

New records of exotic spiders and insects to the Azores, and new data on recently introduced species

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Borges, P.A.V., M. Reut, N.B. da Ponte, J.A. Quartau, M. Fletcher, A.B. Sousa, M. Pollet, A.O. Soares, J.A.P. Marcelino, C. Rego & P. Cardoso 2013. New records of exotic spiders and insects to the Azores, and new data on recently introduced species. *Arquipélago*. Life and Marine Sciences 30: 57-70.

The introduction of exotic species in islands is recognized as a major threat to native biota and ecosystems. In this contribution we list thirteen widespread exotic invertebrate species (two Araneae, one Orthoptera, four Hemiptera, four Coleoptera and two Diptera) that were recorded from the Azorean Islands in the last few years for the first time. In addition, we list another ten invertebrate species (two Araneae, one Orthoptera, two Phasmatodea, one Hemiptera, three Coleoptera and one Diptera) that expanded their known range in the archipelago. The pathways of entrance for species in the Azores, their impact on the local economy and biodiversity, as well as strategies to halt the introduction of alien species are discussed.

Key words: Arthropoda, Azores, exotic, insects, spiders, invasive

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INTRODUCTION

Due to relatively low species richness with presumably higher numbers of empty niches and often lacking mechanisms to resist introduced species bringing novel ecological functions, insular ecosystems are considered more susceptible to the impacts of introductions than continental ecosystems (Williamson 1996; Whittaker &

Fernández-Palacios 2007). For instance, the Azores archipelago flora and fauna is dominated by introduced species, with about 80% of the vascular flora and 60% of arthropod fauna being non-native (Borges et al. 2005), many of them being invasive. Most introductions are due to trade, agriculture and tourism (Williamson 1996; Liebhold et al. 2006). For the Azores, the introduction of many species, some of them cosmo-

politan and others with an invasive potential, is related to the fact that, for centuries, these islands have been (and still are) a strategic gateway for many boats coming from the Americas to Europe and vice-versa. Additionally, the Portuguese brought plants, often with associated fauna, from all over the world to their private gardens, particularly in the most populated islands (S. Miguel, Terceira and Faial).

It is known that of all the introduced species arriving to a new region, just a small percentage is able to become established and naturalized, whereas only a fraction of these actually become invasive, i.e., exotic species which by introduction or spreading threatens biodiversity (Williamson 1996; Marchante 2001; Silva et al. 2008a). Two main factors may hamper or promote the invasion process: i) the biological traits that enable species to invade a new habitat (invasiveness); ii) the characteristics of the new habitat that determine its susceptibility to the establishment and spread of the invader (invasibility) (Marco et al. 2002). A third important aspect linking invasiveness and invasibility is the interaction among the invaders, the species already present, and the habitat (Soares et al. 2008; Evans et al. 2011). Thus, the success rate differs among species, and depends on several factors such as offspring size, presence or lack of natural enemies, availability of resources and local environmental adaptation (Williamson 1996). The impact of exotic invasive species in the Azores is well documented (Silva & Smith 2006; Silva et al. 2008a,b), and has been greater in this archipelago than in the other Macaronesian archipelagos (Silva et al. 2008b; Borges et al. 2009). For example, many exotic plants like *Hedychium gardnerianum*, *Pittosporum undulatum* and *Hydrangea macrophylla*, are threatening several fragments of native vegetation, possibly endangering also several communities of arthropods, native and endemic to the Azores (see also Cardoso et al. 2010a; Triantis et al. 2010).

During the last few years, new records of exotic species have been added to the Azorean arthropod fauna. Such species have been discovered on the Azores in different localities, often fortuitously. In this contribution we list and provide faunistic and ecological information on twenty three species of exotic arthropods recently de-

tected in the Azores, highlighting the potential impacts they may cause to the native habitats or agriculture and suggest strategies to prevent further species introductions.

MATERIAL AND METHODS

No particular standardized methodology was followed to capture most of the specimens of the species listed. However, for some of them several standardized methodologies were used during different multi annual surveys, namely pitfall, Berlese-Tullgreen, sweeping, suction.

Once collected, they were preserved in alcohol and transferred to the Azores University (Angra do Heroísmo, Terceira, Azores) for identification. For uncertain cases, some photos or specimens were sent to experts for confirmation or identification of the species.

All specimens are deposited in the Entomological Collection Dalberto Teixeira Pombo, University of the Azores, under the curation of Paulo A. V. Borges (pborges@uac.pt).

RESULTS

ARANEAE

Corinnidae

Liophrurillus flavitarsis (Lucas, 1846) (Fig. 1)

Santa Maria: Anjos, VIII.2009, 5 specs., José Marcelino & António Soares leg.

Liophrurillus flavitarsis (“Aranha-formigueira-de-tarsos-pálidos”) is a southern European ant mimic (myrmecomorphic) spider. It has a diurnal activity, has the ant *Aphaenogaster senilis* Mayr, 1853 as model, and feeds on small invertebrates found in the same habitat as the ant species previously referred to (Pekár & Jarab 2011). This first record of the species from the Azores originates from forests of introduced *Pittosporum undulatum* on Santa Maria.

Phrurolinillus lisboensis Wunderlich, 1995 (Fig. 2)

Terceira: São Miguel Arcanjo, VIII.2009, 3 specs., José A.P. Marcelino & António Onofre Soares leg.

Phrurolinillus lisboensis (“Aranha-formigueira-lisbonense”) is also an ant mimic spider, but endemic to the Iberian Peninsula (Wunderlich 1995). The species is a new record for the Azores and was found on pasture-land of Terceira Island at low altitude (150 m).

Zoropsidae

Zoropsis spinimana (Dufour, 1820) (Fig. 3)

Faial: Salão, 20.XI.2009, 5 specs., Anonymous leg.

Pico: Madalena (Sete Cidades), VIII.2009, 1 juvenile, José A.P. Marcelino & António Onofre Soares leg.; Madalena, III.2013, 1 spec., Anonymous leg.

Zoropsis spinimana is a spider native to the Mediterranean region of Europe. It does not build a web, and hunts actively during the night. It lives under barks or stones but can be found quite often indoors, in search of prey of its wide spectrum. As all Azorean spiders, *Z. spinimana* is harmless despite the body size of 12 mm. It is considered to be an invasive species in the United States, mostly in California (Griswold & Ubick 2001). This species was first recorded for the Azores by Cardoso et al. (2010b), found on Faial Island associated with agricultural land. A presumable juvenile was found in Pico Island associated with a corn plantation. An adult specimen also from Pico was sent to the University of Azores for identification in March 2013, which may indicate that the species is now spreading also in Pico Island.

Salticidae

Phidippus audax (Hentz, 1845) (Fig. 4)

Terceira: Paúl da Praia da Vitória, 10.III.2012, 1 spec., Alexandre Jacinto leg.

Phidippus audax is a bold jumping spider native to North America, including Eastern Canada and Mexico. It has also been recorded from Cuba (Edwards 2004). As most salticids, this species is a stalker hunter.

(on the right) Fig. 1 (top) The ant mimic (myrmecomorphic) spider *Liophrurillus flavitarsis* (Photo: Salvatore Canu). Fig. 2 (second from above) The ant mimic (myrmecomorphic) spider *Phrurolinillus lisboensis* (Photo: Emidio Machado, Naturdata); Fig. 3 (third from above) The spider *Zoropsis spinimana*;



Fig. 4 (below) The bold jumping spider *Phidippus audax* (Photo 3 and 4: Paulo A. V. Borges)

The majority of *P. audax* specimens are black with three white spots, while juveniles often have orange abdominal spots that turn white at maturity. These markings as well as the iridescent chelicerae (mouthparts) are the main diagnostic characteristics of the species (Edwards 1980). It was first found in Santa Maria by Dalberto Pombo, possibly between 1998 and 2004 (Cardoso et al. 2010b), and now on Terceira (Paúl da Praia da Vitória) in 2012. In both islands, populations were possibly established near airports.

ORTHOPTERA

Tetrigidae

***Paratettix meridionalis* (Rambur, 1838) (Fig. 5)**

São Miguel: Capelas, 13.III.2010, 6 specs.; Ponta Delgada, VII.2012, Nuno Bicudo da Ponte leg.

Santa Maria: Maia, 14.VIII.2012, 1 spec.; Aeroporto, Vila do Porto, 10.X.2012, 1 spec., Nuno Bicudo da Ponte leg.

Paratettix meridionalis is native to the Mediterranean region, being widespread in Southern Europe, Northern Africa, and in the east as far as Turkey and Israel (Tumbrinck 2006). It is confined to wet areas where it feeds on *Algae*. It was found for the first time in Azores (São Miguel) (Bivar de Sousa 2010) and now is recorded from Santa Maria.

Gryllidae

***Trigonnidium cicindeloides* Rambur, 1839 (Fig. 6)**

São Miguel: Ponta Delgada, 30.VIII.2011, 1 spec., Nuno Bicudo da Ponte leg.

Trigonnidium cicindeloides is a sword-tail cricket, generally black with the posterior femora and tibiae reddish. It is native to southern Europe (Mediterranean area), but occurs also on the Canary Islands, Africa, Madagascar, China, Japan and Korea (Tumbrinck 2006). It lives on vegetation near irrigation ditches and also near ponds (Olmo-Vidal 2007). This is a new record for the Azores. It was captured for the first time in Ponta Delgada (São Miguel), while flying around a spotlight during the night.

PHASMATODEA

Bacillidae

***Clonopsis gallica* (Charpentier, 1825) (Fig. 7)**

Faial: Horta, X.2006, 1 spec. André Santos leg. *Clonopsis gallica* is a polyphagous herbivorous insect native from Western Europe (France). The colour varies from light green to brown (light or dark), with a white line on the side of the abdomen (Bragg 1992). Under field conditions, *C. gallica* appears to be most commonly found feeding on *Rosaceae* (Guye 1995). It is generally considered as a pest especially in gardens (Milani et al. 2008). Females reproduce by parthenogenesis and until now no males have been found. The species was first found in São Miguel Island in 1891 by Bolivar (1894), and later on Faial (Bivar de Sousa 2010).

Phasmatidae

***Carausius morosus* (Sinéty, 1901) (Fig. 8)**

Terceira: Biscoitos, XI.2009, 1 spec.; Rua da Miragaia, Angra do Heroísmo, 8.X.2009, 1 spec.; São Bento, Praça de Touros, 8.X.2009, 1 spec.; Aeroporto das Lajes, 16.VI.2009, 1 spec., Anonymous leg.

Santa Maria: Aeroporto, III.2009, 1 spec., Jaime Bairos leg.

São Miguel: São Brás, 31.VIII.2012, 2 specs., Rui Medeiros leg.; Furnas, 23.IX.2012, 1 spec., João Pacheco leg.

Carausius morosus is a wingless stick insect native to southern India. It is a popular indoor pet insect. In the wild it lives on trees, and can feed on valuable ornamental plants. Females are green or brown, with forelegs featuring a bright red colour. The general colour varies according to temperature and humidity. Males are rare and much smaller (45-60 mm) than females (70-95 mm). Reproduction occurs mainly asexually by parthenogenesis (Headrick & Wilen 2011). Previously referred to Faial and Terceira (Bivar de Sousa 2010), it is here reported from São Miguel and Santa Maria islands, living in the wild.

HEMIPTERA

Cicadellidae

***Cicadella viridis* (Linnaeus, 1758) (Fig. 9)**

São Miguel: Ponta Delgada, 17.VII.2010, 1 spec., Nuno Bicudo da Ponte leg.; Fenais da Luz, 15.IX.2010, 3 specs., Nuno Bicudo da Ponte leg.; Água D'Alto, 6.IX.2012, > 10 specs., Carlos Medeiros leg.



Fig. 5 (above). *Paratettix meridionalis*; Fig. 6 (intermediate) The sword-tail cricket *Trigoniidium cicindeloides* (Photos: Nuno Bicudo da Ponte); Fig. 7 (below) The stick insect *Clonopsis gallica* (Photo: André Franco).



Fig. 8 (above) The stick insect *Carausius morosus* (Photo: Paulo A.V. Borges); Fig. 9 (intermediate) The leafhopper *Cicadella viridis* (Photo: Nuno Bicudo da Ponte); Fig. 10 (below) The planthopper *Siphanta acuta* (Photo: Nuno Bicudo da Ponte)

Cicadella viridis is a polyphagous Holarctic leafhopper widespread in the Old World including Europe (Young 1977). It prefers wet areas, feeding on grassy plants (e.g., *Phragmites*, *Arundo* and *Juncus*). It has been occasionally reported as a minor pest in orchards (Frediani 1956). The forewings of the female are bright turquoise green, but those of the male are much darker blue-purple and may even be blackish. This leafhopper is a new record to the Azores. It was first

spotted in Ponta Delgada (São Miguel) and a few more specimens were captured later in September 2010 at Fenais da Luz (São Miguel).

Flatidae

Siphanta acuta (Walker, 1851) (Fig. 10)

São Miguel: Fenais da Luz, 17.VI.2010, 1 spec.; Ponta Delgada, 25.XII.2011, 1 spec.; Capelas, 25.III.2012, 1 spec., Nuno Bicudo da Ponte leg.

Siphanta acuta is a planthopper native to Australia, which has now spread to Hawaii and North America, New Zealand and South Africa. It is polyphagous and is known to attack crops such as coffee, banana, citrus and guava (Zimmerman 1948), besides numerous ornamentals. While feeding, specimens secrete a viscous honeydew liquid on the plant that becomes a feeding culture for fungi and moulds. Moreover, it is possibly a vector of the Australian citrus dieback (Graça et al. 2007). This is a new record for the Azores. It was first observed in 2010 at Fenais da Luz and later on Capelas and Ponta Delgada.

Lygaeidae

Orsillus depressus (Mulsant & Rey, 1852) (Fig. 11)

Terceira: Agualva, 14.VII.2008, 2 males, 1 female and several nymphs on *Cryptomeria japonica*, leg. & coll. B. Aukema; Monte Brasil, III.2010, 1 spec., Paulo A. V. Borges leg.

Orsillus depressus is a seed-bug species native to southern Europe, and specialized in seeds from plants of the Cupressaceae family. It is not considered to be a pest. It has been collected in England for the first time in the late 1980s, and is now common in southern and central England. This species is also known from the Canary Islands (Heiss et al. 1996) (see British Bugs Online; http://www.britishbugs.org.uk/heteroptera/Lygaeidae/orsillus_depressus.html). On the Azores, specimens were found both on the north and south coasts of Terceira by Berend Aukema and Paulo Borges, being the first records for the Azores.

Oxycarenus lavaterae (Fabricius, 1787)(Fig. 12)

Terceira: Angra do Heroísmo, Santa Luzia, 5.XI.2011, 35 specs, Rui Andrade, leg.; Angra do Heroísmo, Fanal, IX.2012, >50 specs., Virgílio Vieira leg.

Oxycarenus lavaterae is a phytophagous insect native to the Western Mediterranean and is not considered to be an insect pest. Currently, it is becoming widespread in the rest of Europe, especially in Central Europe. The species has several known host plants, most of them belonging to Malvales (e.g., *Lavatera*, *Corylus*, *Tilia*). In the region of introduction most records originate from planted *Tilia cordata* trees in suburban and urban habitats (Rabitsch 2008). It is recorded as new from the Azores, where it currently can be spotted frequently in several gardens in Angra do Heroísmo (Terceira) and also on ruderal plants like *Lagunaria patersonii* (Malvaceae) (Virgílio Vieira, personal observation).

Aphanus rolandri (Linnaeus, 1758) (Fig. 13)

Terceira: Terra-Chã, III.2012, 1 spec., Paulo A. V. Borges leg.; Pico da Urze, III.2012, 5 specs., Carla Rego and Mário Boieiro leg.

Aphanus rolandri is a ground bug native to Europe, but also occurs in North Africa to the south and into Soviet Asia, Iran and Afghanistan to the east. This is a very distinctive black ground bug with a dark red or orange spot at the base of the wing membrane. Its preferred habitat is dry sparsely vegetated substrates covered with stones and dry leaf litter (Burgess 2006). It has been previously recorded from São Miguel and Faial (Ribes 2010), and in 2012 also from Terceira Island (Terra Chã and Pico da Urze).

COLEOPTERA

Carabidae

Asaphidion flavipes (Linnaeus, 1761) (Fig. 14)

São Miguel: Ponta Delgada, IV.2009, 1 spec., José Marcelino leg.; Capelas, 2.IV.2012, 1 spec., Nuno Bicudo da Ponte leg.

Asaphidion flavipes is a European ground-beetle that is also reported from the United States (Krinsky 1981). It lives on moderately shaded soil, barren in parts, often near fresh water. Adults overwinter in this habitat (Kromp 1999). It is a predator of springtails (Collembola) and aphids (Krinsky 1981). This is a new record for the Azores. The first observation of the species in the Azores dates from April 2009 in the garden of the University of the Azores, Ponta Delgada, São Miguel. It was subsequently found in Capelas (São Miguel) in 2012.

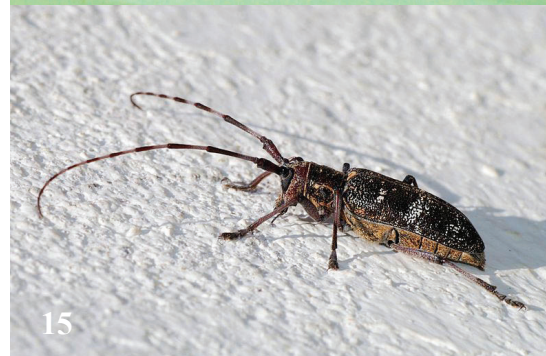


Fig. 11 (above) The seed-bug *Orsillus depressus* (Photo: Paulo A.V. Borges); Fig. 12 (intermediate) The bug *Oxycarenus lavaterae* (Photo: Paulo A.V. Borges); Fig. 13 (below) The ground bug *Aphanus rolandri* (Photo: Paulo A.V. Borges);

Fig. 14 (above) The ground-beetle *Asaphidion flavipes* (Photo: Nuno Bicudo da Ponte); Fig. 15 (intermediate) The longhorn beetle *Monochamus galloprovincialis* (Photo: Alves Gaspar; Wikipedia); Fig. 16 (below) The longhorn beetle *Acanthoderes jaspidea* (Photo: Paulo A.V. Borges)

Elateridae

Heteroderes vagus Candéze, 1893

Terceira: Outeiros, Agualva, IX.2005, 10 specs., Francisco Osvaldo Dinis leg.; Dona Joana, Feteira, VIII.2005, 13 specs., Francisco Osvaldo Dinis leg.; Via Rápida, VII.2005, 1 spec., Francisco Osvaldo Dinis leg.; Canada das Valadas, Fontinhas, VIII.2005, 2 specs., Francisco Osvaldo Dinis leg.; Canada da Ribeirinha, VII.2005, 3

specs., Francisco Osvaldo Dinis leg.; Canada do Mato, São Sebastião, VII.2005, 30 specs., Francisco Osvaldo Dinis leg.; Ribeira do Loiral, VIII.2005, 2 specs., Francisco Osvaldo Dinis leg.; Canada do Boqueirão, Vila Nova, IX.2005, 18 specs., Francisco Osvaldo Dinis leg.; Agualva, VIII.2007, 7 specs.; Lajes, VII.2008, 2 specs., Catarina Melo leg.

Heteroderes vagus is a click beetle native to

South America (Blackwelder 1944). It was found previously in Terceira and Graciosa (Platia 2010), being particularly widespread in intensively managed pastures.

Monotomidae

Rhizophagus ferrugineus (Paykull, 1800)

Terceira: Terra Brava, VII.2010, 1 spec., Paulo A. V. Borges leg.

Rhizophagus ferrugineus is a widespread beetle, found almost all over Europe. It lives in subcortical galleries of bark beetles in coniferous trees, possibly feeding on fungi (Otero 2012). It probably does not have any negative impact on the environment. It is a new record for the Azores. It was captured on Terceira in a pristine native forest dominated by *Laurus azorica* and *Ilex perado* subsp. *azorica*.

Cerambycidae

Monochamus galloprovincialis (Olivier, 1795) (Fig. 15)

Terceira: Serretinha, 15.IX.1991, 1 spec., Paulo A.V. Borges leg.

Faial: Varadouro, VIII.2011, 1 spec., Anonymous leg.

Monochamus galloprovincialis is a longhorn beetle native to Eurasia that lives on *Pinus sylvestris* and *Pinus pinaster*. It is considered to be a pest of those trees, being also a vector of the pathogenic nematode *Bursaphelenchus xylophilus* (Naves et al. 2008). This is a new record for the Azores. It was observed in 2011 in Varadouro (Faial), but there is also an older specimen from Terceira (Serretinha, 15.IX.1991) deposited at the Dalberto Pombo Insect Collection, University of the Azores.

Acanthoderes jaspidea (Germar, 1824) (Fig. 16)

Faial: Horta, 2.VII.2011, 1 spec., Frederico Cardigos leg.

Pico: Madalena (Toledos), 4.12.2009, 1 spec., Nuno Bicudo da Ponte leg.

São Jorge: Velas, 13.X.2011, 1 spec., Nuno Bicudo da Ponte leg.

Acanthoderes jaspidea is a longhorn beetle frequently associated with *Eucalyptus* forests in its native region, South America (Bernardi et al. 2011). It was previously recorded from São Miguel, Pico and Terceira (Oromí et al. 2010) and is

now found on Faial and São Jorge. This species appears to disperse over the archipelago with the transport of wood between islands.

Curculionidae

Gonipterus scutellatus Gyllenhal, 1834 (Fig. 17)

Terceira: Quinta dos Parreiras, Terra-Chã, 4.X.2007, 1 spec., 28.XI.2007, 4 specs.; Caldeira do Guilherme Moniz, 13.IX.2009, 1 spec., Paulo A. V. Borges leg.

Gonipterus scutellatus is a weevil native to Australia, commonly known as the Eucalyptus snout beetle, the Eucalyptus weevil, or the gum tree weevil. Both adult and larval (immature) stages feed on the foliage of a wide range of *Eucalyptus* species. It particularly favors *Eucalyptus globulus* and *E. viminalis*. It can be a major pest in many overseas countries in *Eucalyptus* plantations (Phillips 1992). This was first recorded for the Azores (Terceira) by Oromí et al. (2010). The two specimens collected were observed on *Erica azorica* in a native forest area (Caldeira do Guilherme Moniz) and found in a Malaise trap placed in an orchard with chestnut trees.

Lixus pulverulentus (Scopoli, 1763) (Fig. 18)

Terceira: Corpo Santo, Angra do Heroísmo, III.2009, 1 spec., Pedro Cardoso leg.; Santa Luzia, Angra do Heroísmo, 26.XI.2011, 1 spec., Paulo A. V. Borges leg.; Pico da Urze, Angra do Heroísmo, V.2012, 4 specs., Michal Reut leg.

Lixus pulverulentus is a weevil native to Eurasia, from the Iberian Peninsula to Afghanistan. It feeds and develops on *Malvaceae*. Due to its close association with mallows, it does not have a negative impact on the environment, in general, although sometimes it causes some damage to ornamentals belonging to this plant family. This is a new record for the Azores. It has been observed frequently in several locations in Angra do Heroísmo (Terceira).

DIPTERA

Dolichopodidae

Sciapus pallens (Wiedemann, 1830) (Fig. 19)

São Miguel: Capelas, 16.III.2010, 1 spec., Nuno Bicudo da Ponte leg.

Sciapus pallens is a Nearctic long-legged fly species known from Europe (from Belgium and The Netherlands in the northwest to some of the Do-

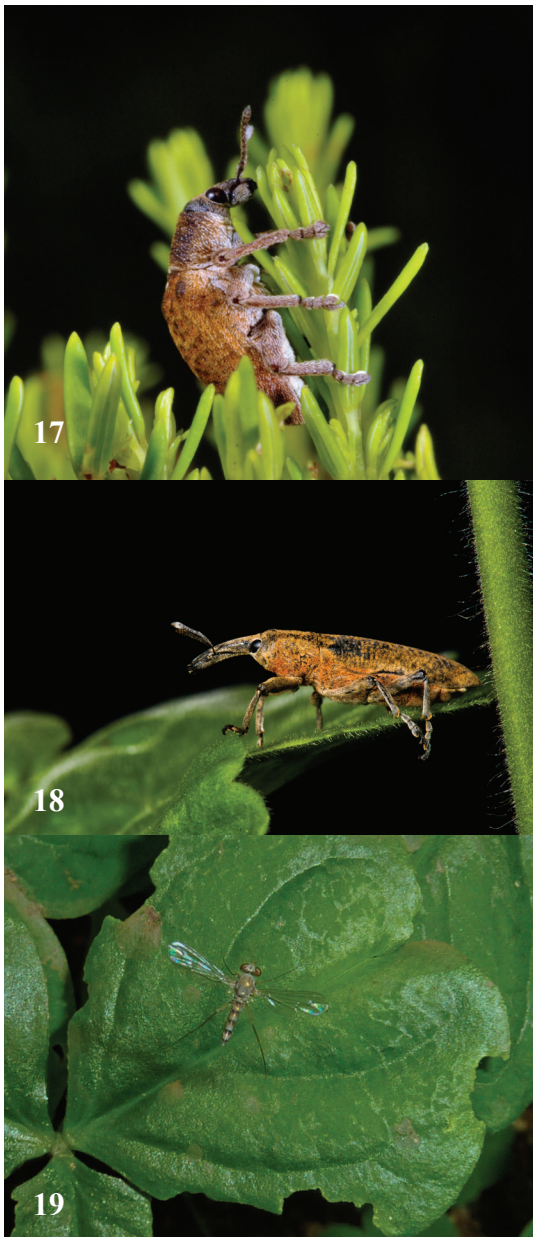


Fig. 17 (above) The Eucalyptus snout beetle *Gonipterus scutellatus* (Photo: Paulo A.V. Borges); Fig. 18 (intermediate) The snout beetle *Lixus pulverulentus* (Photo: Paulo A.V. Borges); Fig. 19 (below) The long-legged fly *Sciapus pallens* (Photo: Nuno Bicudo da Ponte)

-decane Greek islands and Israel in the southeast), including mainland Spain (Grichanov

2007; Pollet 2011) and northeastern USA (Michigan, New York, Massachusetts to Maryland, Washington DC, and North Carolina) (Steyskal 1966; Pollet et al. 2004). Its distribution pattern in North America does not indicate a recent introduction by man (Pollet et al. 2004). In Belgium and The Netherlands, this species has been collected only once and twice respectively, and all records date back from the 19th century (Pollet, unpublished data). It might be more widespread in southern Europe and has recently been collected in urban areas (even indoors) in Barcelona (Carles-Torlá 2001). Its ecology is entirely unknown. This is a new record for the Azores. It was first captured in a greenhouse in Capelas (São Miguel).

Drosophilidae

***Drosophila mercatorum* (Patterson & Wheller, 1942)**

Terceira: Pico da Urze, III.2012, 1 spec., Carla Rego leg.

Drosophila mercatorum is a generalist species (Pereira et al. 1983) feeding on decaying plant matter and fruits. It is one of the most abundant Neotropical drosophilids in areas with open vegetation in South America (Vilela et al. 1983; Tidon 2006). It is also the only Neotropical drosophilid species that reached the subcosmopolitan distribution status, since it has colonized the northern hemisphere (Nearctic and Palaearctic regions), Africa (Afrotropical Region), India (Oriental Region) and Hawaii (O'Grady & Markow 2005; Polejack & Tidon 2007). As far as we know it does not have a negative impact on the environment. It was recorded for the first time in the Azores, on Terceira, in the University Campus at Pico da Urze in March 2012.

***Drosophila immigrans* Sturtevant, 1921**

Flores: Quebradas, VI.2010, 15 specs., Carla Rego leg.

Drosophila immigrans probably originated from South Asia (Sturtevant 1921). Currently it is considered a cosmopolitan domestic species (Bächli et al. 2005) that can also be found in natural habitats. It is common near woodlands and in gardens. Like other drosophilids it feeds on decaying fruits and plant matter. Regarding its possible environ-

mental impact it appears that in an area of Madeiran Laurissilva (laurel forests) it has recently become the most common drosophilid, possibly displacing the endemic *Drosophila madeirensis*, although it is unclear if this is due to habitat degradation or actual competition for resources (Carla Rego, unpublished data). It was previously known from Terceira, Pico and São Jorge (Bächli 2010) and in 2010 it was captured for the first time in Flores in a patch of forest including both native and introduced plant species near Quebradas.

DISCUSSION AND CONCLUSIONS

Most of the introductions in the Azores listed here are beetles (Coleoptera) represented by seven species, four of which are new to the Azores. Some of them are potential pests like *M. galloprovincialis*, harmful for pines, and the vector of the pathogenic nematode *B. xylophilus* which has been associated with major losses in pine timber production in Portugal as well as other regions in Europe (Braasch 2001). In addition, *G. scutellatus*, dangerous for commercial *Eucalyptus* plantations, is also reported in the Azores. Five other new records are Hemiptera, being *S. acuta* known as a pest of a few crops. Thirteen species have their origins in Europe, two in North America, three in South America, two in Australia, and two in South Asia. Four of the species have a cosmopolitan distribution being accidentally introduced in the islands by human action: *C. morosus*, *C. gallica*, *C. viridis* and *S. acuta*. As mentioned, some of these species (*S. acuta*, *M. galloprovincialis*, *C. gallica*, *C. morosus* and *G. scutellatus*) might become pests, or vectors of pests, in the Azores.

There is no evidence so far that the newly introduced species are threatening the Azorean habitats, since they are, at present, closely associated to hosts other than the native ones. An example is *L. pulverulentus*, associated with introduced *Malvaceae*. Although research on their environmental impact was never carried out, it is possible that some species might become environmental problems in the future. Hence their distribution and range expansion should continue to be monitored.

Most recent introductions are not considered to be harmful to the local ecosystems, yet they may present potential risks. Both spiders *Z. spinimana* and *P. audax* are predators and may contribute to changes in trophic webs and the reduction of arthropod richness or may compete with native spider species. This only holds true if they become established in the same habitats as the native ones, which does not seem to be the case so far. *Drosophila immigrans* apparently has the potential to replace endemic drosophilid species in their native habitats (see above). Other species can become agricultural pests and thus harmful to the local economy or disrupt the natural habitats in the archipelago. This is the case of *C. morosus*, as well as *C. gallica* which are polyphagous herbivorous insects, feeding on a wide range of plants, mostly Rosaceae. These insects are frequently traded as pets which explains their extensive worldwide distribution. Their parthenogenetic reproduction strategy might also facilitate their dispersal. In the Azores, they may cause ecological disturbances, as was the case in Southern California (especially San Diego) and Great Britain (Headrick & Wilen 2011).

The most significant pathways for introduction of species associated with anthropogenic activity in islands are commercial cargo operations in harbours and airports passengers' luggage. Despite the fact that some information is available on these invasion pathways for several countries (Liebhold et al. 2006, 2012) and their ecological effects (Muzika & Liebhold 1997), for the Azores no data are available. However, we know that some important agricultural and urban insect pests are currently expanding their range in the Azores, having arrived to the islands through such pathways (e.g. *Popillia japonica* Newman, and the four known species of termites). The control of such introductions is very difficult. However there are some recent successful cases of the control of ants and termites after inspection of imported goods to supermarkets in the Azores (Paulo A.V. Borges, unpublished data). The current costs of these introductions for the Azorean economy are high (e.g. urban termites; Borges & Myles 2007) and demand efficient strategies to monitor their entrance through all harbours and airports to prevent their spread.

The factors causing the recent introductions are obvious. Firstly, the increase in commercial activity in the last 20 years in the Azores; secondly, the almost absence of real monitoring of introduced products and their associated fauna (e.g. food and horticultural and ornamental trade). However, there is recent legislation in the Azores about the protection of the local biodiversity that implies a better monitoring system of plant trade in harbours and airports. However, the implementation of this new law is still not perfect.

How can the introduction of exotic species be halted? As the quantity of imports to the Azores is rising continuously, a first possibility would be to increase the number of random shipment inspections of imports by the agriculture officials. A second possibility would be the improvement of the efficacy of inspection training officials to detect recognizable signs of symptoms of critical pests (e.g. termites). A third possibility is to implement mandatory fumigation (Liebhold et al. 2012), or controlled temperature techniques to eradicate potential pests during the transport and storage of commercial goods to the Azorean main ports. However, this last strategy is expensive and difficult to implement for both technical and logistical reasons. The application of quarantine measures for all imported ornamental plants will also be hard to implement (Liebhold et al. 2012). Finally, there should be a better inspection of the luggage of passengers in airports according to their origin (Liebhold et al. 2006).

A further problem in the Azores is the commercial trading and passenger movements within the archipelago. Using genetic markers, Ferreira (2011) demonstrated that the West Indian dry-wood termite *Cryptotermes brevis* (Walker) is spreading in the Azores due to the transportation of furniture among islands. *P. japonica* started its invasion in Terceira Island and is currently spreading to other islands despite the efforts to prevent it by using traps in most Azorean airports. Summing up, the Azorean biodiversity is increasing due to the introduction of exotic species and, as a result of the current patterns in the number of introductions, some severe impacts to the indigenous species and their habitats in the future is expected. As a result, financial costs to agriculture and urban environments are expected to rise.

ACKNOWLEDGEMENTS

We are very grateful to Dr. M. Wilson (U.K.), Dr. Wolfgang Rabitsch (Environment Agency Austria), Berend Aukema (The Netherlands) and Dr. Hamilton (Canada) for helpful information on some species. Thanks are also due to Henk Meuffels for providing data on Dutch Dolichopodidae. Many thanks are also due to Salvatore Canu, André Franco and Emidio Machado for providing photos of three species. The Azorean Biodiversity Group (CITA-A) also acknowledges all people that sent specimens for identification. This work was supported by a grant from the Fundo Regional Ciência e Tecnologia, Regional Government of the Azores, PROEMPREGO and the research project “PRO-BIO: Profiling Reliable Organisms as Bioindicators: an integrated approach for island systems” financed by the FLAD (Fundação Luso-Americana para o Desenvolvimento).

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- Received 9 Nov 2012. Accepted 5 Apr 2013.
Published online 6 June 2013.