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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 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).

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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)		