotypes from different geographical regions. *Annals of Applied Biology* 125: 311–325.

Bertin S, Guglielmino CR, Karam N, Gomulski LM, Malacrida A R, Gasperi G (2007) Diffusion of the Neartic leafhopper *Scaphoideus titanus* Ball in Europe: a consequence of human trading activity. *Genetica* 131: 275–285.

Binazzi A, Covassi M (1988) Le specie del Gen. *Dreyfusia* in Italia. Nota preliminare (Homoptera Adelgidae). *Atti del XV Congresso Nazionale Italiano di Entomologia*, L'Aquila, 267–273.

Borges PAV, Franquinho Aguiar AM, Boiero M, Carles-Tolra M, Serrano ARM (2008) Capítulo 10.1 - Lista dos Artrópodes (Arthropoda) in Borges PAV, Abreu C, Franquinho Aguiar AM, Carvalho P, Jardim R, Melo I, Oliviera P, Sergio C, Serrano ARM, Vieira P (eds.) *Listagem dos fungos, flora e fauna terrestres dos arquipélagos da Madeira e Selvagens, Secretaria Regional do Ambiente e dos Recursos Naturals do Governo regional da Madeira, Funchal*: 271–438.

Borowiec N, Quilici S, Martin J, Issimaila MA, Chadhouliati AC, Youssoufa MA, Beaudoin-Ollivier L, Delvare G, Reynaud B (2010) Increasing distribution and damage to palms by the Neotropical whitefly, *Aleurotrachelus atratus* (Hemiptera: Aleyrodidae). *Journal of Applied Entomology* 134 (in press).

Bourgoin T, Campbell BC (2002) Inferring a phylogeny for hemiptera: Falling into the 'autapomorphic trap'. *Denisia* 04: 67–82.

Burckhardt D (1981) Insects of Saudi Arabia. Sternorrhyncha: Suborder Psyllodea. *Fauna of Saudi Arabia* 3: 213–226.

Burckhardt D (1998) *Ctenarytaina eucalypti* (Maskell) (Hemiptera, Psylloidea) neu für Mitteleuropa mit Bemerkungen zur Blattflohfauna von *Eucalyptus*. *Mitteilungen der Entomologischen Gesellschaft Basel* 48: 59–67.

Burckhardt D, Elgueta M (2000) *Blastopsylla occidentalis* Taylor (Hemiptera: Psyllidae), a new introduced Eucalyptus pest in Chile. Revista Chilena de Entomología 26: 57–61.

Burckhardt D, Lauterer P (1997) A taxonomic reassessment of the triozid genus *Bactericera* (Hemiptera: Psylloidea). *Journal of Natural History* 31: 99–153.

Burckhardt D, Mühlethaler R (2003) Exotische Elemente der Schweizer Blattflohfauna (Hemiptera, Psylloidea) mit einer Liste weiterer potentieller Arten. *Mitteilungen der Entomologischen Gesellschaft Basel* 53: 98–110.

Cantiani M (1968) L'afide lanigero della Douglasia (*Gilletteella cooley* Gill.) in Italia. *L'Italia forestale e montana* 23, 195–198..

Carter CI (1983) Some new aphid arrivals to Britain's forests, *Proceedings and Transactions of the British Entomological and Natural History Society*, 16: 81–87.

Carter CI (1975) A gall forming adelgid (*Pineus similes* (Gill)) new to Britain with a key to the adelgid galls on Sitka spruce, *Entomologist's Monthly Magazine*, 111, 29–32.

Carver M, Gross GF, Woodward TE (1991) Hemiptera. InCSIRO (Ed) *The Insects of Australia*. Melbourne: Melbourne University Press, 429–509.

Chapin E, Cocquempot, C (2005) Psylle de l'Albizia: 1ers signalements en France. *PHM-Revue horticole* 467: 49–52.

China WE (1935) A North American Jassid (Homoptera) in Surrey. *Entomologist's Monthly Magazine* 71: 277–279.

Chrystal RN (1922) *The Douglas fir Chermes* (*Chermes cooleyi*). *Forestry Commision Bulletin No. 4*. London: His Majesty's Stationery Office. 50 pp.

Cocquempot C (2008) Un nouveau psylle sur pittospore du Japon en France. *PHM-Revue horticole*, 498: 33–36.

Cocquempot C, Constance, unpublished observations.

Cocquempot C, Germain JF (2000) Un nouveau ravageur de l'*Elaeagnus* x *ebbingei* en France : *Cacopsylla fulguralis*. *PHM-Revue horticole* 416: 32–34.

Conci C, Tamanini L (1985) *Lauritrioza* n. gen. for *Trioza alacris* (Homoptera Psylloidea). *Atti della Societa italiana di Scienze Naturali (Museo Civico di Storia Naturali di Milano*) 126: 237–256.

Conci C, Tamanini L (1989) *Acizzia hollisi*, new for Europe, and other psyllids from Isles Lampedusa and Linosa (Sicily) (Hemiptera, Homoptera). *Naturalista Siciliano* S. IV,13 (1–2): 75–80.

Costanzi M, Malausa JC, Cocquempot C (2003) Un nouveau psylle sur les Eucalyptus de la Riviera Ligure et de la Côte d'Azur. Premières observations de *Ctenarytaina spatulata* Taylor dans le Bassin méditerranéen occidental. *Phytoma – La Défense des Végétaux* 556: 48–51.

Covassi M, Binazzi A (1981) - Contributi alla conoscenza degli Afidi delle Conifere. IV, Note su alcune specie di Adelgidi reperite in Italia (Homoptera Adelgidae). *Redia* 64, 303–329.

Cryan JR (2005) Molecular phylogeny of Cicadomorpha (Insecta: Hemiptera: Cicadoidea, Cercopoidea and Membracoidea): adding evidence to the controversy. *Systematic Entomology* 30: 563–574.

DAISIE (2009) *Handbook of Alien Species in Europe*. Dordrecht:: Springer, 399 pp.

De Barro PJ, Liebregts W, Carver M (1998) Distribution and identity of biotypes of *Bemisia tabaci* (Gennadius) (Hemiptera : Aleyrodidae) in member countries of the Secretariat of the Pacific Community. *Australian Journal of Entomology* 37: 214–218.

Della Giustina W (1986) *Metcalfa pruinosa* (Say, 1830), nouveauté pour la Faune de France. *Bulletin de la Société Entomologique de France* 91: 89–92.

Della Giustina W (2002) Migration in Auchenorrhyncha. *Denisia* 04: 513–522.

Della Giustina W, Balasse H (1999) Gone with the wind: Homoptera Auchenorrhyncha collected by the French network of suction traps in 1994. *Marburger Entomologische Publikationen* 3: 7–42.

Della Giustina W, Remane R (2001) Compléments à la faune de France des Auchenorrhyncha: espèces et données additionnelles; modifications à l'ouvrage de Nast (1987) (Homoptera). *Bulletin de la Société Entomologique de France* 106: 283–302.

Dietrich CH (2002) Evolution of Cicadomorpha (Insecta, Hemiptera). *Denisia*, 04: 155–170.

Dietrich CH (2005) Keys to the families of Cicadomorpha and subfamilies and tribes of Cicadellidae (Hemiptera: Auchenorrhyncha). *Florida Entomologist* 88: 502–517.

Dimitrov T, Ruskov M (1927) Nasekomni I gubni vrediteli v naschite gori. *Gorski pregled* 13: 207–214.

Dlabola J (1981) *Metcalfa pruinosa* (Say, 1830), eine schadliche nordamerikanische Flatide als Erstfund in der Palaearktis (Insecta, Homoptera, Auchenorrhyncha). *Faunistische Abhandlungen (Dresden)* 8: 91–94.

Dolling WR (1991) *The Hemiptera*. London: Oxford University Press. 274 pp.

D'Urso V, Uliana M (2006) *Acanalonia conica* (Hemiptera, Fulgoromorpha, Acanaloniidae), a Nearctic species recently introduced in Europe. *Deutsche Entomologische Zeitschrift* 53: 103–107.

Duso C, Bressan A, Mazzon L, Girolami V (2005) First record of the grape leafhopper *Erythroneura vulnerata* Fitch (Hom., Cicadellidae) in Europe. *Journal of Applied Entomology* 129: 170–172.

Eichhorn O (1967) On methods of differentiating the species of the harmful white woolly aphids (Genus *Dreyfusia* CB. = *Adelges* AN.) on fir, and the consequences for forest protection. *Technical Bulletin of the Commonwealth Institute of Biological Control* 8: 53–82.

Eichhorn O (1991) On the generation cycle of *Dreyfusia nordmannianae* Eckst. (Hom., Adelgidae). *Journal of Applied Entomology* 112: 217–219.

Eichhorn O, Carter CI (1978) Investigation into conifer woolly aphids (Hemiptera: Adelgidae) in Japan, with the descriptions of two new species. *Zeitschrift fur Angewandte Entomologie* 86: 273–289.

Essl F, Rabitsch W (2002) Neobiota in Österreich. Umweltbundesamt, Wien, 432 pp.

Fauna Italia. *Checklist of the species of the italian fauna*. On-line version 2.0. www.faunaitalia.it/checklist/invertebrates/families/.

Forster B (2002) Auswirkungen eingewanderter oder eingeschleppter Insekten auf die Wald- und Parkbäume der Schweiz. *Mitteilungen der Schweizerischen Entomologischen Gesellschaft* 75: 135–136.

Francke-Grossmann H (1937) Ökologie und Schadwirkung von *Dreyfusia prelli* Grossman. *Zeitschrift für Pflanzenkrankheiten und Pflanzenschutz* 47: 497–516.

Francke-Grossmann H (1937) Zur Morphologie der Tannenlaus *Dreyfusia prelli* Grossmann und ihrer Galle auf *Picea orientalis* Lk. *Zeitschrift für Pflanzenkrankheiten und Pflanzenschutz* 47: 465–482.

Garcia Garcia EJ, Garijo Alba C, Garcia Segura S (1992) Presencia de *Paraleyrodes* sp. pr. *citri* (Bondar, 1931) (Insecta: Homoptera: Aleyrodidae) en los cultivos de cítricos de la provincia de Málaga (sur de Espana) : aspectos biológicos y ecológicos de la plaga. *Boletin de Sanidad Vegetal* 18: 3–9.

Gederaas L., Salvesen I, Viken Å (Eds) (2007) *Økologiske risikovurderinger av fremmede arter [2007 Norwegian Black List – Ecological Risk Analysis of Alien Species].* Trondheim: Artsdatabanken. 152 p.pp.

Geiter O, Homma S, Kinzelbach R (2002) *Bestandsaufnahme und Bewertung von Neozoen in Deutschland*. Berlin: Umweltbundesamt 25: 1–173.

Ghauri MSK (1983) A case of long-distance dispersal of a leafhopper. In Knight WJ, Pant NC, Robertson TS, Wilson MR (Eds) Proccedings of the *1st International Workshop on leafhoppers and planthoppers of economic importance*. London: CIE. 249–255.

Glavendekić M, Mihajlović L, Petanović R (2007) Introduction and spread of invasive mites and insects in Serbia and Montenegro. In: Alford DV & Backhaus GF (Eds) *Abstracts of the Conference on Plant Protection and Plant Health in Europe, 'Introduction and spread of invasives species'.* Berlin, Germany: Humboldt University, June 2005

Gonzalez AD (2003) *Trioza erytreae* (Del Guercio, 1918): nueva plaga de los cítricos de Canarias. *Phytoma España*, 153: 112–120.

Guglielmino A (2005) Observations on the genus *Orientus* (Rhynchota, Cicadomorpha, Cicadellidae) and description of a new species*: O. amurensis* n.sp. from Russia (Amur Region and Maritime Territory) and China (Liaoning Province). *Marburger Entomologische Publikationen* 3, 99–110.

Günthart H, Mühlethaler R, Lauterer P (2004) Für die Schweiz neue Zikadenarten und Ergänzungen zu bereits bekannten Arten (Hemiptera, Auchenorrhyncha*). Mitteilungen der Entomologischen Gesellschaft Basel* 54, 150–160.

Havill NP, Foottit RG (2007) Biology and Evolution of Adelgidae. Annual *Review of Entomology* 52: 323–349.

Hill M, Baker R, Broad G, Chandler PJ, Copp GH, Ellis J, Jones D, Hoyland C, Laing I, Longshaw M, Moore N, Parrott D, Pearman D, Preston C, Smith RM, Waters R (2005) *Audit of non-native species in England. English Nature Research Reports N° 662*. Peterborough: English Nature, 81 pp.

Hodkinson ID (1999) Biocontrol of eucalyptus psyllids *Ctenarytaina eucalypti* by the Australian parasitoid *Psyllaephagus pilosus*: a review of current programmes and their success. *Biocontrol News and Information* 20 (4): 129–134.

Hodkinson ID (2007) A new introduced species of *Ctenarytaina* (Hemiptera, Psylloidea) damaging cultivated *Eucalyptus parvula* (=*parvifolia*) in Europe. *Deutsche Entomologische Zeitschrift* 54 (1): 27–33.

Hodkinson ID, Hollis D (1987) The legume-feeding psyllids (Homoptera) of the west Palaearctic Region. *Bulletin of the British Museum of natural History* 56: 1–86.

Hodkinson ID, White IM (1979a) *Homoptera Psylloidea. Handbooks for the Identification of British Insects. Vol II, Part 5 (a)*. London: Royal Entomological Society. 98 pp.

Hodkinson ID, White IM (1979b) New psyllids from France with redescriptions of the type species of *Floria* Löw and *Amblyrhina* Löw (Homoptera Psylloidea). *Entomologica Scandinavica*, 10: 55–63.

Hollis D (1978) *Floria variegata* Löw (Homoptera: Psylloidea) on *Laburnum* in Britain. *Plant Patology* 27: 149.

Hollis D (1984) Afrotropical jumping plant lice of the family Triozidae (Homoptera: Psylloidea). *Bulletin of the British Museum (Natural History), Entomology series 49*: 1–102.

Hollis D, Broomfield PS (1989) *Ficus*-feeding psyllids (Homoptera), with special reference to the Homotomidae. *Bulletin of the British Museum (Natural History)*, *Entomology series* 58: 131–183.

Holman J, Pintera A (1977) Check-list of Czechoslovak Insects. *Acta Faunistica Entomologica Musei Nationalis Pragae* I: 101–116.

Holzinger WE, Jantscher E, Remane R (1996) Erstnachweise von Zikaden aus Österreich, mit Bemerkungen zu zwei weiteren Arten (Ins.: Homoptera, Auchenorrhyncha). *Linzer Biologische Beitraege* 28: 1149–1152.

Holzinger WE, Remane R (1994) Zikaden-Erstnachweise aus Österreich (Ins.: Homoptera, Auchenorrhyncha). *Mitteilungen des naturwissenschaftlichen Vereins für Steiermark* 124, 237–240.

Horvaáth G (1912) Az amerikai bivalykabócza Magyarországon. *Rovartani lapok. Budapest* 19: 145–147.

Iaccarino FM (1985) Nuovi generi e specie di Aleirodidi per la fauna italiana. *Bolletino del laboratorio di entomologia agraria "Filippo Silvestri"* 42: 135–141.

Kenis M (2005) Insects-Insecta. In: Wittenberg R (Ed) *An inventory of alien species and their threat to biodiversity and economy in Switzerland*. Délemont: CABI Bioscience Switzerland, 131–212.

King PD, Rilling G (1985) Variations in the galling reaction of grapevines: evidence of different Phylloxera biotypes and clonal reaction of Phylloxera. *Vitis*, 24: 32–42.

Klasa A, Soika G, Labanowski G (2003) *Massilieurodes chittendeni* (Laing, 1928) (Hemiptera: Aleyrodidae) – the whitefly species new to the Polish fauna. *Wiadomosci Entomologiczne* 22 (4): 197–200.

Kozár F, Bink-Moenen RM, Darvas B, Urfiné-Fogarsi E (1987) Új kártevö, a szamóca-molytetü (Trialeurodes packardi Morrill; Homoptera: Aleyrodidae) megjelenése Magyarországon. *Növényvédelem* 23: 351–354.

Kristensen NP (1991) Phylogeny of Extant Hexapods. In CSIRO (Ed) *The Insects of Australia*. Melbourne: Melbourne University Press, 125–140.

Laing F (1922) *Rhinocola eucalypti* Mask. In England. *Entomologist's Monthly Magazine* 58: 141.

Laing F (1928) Description of a white fly pest of rhododendrons. *Entomologist's Monthly Magazine* 64: 228–230.

Laudonia S (2006) Un nuovo psillide su eucalipto. *L'Informatore Agrario* : 89.

Lauterer P (1993) Notes on the bionomics and occurrence of some Psyllids (Homoptera, Psylloidea) in Czechoslovakia and the Balkan Peninsula. *Acta Musei Moraviae* 77: 147–156.

Lauterer P, Malenovský I (2002a) *Metcalfa pruinosa* (Say, 1830) introduced into the Czech Republic (Hemiptera, Flatidae). *Beiträge zur Zikadenkunde* 5: 10–13.

Lauterer P, Malenovský I (2002b) New distributional and biological data on European Psylloidea (Hemiptera, Sternorrhyncha), with special reference to the fauna of the Czech Republic and Slovakia. *Entomologica Basiliensia* 24: 161–177.

Louro V, Cabrita P (1989) Contribuição para o conhecimento da sua cultura em Portugal. Estudos e Informação Nº 126, 128. Lisboa: Direcção Geral das Florestas.

Maczey N, Wilson MR (2004*) Eupteryx decemnotata* Rey (Hemiptera, Cicadellidae) new to Britain. *British Journal of Entomology and Natural History* 17: 111–114.

Malausa JC, Sappei J, Franco E (1997) *Psylla acaciae-baileyanae*, un second psylle sur le mimosa dans le sud-est de la France. *Phytoma – La Défense des Végétaux*, 490: 57–59.

Malumphy C (2003) The status of *Bemisia afer* (Priesner & Hosny) in Britain (Homoptera: Aleyrodidae). *Entomologist's Gazette* 54: 191–196.

Malumphy C (2005) The Neotropical solanum whitefly, *Aleurotrachelus trachoides* (Back) (Hem., Aleyrodidae), intercepted in the U.K. on sweet potato leaves imported from Gambia. *Entomologist's Monthly Magazine* 141: 94.

Malumphy C, Halstead C (2003) *Cacopsylla fulguralis* (Kuwayama), an Asian jumping plant louse (hemiptera: psyllidae), causing damage to *Elaeagnus* in Britain. *British Journal of Entomology and Natural History* 16: 89–93.

Mani E, Baroffio C (1997) Biologische Bekämpfung der San-José-Schildlaus im Kanton Zug mit der Schlupfwespe *Encarsia perniciosi*. *Schweizer Zeitschrift für Obst- und Weinbau* 133, 392.

Mansilla J-P, Perez R, Del Estal P, Blond A (2004) Deteccion en Espana de *Ctenarytaina spatulata* Taylor sobre *Eucalyptus globulus* Labill. *Boletín de Sanidad vegetal, Plagas*, 30: 57–63.

Marchal P (1913) Contribution à l'étude de la biologie des Chermes. *Annales des Sciences Naturelles-Zoologie et Biologie Animale* 18: 153–385.

Martelli M (1960) Cenni su alcuni degli insetti più preoccupanti per le conifere a rapido incremento. Atti I Convegno nazionale Pioppo e Conifere a rapido incremento, Torino 23–25 aprile 1960, 3–9.

Martin JH (1996) Neotropical whiteflies of the subfamily Aleurodicinae established in the western Palaearctic (Homoptera: Aleyrodidae). *Journal of Natural History* 30: 1849–1859.

Martin JH (2000) The occurrence of *Dialeurodes citrifolii* and *Aleurochiton pseudoplatani* (Hemiptera: Aleyrodidae) in Lebanon – important new records in the Europe-Mediterranean Region. *Bulletin of Entomological Research* 90: 527–528.

Martin JH (2001) Description of an invasive new species of Neotropical aleurodicine whitefly (Hemiptera : Aleyrodidae) – a case of complete or partial misidentification ? *Bulletin of Entomological Research* 91: 101–107.

Martin JH, Aguiar AMF, Baufeld P (2001) *Crenidorsum aroidephagus* Martin & Aguiar sp. nov. (Sternorrhyncha : Aleyrodidae), a New World whitefly species now colonising cultivated Araceae in Europe, Macaronesia and the Pacific. *Zootaxa* 4: 1–8.

Martin JH, Hernandez-Suarez E, Carnero A (1997) An introduced new species of *Lecanoideus* (Homoptera : Aleyrodidae) established and causing economic impact on the Canary Islands. *Journal of Natural History* 31: 1261–1272.

Martin JH, Malumphy CP (1995) *Trioza vitreoradiata*, a New Zealand jumping plant louse (Homoptera : Psylloidea), causing damage to *Pittosporum* spp. in Britain. *Bulletin of Entomological Research* 85: 253–258.

Martin JH, Mound LA (2008) An annotated check list of the world's whiteflies (Hemiptera: Aleyrodidae). *Zootaxa* 1492: 1–84.

Martin JH, Aguiar A, Pita M (1996) Aleyrodidae of Madeira - Description of three new species and notes on a pan-mediterranean species of *Aleurotrachelus*. *Journal of Natural History* 30: 113–125.

Martin JH, Rapisarda C, Mifsud D (2000) The whiteflies (Hemiptera: Aleyrodidae) of Europe and the Mediterranean Basin. *Bulletin of Entomological Research* 90: 407–448.

Mercier L, Poisson R (1926) Un hémiptère de la famille des psyllines, parasite d'eucalyptus cultivés à Cherbourg. *Bulletin de la Société Linnéan de Normandie, Series 79*: 34–37.

Mifsud D (2010) Jumping plant-lice (Hemiptera : Psylloidea) of the Maltese Islands. *Bulletin of the Entomological Society of Malta* 3: in press.

Mifsud D, Watson GW (1999) Introduced sap-feeding insect pests of crop plants in the Maltese Islands. *The Central Mediterranean Naturalist* 3: 29–34.

Mound L (1961) A new genus and four new species of whitefly from ferns (Homoptera, Aleyrodidae). *Revue de Zoologie et de Botanique Africaine* 64: 127–132.

Mound LA, Halsey SH (1978) *Whitefly of the World*. Chichester, British Museum (Natural History): John Wiley & Sons. 340 pp.

Nickel H, Holzinger WE (2006) Rapid range expansion of Ligurian leafhopper, *Eupteryx decemnotata* Rey, 1891 (Hemiptera: Cicadellidae), a potential pest of garden and greenhouse herbs, in Europe. *Russian Entomological Journal* 15: 57–63.

Nielson MW (1985) Leafhopper systematics. In Nault LR, Rodriguez JG (Eds) *The leafhoppers and planthoppers*. New York: Wiley-Interscience. 11–39.

Nieto Nafria JM, Binazzi A (2005) *Super family Phylloxeroidea, Fauna Europaea*. http//www.faunaeur.org [accessed 07.03.2005].

O'Connor J-P, Dunne R, Whelton A (2004) *Trioza vitreoradiata* (Maskell) (Homoptera: Psylloidea), a New Zealand species new to Ireland. *Irish Naturalist' Journal* 27: 349–350.

O'Brien LB (2002) The Wild Wonderful World of Fulgoromorpha. *Denisia* 4: 83–102.

O'Brien L, Wilson SW (1985) Planthopper systematics and external morphology. In: Nault LR, Rodriguez JG (Eds) *The leafhoppers and planthoppers*. New York: Wiley-Interscience. 61–102.

OEPP/EPPO (1988) Data sheets on quarantine organisms No. 151, Citrus greening bacterium and its vectors *Diaphorina citri* & *Trioza erytreae*. *Bulletin OEPP/EPPO Bulletin* 18: 497–507.

Pašek V (1954) *Vošky našich lesných* drevín [Adelgids of our. Coniferous Trees]. Bratislava: Veda. 322 pp.

Pellizari G, Šimala M (2007) First record of *Aleuroclava guyavae* (Takahashi, 1932) (Hemiptera, Aleyrodidae) in Europe. *Bollettino di Zoologia Agraria e di Bachicoltura Serie II* 39(2): 91–95.

Pettey FW (1925) New South African psyllids. *South African Journal of Natural History* 5: 125–142.

Porcelli F (2008) First record of *Aleurocanthus spiniferus* (Homoptera: Aleyrodidae) in Apulia, Southern Italy. *Bulletin OEPP/EPPO Bulletin* 38: 518–520.

Priore R (1969) Il *Dialeurodes citri* (Ashmead) (Homoptera: Aleyrodidae) in Campania. *Bolletino del laboratorio di entomologia agraria "Filippo Silvestri"* 27: 287–316.

Rapisarda C (1985) Sulla presenza in Italia di *Acizzia acaciaebaileyanae* (Froggatt) (Homoptera, Psylloidea), nuovo parassita di Acacie ornamentali. *Informatore fitopatologico* 1985: 45–49.

Rapisarda C, Siscaro G, Leocata S, Asero C (1990) *Parabemisia myricae*, un nuovo aleirode degli agrumi in Italia. *Informatore fitopatologico* 40 (12): 25–30.

Redel D, Penzes B (2006) First occurrence of *Acizzia jamatonica* (Kuwayama, 1908) (Sternorrhyncha: Psyllidae: Acizziinae) in Hungary. *Novenyvedelem* 42: 153–157.

Roll E, Dayan T, Simberloff D (2007) Non-indigenous species in Israel and adjacent areas. *Biological Invasions* 9: 629–643.

Roversi PF, Binazzi A. 1996. Life cycle of the Douglas-fir woolly aphid *Gilletteella coweni* (Gillette) in central Italy (Homoptera Adelgidae). *Redia* 79: 241–45.

Russell LM (1964) *Dialeurodes kirkaldyi* (Kotinsky), a whitefly new to the United States (Homoptera : Aleyrodidae). *The Florida Entomologist* 47: 1–4.

Schaefer HA (1949) Beiträge zur Kenntnis der Psylliden der Schweiz. *Mitteilungen der Schweizerischen Entomologischen Gesellschaft* 22: 1–96.

Šefrová H, Laštùvka Z (2005) Catalogue of alien animal species in the Czech Republic. *Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis* 53: 151–170.

Seljak G (2002) Non-european Auchenorrhyncha (Hemiptera) and their Geographical distribution in Slovenia. *Acta Entomologica Slovenica* 10: 97–101.

Seljak G (2003) *Acizzia jamatonica* endangers Albizia trees. *Moj mali svet* 35: 20–21.

Seljak G (2004) Prokelisia marginata (Van Duzee, 1897) - nearkticna vrsta škržatkov, nova za Slovenijo in Evropo (Auchenorrhyncha: Delphacidae) *Prokelisia marginata* (Van Duzee, 1897) - a nearctic planthopper, new to Slovenia and Europe (Auchenorrhyncha: Delphacidae). *Acta Entomologica Slovenica* 12: 260–262.

Seljak G, Simala M, Stigter H (2004) Three new non-European psyllids (Hemiptera, Psyllidae) in Slovenia and Croatia. In: *Abstracts of the Third European Hemiptera Congress*, St Petersburg, November 2004: 66–67.

Sergel R (1987) On the occurrence and ecology of the Rhododendron-leafhopper *Graphocephala fennahi* Young 1977, in the western palaearctic region (Homoptera, Cicadellidae). *Anzeiger für Schädlingskunde, Pflanzenschutz, Umweltschutz* 60: 134–136.

Söderman G (2005) The eastern palaearctic leafhopper *Igutettix oculatus* (Lindberg, 1929) in Finland: morphology, phenology and feeding (Insecta, Hemitpera, Cicadellidae, Typhlocybinae). *Beiträge zur Zikadenkunde* 8: 1–4.

Stani A, Murraj Xh, Kapidani A (1974) *Entomologjia Bujqësore*-cited in Tomov et al (2009) (147).

Steffan AW (1972) Unterordnung Aphidina, Blattläuse. In: Schwenke W (Ed) (1972) *Die Forstschädlinge Europas, I. Band. Würmer, Schnecken, Spinnentier, Tausendfüssler und Hemimetabole Insecten.* Paul Parey, Hamburg and Berlin. pp. 162–386.

Stewart AJA (1993) *Placotettix taeniatifrons* (Kbm.) (Hem., Cicadellidae) in Bedfordshire. *Entomologist's Monthly Magazine* 129: 80.

Streito JC (2004) Découverte en France de *Crenidorsum aroidephagus* Martin & Aguiar, 2001, description de la femelle, caractères permettant de la différencier d'autres aleurodes d'intérêt agronomique (Hemiptera, Aleyrodidae). *Nouvelle Revue d'Entomologie* 21: 375–382.

Süss L, Salvodelli S (2003) Rinvenimento di *Cacopsylla fulguralis* (Kuwayama) (Homoptera Psyllidae) in Italia. *Bollettino di Zoologia agraria e di Bachicoltura* 35: 95–98.

Teodorescu I, Manole T, Iamandei M, Vadineanu A (2005) The main alien/invasive insect species in Romania. *Revue Roumaine de Biologie - Série de Biologie Animale* 51: 43–61

Tomov R, Trencheva K, Trenchev G, Cota E, Ramadhi A, Ivanov B, Naceski S, Papazova-Anakieva I, Kenis M (2009) *Non-indigenous insects and their threat to biodiversity and economy in Albania, Bulgaria and Republic of Macedonia*. Sofia-Moscow: Pensoft, publishers, 112 pp.

Trehan KN (1938) Two new species of Aleurodidae found on ferns in greenhouses in Britain (Hemiptera). *Proceedings of the Royal Entomological Society of London* (B) 7: 182–189.

Tremblay E (1981) *Entomologia applicata*, vol II (1), Napoli: Liguori Editore, 310pp.

Tremblay E (1988) Avversità delle colture di recente o temuta introduzione. Parassiti animali: Insetti. *Italia agricola* 115–128.

Tsitsipis JA, Katis N, Margaritopoulos J, Lykouressis D, Avgelis A, Gargalianou I, Zarpas K, Perdikis D, Papapanayotou A (2007) A contribution to the aphid fauna of Greece. *Bulletin of Insectology* 60: 31–38.

Valente C, Hodkinson I (2008) First record of the Red Gum Lerp Psyllid, *Glycaspis brimblecombei* Moore (Hem.: Psyllidae) in Europe. *Journal of Applied Entomology* 133: 315–317.

Valente C, Manta A, Vaz A (2004) First record of the Australian psyllid *Ctenarytaina spatulata* Taylor (Homoptera: Psyllidae) in Europe. *Journal of Applied Entomology* 128: 369–370.

Varty IW (1956). *Adelges Insects of Silver Firs*. Edinburgh: Her Majesty's Stationery Office. 75 pp.

Visnya A (1941) A gigantic species of Aleurodidae (Homoptera) from greenhouse-Orchideas. *Folia Entomologica Hungarica* 6: 4–15.

Wheeler Jr AG, Richard Hoebeke E (2009) *Acizzia jamatonica* (Kuwayama) (Hemiptera: Sternorrhyncha: Psyllidae): U.S. distribution of a recently detected Asian Psyllid. *Proceedings of the Entomological Society of Washington* 111 (2) : 505–514.

Wilson MR (1981) Identification of European *Iassus* species (Homoptera: Cicadellidae) with one species new to Britain. *Systematic Entomology* 6: 115–118.

Wilson MR, Claridge MF (1991)*Handbook for the identification of leafhoppers and planthoppers of rice*. Wallingford, Oxon: CAB International,142 pp.

Wilson SW, MacPherson JE (1981) Life histories of *Anormenis septentrionalis*, *Metcalfa pruinosa*, and *Ormenoides venusta* with descriptions of immature stages. *Annals of the Entomological Society of America* 74 (3): 299–311.

Wittenberg R (2005) *An inventory of alien species and their threat to biodiversity and economy in Switzerland*. CABI Bioscience Switzerland Centre report to the Swiss Agency for Environment, Forests and Landscape: 417pp.

Yoshizawa K, Saigusa T (2001) Phylogenetic analysis of paraneopteran orders (Insecta: Neoptera) based on forewing base structure, with comments on monophyly of Auchenorrhyncha (Hemiptera). *Systematic Entomology* 26: 1–13.

Zandigiacomo P, Bernardinelli I, Stergule F (2002) Psilla dell' albizzia: prima segnalazione per l'Italia nord-orientale. *Notizia/ERSA* 2002: 18–20

Table 9.4.1. List and main characteristics of Aleyrodidae, Psylloidea, Phylloxeroidea, and Auchenorrhyncha species alien *to* Europe. Country codes abbreviations refer to ISO 3166 (see Appendix I). Habitat abbreviations refer to EUNIS (see Appendix II). Only selected references are given

Suborder ***Superfamily*** **Family (*Subfamily*)**	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Sternorrhyncha								
Aleyrodidae (*Aleyrodinae*)								
Acaudaleyrodes rachipora (Singh, 1931)	A	Phytophagous	Oriental Region	2000, ES-CAN	ES-CAN	I2	Polyphagous	Martin et al. (2000)
Aleurocanthus spiniferus (Quaintance, 1903)	A	Phytophagous	Oriental Region	2008, IT	IT	I	Polyphagous; occasionally a pest on *Annona* and *Citrus*	Porcelli (2008)
Aleuroclava aucubae (Kuwana, 1911)	A	Phytophagous	Oriental Region	2007, IT	IT	I2, J100	*Psidium*, *Cinnamomum*, *Citrus*, *Ficus*, *Pittosporum*, *Prunus*, *Photinia*	Pellizari and Šimala (2007)
Aleuroplatus perseaphagus Martin et al., 1996	A	Phytophagous	Neotropical Region	1991, ES-MAD	PT-MAD	I2	Avocado mainly	Martin et al. (1996)
Aleuropteridis filicicola (Newstead, 1911)	A	Phytophagous	Africa	1961, GB	GB	J100	*Pteris togoensis*, *Cyclosorus dentatus*, *Oleandra articulata*	Mound (1961)[1]
Aleurothrixus floccosus Maskell, 1895	A	Phytophagous	Neotropical Region	1968, ES-CAN; 1969, FR	AL, ES-CAN, FR, FR-COR, GR, IL, IT, IT-SAR, IT-SIC, MT, PT, GB	I2, J100	Polyphagous; a preference for *Citrus* where established	Martin et al. (2000)
Aleurotrachelus atratus Hempel, 1922	A	Phytophagous	Neotropical Region	2000, ES-CAN	ES-CAN, FR	I2, J100	*Cocus* spp.	Borowiec et al. (2010)

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[1] Mound (Mound 1961) redescribed this species under the name of *A. douglasi* from material collected on ferns in Kew Gardens, UK.

Suborder ***Superfamily*** **Family (*Subfamily*)**	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Aleurotrachelus trachoides (Back, 1912)	A	Phytophagous	Neotropical Region	2005, GB	GB	? J100	Sweet potato leaves	Malumphy (2005)
Aleurotulus nephrolepidis (Quaintance, 1900)	A	Phytophagous	C & S America	1938, GB	ES, ES-CAN, GB, HU	J100	Ferns	Trehan (1938)
Bemisia tabaci (Gennadius, 1889)	A	Phytophagous	? Asia	?	AL, AT, BE, BG, CH, CY, CZ, DE, ES, ES-BAL, ES-CAN, FR-COR, FR, DE, GR-CRE, GR, HU, HR, IL, IT, IT-SAR, IT-SIC, MT, NL, NO, PL, PT, RO, RU	I1, J100	Polyphagous crops & greenhouses	Martin et al. (2000)
Crenidorsum aroidephagus Martin & Aguiar, 2001	A	Phytophagous	C & S America	1998, PT-MAD	DE, FR, PT-MAD	J100, I2	Araceae	Martin et al. (2001), Streito (2004)
Dialeurodes citri (Ashmead, 1885)	A	Phytophagous	Oriental Region	1945 ?	AL, FR, FR-COR, IL, IT, IT-SAR, IT-SIC, MT, SI	I2	Polyphagous; a preference for *Citrus* where established	Priore (1969)
Dialeurodes kirkaldy (Kotinsky, 1907)	? A	Phytophagous	? New World	?	CY, IL, PT	I2	Polyphagous; a preference for *Jasminum* and *Morinda citrifolia*	Russell (1964)
Filicaleyrodes williamsi (Trehan, 1938)	A	Phytophagous	? Tropical Africa	1938, GB	GB, HU	J100	Ferns	Trehan (1938)
Massilieurodes chittendeni (Laing, 1928)	A	Phytophagous	Northern Asia	1928, GB	BE, CH, CZ, DE, DK, FI, FR, GB, IT, NL, PL, SE	I2	Rhododendron	Laing (1928)

Suborder ***Superfamily*** **Family (*Subfamily*)**	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Parabemisia myricae (Kuwana, 1927)	A	Phytophagous	Asia	mid 1980's	CY, ES, ES-CAN, FR, FR-COR, GR-CRE, IL, IT, IT-SAR, IT-SIC, PT	I2	Polyphagous; a preference for citrus and avocados (in Europe)	Rapisarda et al. (1990)
Pealius azaleae (Baker & Moles, 1920)	A	Phytophagous	Eastern Asia	1920, BE	BE, GB, IT, NL	I2, J100	Rhododendron	Martin et al. (2000)
Singiella citrifolii (Morgan, 1893)	? A	Phytophagous	? New World	1998, PT-MAD	PT-MAD	I2	*Citrus* mainly	Martin (2000)
Trialeurodes packardi (Morrill, 1903)	A	Phytophagous	Nearctic Region	1987, HU	HU	I2	Strawberries (in Europe)	Kozár et al. (1987)
Trialeurodes vaporariorum (Westwood, 1856)	A	Phytophagous	North America	1856, GB	AL, AT, BG, CH, CZ, DE, DK, EE, FR, HU, IT, IT-SAR, IT-SIC, LT, MT, PT, RO, RS, SI	I2, J100	Polyphagous	Martin et al. (2000)
Aleyrodidae (*Aleurodicinae*)								
Aleurodicus destructor Mackie, 1912	A	Phytophagous	Neotropical Region	?, GB	GB	J100	Polyphagous	Martin (1996)
Aleurodicus dispersus Russell, 1965	A	Phytophagous	Neotropical Region	1962, ES-CAN	ES, ES-CAN, PT-MAD	I2	Polyphagous; a preference for *Citrus* where introduced	Martin (1996)
Ceraleurodicus varus (Bondar, 1928)	A	Phytophagous	Neotropical Region	1939	HU	J100	Orchids	Visnya (1941)
Lecanoideus floccissimus Martin et al., 1997	A	Phytophagous	Neotropical Region	1994, ES-CAN	ES-CAN	I2	Polyphagous	Martin et al. (1997)
Paraleyrodes bondari Peracchi, 1971	A	Phytophagous	Neotropical Region	1995, PT-MAD	PT-MAD	I2	Polypagous, also on *Citrus* spp.	Martin (1996)

Suborder ***Superfamily*** **Family (*Subfamily*)**	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Paraleyrodes citricolus Costa Lima, 1928	A	Phytophagous	Neotropical Region	1994, PT-MAD	PT-MAD	I2	*Citrus* spp., *Persea Americana*	Martin (1996)
Paraleyrodes minei Iccarino, 1990	A	Phytophagous	Neotropical Region	1990, ES	ES	I2	Mainly on *Citrus* spp.	Garcia Garcia et al. (1992)
Psylloidea								
Psyllidae								
Acizzia acaciaebaileyanae (Froggatt, 1901)	A	Phytophagous	Australia	1981, FR	FR, IT, IT-SIC, SI	I2, F	*Acacia baileyana*	Malausa et al. (1997), Rapisarda (1985),Stoch (2003), Seljak et al. (2004)
Acizzia hollisi Burckhardt, 1981	A	Phytophagous	Africa	1987, IT	IT (Lampedusa)	I2, F	*Acacia raddiana*, cultivated *Acacia* spp.	Conci and Tamanini (1989)
Acizzia jamatonica (Kuwayama, 1908)	A	Phytophagous	Western Asia	2002, IT	CH, FR, FR-COR, HR, HU, IT	I2, F	*Albizzia julibrissima*	Chapin and Cocquempot (2005), Seljak et al. (2004), Seljak (2003), Wittenberg (2005), Rédei and Pénzes (2006), Zandigiacomo
Acizzia uncatoides (Ferris & Klyver, 1932)	A	Phytophagous	Australia	1974, FR	ES-CAN, FR, IL, IT, IT-SIC, ME, MT, PT	I2, F	*Acacia floribunda*	Hodkinson and Hollis (1987), Lauterer (1993), Malausa et al. (1997), Stoch (2003), Seljak et al. (2004)
Blastopsylla occidentalis Taylor, 1985	A	Phytophagous	Australia	2006, IT	IT	I2	*Eucalyptus* spp.	Laudonia (2006)
Cacopsylla fulguralis (Kuwayama, 1908)	A	Phytophagous	Western Asia	1999, FR	BE, CH, ES, FR, GB, IT	I2	*Elaeagnus* x *ebbingei*	Baugnée (2003), Cocquempot (2008), Cocquempot and Germain (2000), Malumphy and Halstead (2003), Süss and Salvodelli (2003), Wittenberg (2005)
Cacopsylla pulchella (Löw, 1877)	A	Phytophagous	Eastern Mediterranean	1964, FR	FR, GB, CH, IT, IT-SIC	I2	*Cercis siliquastrum*	Klimaszewski (1973), Hodkinson and White (1979a), Hodkinson and White (1979b), Burckhardt (1983), Stoch (2003)

Suborder ***Superfamily*** **Family (*Subfamily*)**	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Ctenarytaina eucalypti (Maskell, 1890)	A	Phyto-phagous	Australia	1922, GB	CH, DE, ES, FR, GB, IE, IT, PT	I2, G5	*Eucalyptus* spp.	Burckhardt (1998), Cavalcaselle (1982), Hodkinson (1999), Hodkinson and White (1979a), Laing (1922), Mercier and Poisson (1926), Nogueira (1971), Rupérez and Cadahia (1973), Wittenberg (2005)
Ctenarytaina peregrina Hodkinson, 2007	A	Phyto-phagous	Australia	2006, GB	FR, GB, IT	I2	*Eucalyptus parvula*	Hodkinson (2007)
Ctenarytaina spatulata Taylor, 1967	A	Phyto-phagous	Australia	2002, PT	ES, FR, IT, PT	I2, G5	*Eucalyptus* spp.	Costanzi et al. (2003), Mansilla et al. (2004), Valente et al. (2004)
Glycaspis brimblecombei (Moore, 1964)	A	Phyto-phagous	Australia	2008, ES, PT	ES, PT	I2, G5	*Eucalyptus* spp.	Valente and Hodkinson (2008)
Triozidae								
Trioza erythreae (Del Gercio, 1918)	A	Phyto-phagous	Western Africa	1994, MAD	ES-CAN, PT-MAD	I2	*Citrus* trees	Borges et al. (2008), Gonzalez (2003)
Trioza neglecta (Loginova, 1978)	A	Phyto-phagous	South-western and Central Asia	1982, CZ	AT, BG, CZ, HU, SK, RO, YU	I2	*Elaeagnus angustifolia*	Lauterer (1993), Lauterer and Malenovský (2002b)
Trioza vitreoradiata (Maskell, 1879)	A	Phyto-phagous	New Zealand	1993, GB	FR, GB, IE	I2	*Pittosporum* spp.	Cocquempot (2008), Malumphy et al. (1994), O'Connor et al. (2004)
Phylloxeroidea								
Adelgidae								
Adelges (*Gilletteella*) *cooleyi* (Gillette, 1907)	A	phyto-phagous	Western North America	1913, GB	AT, CH, CZ, DE, DK, FR, GB, IE, IT, NL, PL, PT, RO, RS, SE, SK, UA	G3, I2	*Picea (I), Pseudotsuga (II)*	Chrystal (1922), Covassi and Binazzi (1981), Essl and Rabitsch (2002), Forster (2002), Glavendekić et al. (2007), Nieto Nafria and Binazzi (2005), Pašek (1954)

Suborder *Superfamily* Family (*Subfamily*)	Status	Regime	Native range	1st record in Europe	Invaded countries	Habitat	Hosts	References
Adelges (*Gilletteella*) *coweni* (Gillette, 1907)	A	phyto-phagous	North America	>1900, IT	AT, IT, PT	G3, I2	*Pseudotsuga* (anholocyclic)	Carter (1983), Essl and Rabitsch (2002), Louro and Cabrita (1989), Nieto Nafria and Binazzi (2005), Roversi and Binazzi (1996), Steffan (1972)
Adelges (*Dreyfusia*) *merkeri* Eichhorn 1957	A	phyto-phagous	Asia Minor	>1900, IT	AT, CZ, DE, IT, SE	G3	*Picea (I), Abies (II)*	Binazzi and Covassi (1988), Fauna Italia, Nieto Nafria and Binazzi (2005)
Adelges (*Dreyfusia*) *nordmannianae* (Eckstein, 1890)	A	phyto-phagous	Caucasus Mountains	1840, DE	AT, BG, CH, CZ, DE, DK, EE, FR, GB, HU, IE, IT, LV, NL, PL, PT, RS, SE, SI, SK, UA	G3	*Picea (I), Abies (II)*	Binazzi and Covassi (1988), Dimitrov and Ruskov (1927), Eichhorn (1967), Eichhorn (1991), Essl and Rabitsch (2002), Fauna Italia, Glavendekić et al. (2007), Marchal (1913), Nieto Nafria and Binazzi (2005), Pašek (1954), Varty (1956)
Adelges (*Dreyfusia*) *prelli* Grosmann, 1935	A	phyto-phagous	Caucasus mountains	<1900, IT	AT, CH, CZ, DE, IT, SE, SK	G3	*Picea, Picea orientalis (I), Abies (II)*	Binazzi and Covassi (1988), Eichhorn (1967), Francke-Grossmann (1937a), Francke-Grossmann (1937b), Nieto Nafria and Binazzi (2005), Šefrová and Laštùvka (2005)
Adelges (*Cholodkovskya*) *viridula* (Cholodkowsky, 1911)	A	phyto-phagous	North-western Russia	?, CZ	CZ, DK, ES, GB, SE, SI, SK, YU	G3	*Larix* (anholocyclic)	Nieto Nafria and Binazzi (2005), Šefrová and Laštùvka (2005), Steffan (1972)
Pineus (*Pineus*) *orientalis* (Dreyfuss, 1889)	A	phyto-phagous	Caucasus mountains	1913, CZ	CZ, DE, DK, GB, IT, NL, SK, UA	G3, I2	*Picea orientalis (I), Pinus (II)*	Bayer (1914), Covassi and Binazzi (1981), Hill et al. (2005), Marchal (1913), Nieto Nafria and Binazzi (2005)

Suborder ***Superfamily*** **Family (*Subfamily*)**	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Pineus (*Pineus*) *similis* (Gillette 1907)	A	phyto-phagous	North America	1971, GB	GB	G3	*Picea sitchensis* (anholocyclic)	Carter (1975), Carter (1975)
Pineus (*Eopineus*) *strobi* (Hartig, 1837)	A	phyto-phagous	Eastern North America	1900, CZ	AT, BG, CH, CZ, DE, DK, GB, IT, LV, NL, PL, RO, RS, SE, SK, UA	G3, I2	*Pinus strobus* (anholocyclic)	Bayer (1920), Essl and Rabitsch (2002), Glavendekić et al. (2007), Martelli (1960), Nieto Nafria and Binazzi (2005), Steffan (1972)
Phylloxeridae								
Moritziella corticalis (Kaltenbach, 1867)	C	phyto-phagous	Cryptogenic	1970, GB	AT, DE, GB, IT, MD, NL, UA	G,I2	*Quercus petreae*	Barson and Carter (1972), Fauna Italia, Nieto Nafria and Binazzi (2005)
Viteus vitifoliae (Fitch, 1855)	A	phyto-phagous	North America	1860, FR	AL, AT, BG, CH, CZ, DE, ES, FR, GR, HR, HU, IE, IL, IT, IT-SAR, IT-SIC, MD, MT, PT, PT-MAD, RO, RS, SI, UA	I	*Vitis*	Aloi (1898), Anonymous (1894), Baudyš (1935), Essl and Rabitsch (2002), Fauna Italia, Glavendekić et al. (2007), Nieto Nafria and Binazzi (2005), Roll et al. (2007), Stani et al. (1974), Teodorescu et al. (2005), Tremblay (1981), Tsitsipis et al. (2007), Wittenberg (2005)
Auchenorrhyncha								
Cicadomorpha								
Cicadellidae								
Erythroneura vulnerata (Fitch, 1851)	A	Phyto-phagous	North America	2004, IT	IT	I	*Vitis*	Duso et al. (2005)
Graphocephala fennahi Young, 1977	A	Phyto-phagous	North America	1933, GB	AT, BE, CH, CZ, DE, DK, FR, GB, IT, NL, SI	FB, G, I2, X11, F	*Rhododendron*	Sergel (1987)
Igutettix oculatus (Lindberg, 1929)	A	Phyto-phagous	East Asia	1984, RU	FI, RU	I2	*Syringa*	Söderman (2005)

Suborder ***Superfamily*** **Family (*Subfamily*)**	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Japananus hyalinus (Osbom, 1900)	A	Phyto-phagous	East Asia	1942, AT	AT, BG, CH, CZ, DE, ES, FR, HU, IT, ME, RO, RS, RU, SI, SK	I2, G1	*Acer*	Seljak (2002)
Kyboasca maligna (Walsh, 1862)	A	Phyto-phagous	North America	1997, FR	BE, FR	I	*Pyrus, Crataegus*	Della Giustina and Remane (2001)
Macropsis elaeagni Emeljanov, 1964	A	Phyto-phagous	Asia (Caucasus)	1982, CZ	AT, BG, CZ, DE, HU, RO, SI, UA	I2, G5	*Elaeagnus*	Holzinger and Remane (1994)
Orientus ishidae (Matsumura, 1902)	A	Phyto-phagous	East Asia	2002, CH	AT, CH, CZ, DE, FR, IT, SI	I2	*Salix, Betula,* fruit tress	Guglielmino (2005), Günthart et al. (2004)
Scaphoideus titanus Ball, 1932	A	Phyto-phagous	North America	1958, FR	AL, AT, BG, CH, ES, FR, HU, IT, PT, RS, SI	I1	*Vitis*	Arzone et al. (1987)
Membracidae								
Stictocephala bisonia Kopp & Yonke, 1977	A	Phyto-phagous	North America	< 1912, HU	AL, AT, BA, BE, BG, CH, CZ, DE, ES, FR, HR, HU, IT, IT-SAR, IT-SIC, MD, ME, MK, NL, PL, RO, RS, SI, SK, UA	I2	Polyphagous	Arzone et al. (1987), Seljak (2002)
Fulgoromorpha								
Acanaloniidae								
Acanalonia conica (Say, 1830)	A	Phyto-phagous	North America	2003, IT	IT	I, J	Polyphagous	D'Urso and Uliana (2006)
Delphacidae								
Prokelisia marginata (Van Duzee,1897)	A	Phyto-phagous	North America	2003, SI	ES, FR, GB, PT, SI	D6	*Spartina maritima*	Seljak (2004)

Suborder ***Superfamily*** **Family (*Subfamily*)**	**Status**	**Regime**	**Native range**	**1st record in Europe**	**Invaded countries**	**Habitat**	**Hosts**	**References**
Flatidae								
Metcalfa pruinosa (Say, 1830)	A	Phytophagous	North America	1970, FR	AL, AT, BA, BG, CH, CZ, FR, FR-COR, GR, HR, HU, IT, IT-SAR, IT-SIC, RS, SI, SK	I	Polyphagous	Dlabola (1981), Lauterer and Malenovský (2002a)

Glossary of the technical terms used in the book (marked by *)

Alatae: winged forms in aphids, adelgids, and other hemipterans.

Ampelophagous: related to the grapevine.

Anholocyclic: in cyclically parthenogenetic organisms, life cycles that do not include a sexual generation (e.g., in adelgids).

Archegonia: female multicellular egg-producing organ occurring in mosses, ferns, and most gymnosperms.

Archeozooan: an alien animal introduced to Europe since the beginning of the Neolithic agriculture but before the discovery of America by Columbus in 1492 (Daisie 2009).

Arrhenotoky: a common form of sex-determination in Hymenoptera and some other invertebrates, in which progeny are produced by mated or unmated females, but fertilized eggs produce diploid female offspring, whereas unfertilized eggs produce haploid male offspring by parthenogenesis (only the females are biparental).

Carina (sg.), **Carinae (pl.):** a ridgelike structure (e.g. antennal longitudinal ridge).

Cercus (sg.), **Cerci (pl.):** paired sensory structures at the posterior end of some arthropods.

Clava: apically differentiated region (sometimes club-like) of the antennal flagellum.

Dealate: having lost its wings; used for ants and other insects that shed their wings after the mating flight.

Declivity: posterior portion of the elytra that descends to its apex.

Domestic: living in human habitats.

Endofurca: the internal skeleton of the meso-and metathorax, that provides important muscle insertion points. In some thrips, the metasternal endofurca provides the insertion for powerful muscles that are associated with a remarkable jumping ability of adults.

Endophytic (adj): living inside a plant.

Endopterygote: insect that undergoes complete metamorphosis, with the larval and adult stages differing considerably in their structure and behaviour.

Epigyne: the external female sex organ in arachnids.

Exarate: for a pupa, having the appendages free and not attached to the body (as opposed to Obtect).

Exopterygote: insect that undergoes incomplete metamorphosis. The young (called nymphs) resemble the adults but lack wings; these develop gradually and externally in a series of stages or instars until the final moult produces the adult insect. There is no pupal stage.

Flagellum: the part of the antenna beyond the pedicel, which is differentiated into three regions, the anellus, funicle and clava.

Frass: waste material produced by feeding insects, including excrement and partially chewed vegetation.

Funicle: region of the antennal flagellum between the anellus and clava.

Gallicolae: leaf gall making forms; e.g., in phylloxerans.

Gnathosoma: anterior body region in mites.

Halobiont: an organism that lives in a salty environment.

Hemimetabolous: the type of insect development in which there is incomplete or partial metamorphosis, typically with successive immature stages increasingly resembling the adult; see Exopterygote.

Holocyclic: in cyclically parthenogenetic organisms, life cycles that include a sexual generation (e.g., in adelgids).

Holoptic: as in flies, with compound eyes meeting along the dorsal midline of the head.

Hyperparasitoid: a parasitoid living on or in another parasitoid.

Idiobiont parasitoid: a parasitoid which prevents further development of the host after initial parasitization.

Idiosoma: abdomen of mites and ticks.

Kleptoparasitoid: a parasitoid which preferentially attacks a host that is already parasitized by another species.

Koinobiont parasitoid: a parasitoid which allows the host to continue its development and often does not kill or consume the host until the host is about to either pupate or become an adult.

Ligula: the apical lobe of the labium.

Megagametophyte: female haploid, gamete-producing tissue in conifers.

Mesothorax: the second, and usually the largest, of the three primary subdivisions of the thorax in insects.

Mesonotum: the dorsal part of the mesothorax.

Metathorax: the third of the three primary subdivisions of the thorax in insects.

Metanotum: the dorsal part of the metathorax.

Moniliform: bead-like (as in antennae).

Mycangium (sg.), **mycangia (pl.):** usually complex structures on the insect body that are adapted for the transport of symbiotic fungi, usually spores.

Neozooan: an alien animal introduced to Europe after the discovery of America by Columbus in 1492 (Daisie 2009) .

Notaulix (sg.), **Notaulices (pl.):** one of a pair of grooves on the mesoscutum, from the front margin to one side of the midline and extending backward; divides the mesoscutum into three parts.

Obtect: for a pupa, having the legs and other appendages fused to the body.

Oniscomorph: the state as in 'pill' millipedes of being able to roll up in a ball.

Opisthosoma: posterior part of the body in spiders and mites.

Paranota: lateral wings.

Parthenogenesis, parthenogenetic (adj.): the production of offspring from unfertilized eggs. Special cases of this state are arrhenotoky, pseudo-arrhenotoky, and thelytoky.

Phytoplasma: prokaryotes that are characterized by the lack of a cell wall, associated with plant diseases.

Phytotelmatum (sg.), **Phytotelmata (pl.):** a small, water-filled cavity in a tree or any similar environment.

Podosoma: anterior section of idiosoma in ticks; serving as connecting area for the four pairs of legs.

Porrect: extended, especially forward; e.g., porrect mandibles.

Proctiger: the reduced terminal segment of the abdomen which contains the anus.

Prognathous: with the head more or less in the same horizontal plane as the body, and the mouthparts directed anteriorly.

Pronotum: the dorsal part of the prothorax.

Propodeum: the first abdominal segment.

Prosoma: anterior part of the body in spiders and mites; also called cephalothorax.

Prothorax: The first of the three primary subdivisions of the thorax in insects.

Pseudo-arrhenotoky: A form of sex-determination (especially in some scale insects and mites) in which males and females arise from fertilized eggs and are diploid. However, males become haploid by inactivation of the paternal genomic complement.

Puparium (sg.), **puparia (pl.):** the enclosing case of a pupa.

Reticulate: net-like, anastomosing.

Rostrum: beak-shaped projection on the head; e.g., in weevils.

Scutellum: the middle region of the mesonotum or metanotum, behind the scutum.

Scutum: the anterior part of the mesonotum or metanotum.

Secondary pest: a pest that attacks only weakened plants.

Sensorium: sensory structure present on antenna.

Siphunculi, **siphuncular (adj.):** pair of protruding horn-shaped dorsal tubes in aphids which secrete a waxy fluid.

Spatula sternalis: median cuticular sclerite, often bilobed, on the ventral side of the prothoracic segment of the last instars of some midge larvae; plays a role in larval locomotion.

Stigma: conspicuous, usually melanised area at the apex of a vein of the forewing, generally at the leading wing edge.

Sulcate: having narrow, deep furrows or grooves.

Synanthropic: ecologically associated with humans.

Tegula: Small, typically oval sclerite that covers the region of the mesothorax where the forewing and thorax articulate.

Thelitoky: A form of sex-determination (especially in Hymenoptera Symphyta and Cynipidae) in which only diploid female progeny are produced by parthenogenesis.

Termen: distalmost edge of wing.

Transhumance: in the case of hives, moving to new environments, according to the change in season.

Xylophagous (adj.): feeding on wood.