Versión española

The biodiversity of terrestrial arthropods in Madeira and Selvagens archipelagos

Mário Boieiro[1,2], António Franquinho Aguiar[3], Carla Rego[1,2], Paulo A.V. Borges[1,2] & Artur R.M. Serrano[4]

[1] cE3c – Centre for Ecology, Evolution and Environmental Changes / Azorean Biodiversity Group and Universidade dos Açores - Departamento de Ciências Agrárias, 9700-042 Angra do Heroísmo, Açores, Portugal.
[2] CITA-A and Portuguese Platform for Enhancing Ecological Research & Sustainability (PEERS).
[3] Núcleo de Entomologia, Laboratório Agrícola da Madeira, 9135-372 Camacha, Madeira, Portugal.
[4] cE3c – Centre for Ecology, Evolution and Environmental Changes / Faculdade de Ciências, Universidade de Lisboa, 1749-016 Lisboa, Portugal.

1. The archipelagos of Madeira and Selvagens

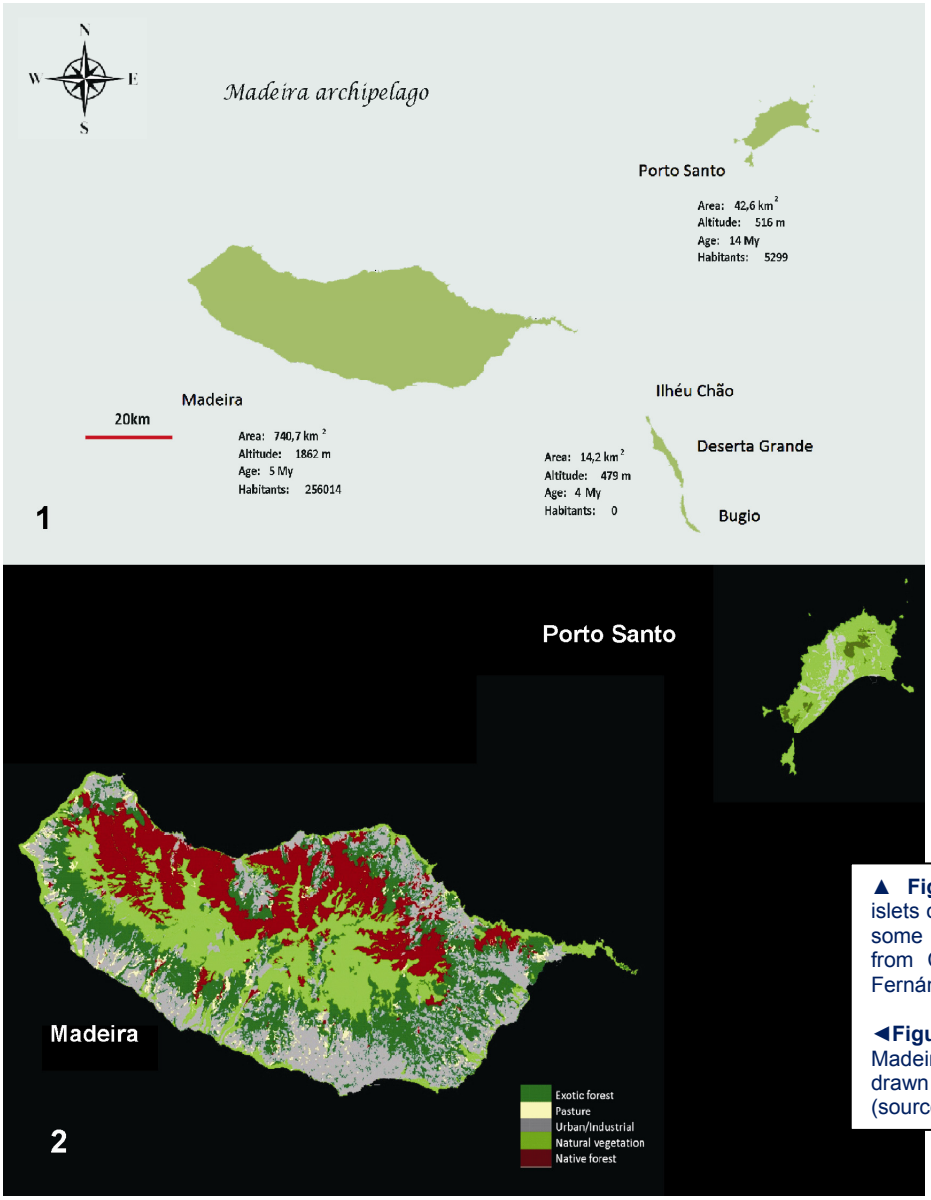
The oceanic archipelagos of Madeira and Selvagens are located in the eastern Atlantic, between 30-33ºN and 15-17ºW, being part of the Macaronesia biogeographical region.

The archipelago of Madeira is composed of Madeira Island, Porto Santo Island and its surrounding islets, and the Desertas islands, which include Deserta Grande, Bugio and Ilhéu Chão (Fig. 1). This archipelago is distanced from the Iberian Peninsula by 1000 km, but its distance to the nearest mainland (coast of Morocco) is just 600 km. All the islands of Madeira archipelago are volcanic in origin and have originated from a single volcanic building – the Madeira-Porto Santo complex.

The rugged orography and the altitudinal span of Madeira Island led to the occurrence of some natural habitat-types which are distributed along the altitudinal gradient (see Plate I). In the basal floor, coastal vegetation and scrublands are dominated by sclerophyllous, xerophytic and thermophilous shrub species, like *Euphorbia piscatoria*, *Maytenus umbellata* and *Sideroxylon mirmulans*. At intermediate altitudes, the relict native forest – the Laurisilva – covers a considerable area. This forest is dominated by tree species of the Lauraceae family, like *Apollonias barbujana*, *Laurus canariensis*, *Ocotea foetens* and *Persea indica*, together with other tree species like *Clethra arborea*, *Ilex perado* and *Morella faya*. Madeira has the largest area of Laurisilva (~15,000 ha), encompassing a fifth of the island area, and presents a large number of pristine fragments, reasons that led to its classification as a World Heritage Site by UNESCO (IUCN, 1999).

Most of the Laurisilva area is included in the Madeira Natural Park and benefits from regional, national and international legislation (Menezes *et al*., 2005a). Further, Madeira Laurisilva is a priority habitat under the Habitats Directive and was designated a Natura 2000 Network Site. The upper margin of Laurisilva and above (between 1400-1650 m) is dominated by a scrubland where two *Erica* species (*E. arborea* and *E. platycodon maderincola*) are the dominant plants. Above 1650 m, the vegetation is composed by a mosaic of three different altitudinal rupicolous communities, mostly represented by small shrub or herb species (e.g., *Aeonium glandulosum*, *Deschampsia maderensis*, *Parafestuca albida*, *Thymus micans*). In Porto Santo and Desertas, the dominant plant cover is composed by herbaceous communities, but several sclerophyllous and thermophilous tree and shrub species (like *Artemisia argentea*, *Echium nervosum, Euphorbia piscatoria*, *Jasminum odoratissimum*, *Olea europaea maderensis*) are also found in vegetation mosaics. Detailed information on the native vegetation of Madeira archipelago, particularly Laurisilva, can be found elsewhere (Neves *et al*., 1996; Capelo, 2004).

In Madeira and Porto Santo a fraction of the land surface is also covered with planted forest (Uva, 2008) (Fig. 2; Plate I). In Porto Santo, pine (*Pinus halepensis*) and cypress (*Cupressus macrocarpa*) forests were planted on mountaintops and on the southwestern tip aiming to minimize the effects of soil erosion and combat desertification. In Madeira, most of the cultivated forest is distributed throughout the south slope at low and mid altitudes and was planted mostly for economic reasons. The dominant plantations are (*Eucalyptus* spp.) and pine (*Pinus* spp.), but Acacia (*Acacia* spp.) and chestnut (*Castanea sativa*),



▲ **Figure 1.** The islands and islets of Madeira archipelago with some geographic notes (adapted from Clara Gaspar's original in Fernández-Palacios, 2010).

◄**Figure 2** . Main land uses in Madeira and Porto Santo. Maps drawn by Enésima Mendonça (source DROTA).

though more localized, are also important. In the last years, cultivated forest abandonment and the impact of the pine wood nematode are leading to significant changes in the scenario of Madeira planted forests.

Since its colonization by man, the natural plant cover of Madeira archipelago suffered a progressive destruction leading to a drastic panorama in many areas of Madeira and Porto Santo. In spite of consecutive efforts across centuries to control tree logging for timber and fuel, to stop the clearing of fields using fire and to limit the adverse effects of goats and sheep grazing, the situation has continued to worsen. It was not until the second half of the XXth century (between 1952-1974) that a major program to recover the plant cover of Madeira archipelago was carried by the Forestry Services (Andrada, 1990). This ambitious and multidisciplinary enterprise was structured in several modalities, among which the establishment of nurseries for native plants, forest restoration activities and soil protection initiatives against erosion have played a determinant role. Further, the obligation to prevent past environmental harmful practices and the growing awareness of regional/national entities and of the general public for the urgent need to value and safeguard Madeira Natural Heritage led to an increasing willingness for the establishment of a protected area in Madeira Island. Thus, in 1982, the Natural Park of Madeira was created with the aim to conserve and enhance natural and cultural heritage, promote the sustainable use of natural resources and to foster the economic and social well-being of local communities. Presently, the network of protected areas of Madeira and Selvagens archipelagos comprehend the Selvagens Islands Natural Reserve, the Madeira Natural Park, the Garajau Partial Natural Reserve, the Desertas Islands Natural Reserve, the Rocha do Navio Natural Reserve and the Network of Marine Protected Areas of Porto Santo, together with other areas included in the Natura 2000 Network (Freitas *et al*., 2004, 2011; Menezes *et al*., 2004, 2005a, 2005b; Medeiros *et al*., 2010; see also http://www.pnm.pt/).

Freshwater habitats are poorly represented in the archipelago, with the exception of Madeira Island which presents a complex hydrographic network with many streams and their subsidiaries having a very good water and habitat quality, particularly in areas near headwaters in northern Madeira. Downstream and near the mouth, most streams present a poorer water quality due to pollution (mostly organic) and physical disturbance of the environment (Hughes & Furse, 2001).

Fig. 3. The islands and islets of Selvagens archipelago with some geographic notes (adapted from Clara Gaspar's original in Fernández-Palacios, 2010).

In Madeira archipelago, the human population is over 260,000 people (DREM, 2014). Most people live in Madeira Island, particularly in the southern localities of the island where most infrastructures, industries and services are established. Only around 5,000 people have been reported from Porto Santo and most live in the capital Vila Baleira. Besides the resident human population, the archipelago of Madeira receives around a million visitors a year that come to Madeira in search of good weather and to engage in a variety of cultural activities and tours to natural habitats (e.g., bird and whale watching, mountain hiking, levada walks). During the last decade there has been massive construction in several areas of Madeira, particularly on the areas surrounding Funchal, and the network of paved roads expanded considerably leading to a higher mobility of people and goods throughout the island and the possibility to reach once inaccessible areas.

The archipelago of Selvagens is composed of Selvagem Grande, Selvagem Pequena and Ilhéu de Fora (Fig. 3) and lies 175 km north to the Canary Islands. These islands are among the oldest of Macaronesia (27 My) and represent the last stages of the island life-cycle, when islands become more flat due to erosion and tend to disappear below sea level (Fernández-Palacios & Whittaker, 2010). The vegetation of Selvagens is dominated by xerophytic and halophytic herbs and small shrubs, including some endemic plants like two subspecies of *Lobularia canariensis* and the natives *Astydamia latifolia*, *Frankenia laevis*, *Limonium papillatum, Schizogyne sericea* and *Suaeda vera*.

In spite of the attempts of colonization, the lack of potable water and the harsh environment were insurmountable obstacles for human settlement in Selvagens. Some geographic characteristics of Madeira and Selvagens archipelagos are summarized in figures 1 and 3. Further, information on these archipelagos can be found in specialized literature (see Menezes *et al*., 2004, 2005a, 2005b; Fernández-Palacios, 2010; Freitas *et al*., 2011; Ulbrich, 2014 and references therein).

2. History of the knowledge on terrestrial arthropods

The first registered visits of naturalists to the archipelago of Madeira date back to the final stages of the seventeenth century, more precisely by the British physician and naturalist Hans Sloane in 1687. Nevertheless, we know that apparently the first insect samples were only collected in 1768 during Captain James Cook first expedition which had the confidential purpose from the British Admiralty of finding the hypothetic *Terra Australis Incognita*, although other scientific activities were intended, as the study of the fauna and flora of newly discovered territories. The scientific team on board HMS Endeavour was led by the British aristocrat botanist Sir Joseph Banks (1743-1820) and the Swedish botanist Daniel Carlsson Solander (1733-1782). The team also included Herman Dietrich Spöring (1733-1771), a Finnish native and gifted instrumentalist who was put in charge of scientific equipment maintenance and of cataloguing the expedition findings.

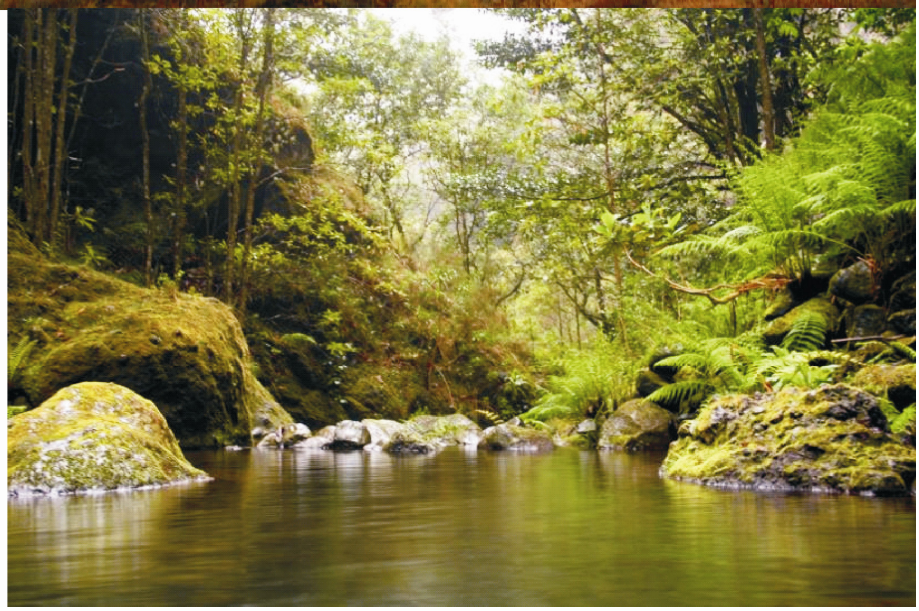
En route to Brazil and according to Banks' expedition diary, the Endeavour anchored in Funchal bay on the 12th of September. The following day Banks and Solander were welcomed by the British Consul on the island, Mr Cheap, who offered them shelter and all the resources and men to help in the island's exploration. During the next 5 days they searched for plants, shells, fishes and insects. Given the limited time available the exploration summed up to barely 3 miles surrounding Funchal and it appears that the results were somewhat disappointing given that Banks wrote in his diary that "The season of the year was undoubtedly the worst for both plants and insects".

And what about the fate of these first insect samples collected in Madeira? It is known that Johan Christian Fabricius (1745-1808), a Danish botanist and entomologist, previously a student of Carl Linnaeus, regularly visited London during summer, where he studied many entomological collections of English naturalists such as Banks and Drury. It was probably on one of these occasions that Fabricius had access to specimens of Banks' collection from Madeira and as a result he described several endemic species in his *Entomologia Systematica Emendata et Aucta*, published between 1792 and 1799, namely the satyrine butterfly *Pararge xiphia*, the beetles *Melademа lanio* and *Ellipsodes glabrata* and the ant-lion *Dystoleon catta*.

A

B

C



D

Plate I. Some habitats of Madeira archipelago: **A**. coastal vegetation at Ilhéu Chão; **B**. grassland cover in Porto Santo; **C**. grassland with interspersed shrubs at Ilhéu Chão; **D**. Laurisilva. A-C: © A.R.M. Serrano; D: C. Viveiros.

Several other naturalists visited Madeira after Banks and Solander, but it was only in the middle of the nineteenth century that the study of insects in the archipelago was given a notable advance in quantity and quality by the hand of Thomas Vernon Wollaston (1822-1878). Young Wollaston, with a degree from Cambridge and being a member of the famous *Linnean* and *Cambridge Philosophical* Societies, was 24 years old when he was diagnosed with tuberculosis. As was common at that time doctors recommended a prolonged stay in Madeira for convalescence. On his first visit to this island, from October 1847 to May 1848, Wollaston becomes friend of Reverend Richard Thomas Lowe (1822-1878) a notable British naturalist and leader of the Anglican Church in Madeira. Lowe, himself very interested in plants and molluscs, convinces Wollaston to collect insects and shells, which he does without a clear purpose, just to pass time in a remote island. The return trip to England affects his health so badly that Wollaston decides for a second stay in Madeira six months later. This time Wollaston has decided to collect insects and publish the results, and so, from November 1848 to June 1849, he does collections in Madeira, Porto Santo and Desertas. Next year he is back a third time and stays from May to September with an unstoppable enthusiasm; equipped with a tent, he sampled systematically the main island. The sheer volume of data gathered results in his majestic work *Insecta Maderensia* published in 1854, where he lists more than 500 species of Coleoptera, and three years later followed the *Catalogue of the coleopterous insects of Madeira in the collection of the British Museum,* which provides an overview of beetle species distribution in Madeira archipelago. In 1865 Wollaston publishes *Coleoptera Atlantidum*, a catalogue of all species known at the time from the archipelagos of Madeira, including the Salvage islands, and the Canary Islands. Until his early death in 1878, Wollaston visits Madeira archipelago several more times and publishes several additional books on the coleopteran fauna of other Atlantic archipelagos, namely Cape Verde (1867) and Saint Helena (1877). This impressive legacy of scientific production includes 8 books and 33 articles totalling more than 3000 pages describing more than 1000 species of beetles and other insects (Machado, 2006).

Wollaston's work was extremely important in directing the international scientific community's attention to a still under explored region with an entomological fauna promising many new species to be described. Until the end of the nineteenth century and the beginning of the twentieth many more entomologists and naturalists visited the archipelago and made important contributions, although it was only near the middle of the twentieth century that the first scientific expedition with the main purpose of collecting arthropods was organised. In 1935, between July and August, a team from the Swedish Museum of Natural History led by zoologist Carl Olov Lundblad (1890-1970), an aquatic mite specialist, sampled an enormous quantity of insects, spiders, ticks, mites and pseudoscorpions. All this material was subsequently studied by many specialists and the results were published in several volumes of the journal *Arkiv för Zoologi* between 1938 and 1958. Among the contributors, the hemipterologist William Edward China (1895-1979) authored the most complete catalogue on Madeira Terrestrial Hemiptera (China, 1938), which included also poorly studied material collected by Wollaston and deposited in the British Museum, where China was assistant keeper. Lundblad himself published an extensive list of Coleoptera and updated the knowledge on this insect group (Lundblad, 1958).

Richard Frey (1886-1965), a Finnish entomologist, together with Ragnar Storå and Carl Cedercreutz organised an expedition to Madeira and the Azores, the "Iter entomologicum et botanicum ad insulas Madeiram et Azores anno 1938". Frey, particularly interested in Diptera, published his findings, including the discovery of new species, a few years later in a paper in *Commentationes Biologicae* (Frey, 1949).

Almost two decades later, in December 1957, two members of the Royal Entomological Society, A.E. Gardner and Eric W. Classey, stayed in Madeira to collect insects. Although the time of the year was not the best for this activity, they managed to collect more than a thousand specimens from different insect groups, including series of many rare species. They published their results in 1960 and 1962 in two articles of the *Proceedings of the South London Entomological and Natural History Society*.

More or less at the same period, Håkan Lindberg, a professor at the University of Helsinki, organized two expeditions to the entire archipelago, the first in June/July 1957 and the second in April/May 1959. Most of the material collected in both expeditions was deposited in the Finnish Museum of Natural History and the results were published in at least two volumes of the *Societas Scientarum Fennica – Commentationes Biologicae,* one by Lindberg himself in 1961 totally dedicated to the Hemiptera and a second one in 1963, with 20 articles by several authors, on the Coleoptera found by the expeditions. The 1961 volume, entitled "Hemiptera Insularum Madeirensium", catalogues all the Heteroptera, Cicadomorpha and Fulgoromorpha collected during the expeditions. This volume also includes two contributions of German mirid specialist Eduard Wagner (1896-1978), one of them an extensive revision of genus *Chinacapsus* Wagner, 1961, endemic from Madeira, and genus *Lindbergocapsus* Wagner, 1961, endemic from the Canary Islands. Also based on material collected during Lindberg's expeditions, Marina Mikhailovna Loginova publishes in 1976 the first extensive account on the psyllids of Madeira. The paper "Psyllids of the Canary Islands and Madeira" lists 29 species, 20 of them as new to science.

It seems that Atlantic Islands were a sought of destination by Nordic entomologists and zoologists as in 1957 another expedition, this time Swedish, was organized by two Lund University professors, Per Brinck and Erik Dahl. These scientists stayed in the Azores between February and April and in Madeira on the second half of April. Most of the material collected in this expedition is deposited in the Zoological Museum of Lund University and an important part of the results were published in the 1960 volume of the *Boletim do Museu Municipal do Funchal*.

Between February and March 1976 the Natural History Museum of Tenerife (Spain) organized a scientific expedition, "Agamenon 76", to study the zoology, botany and geology of the Selvagens. The results were published in 1978, in a single volume of *Aula de Cultura de Tenerife*, entitled "Contribución al estudio de la Historia Natural de las Islas Salvajes".

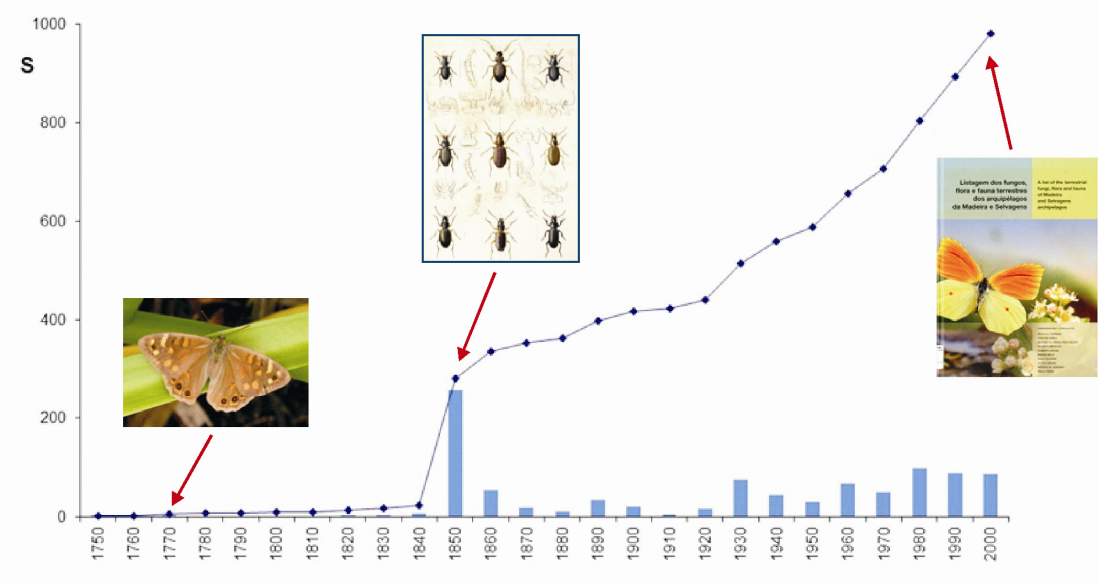


Figure 4. The description of endemic terrestrial arthropod taxa (S) of Madeira and Selvagens archipelagos per decade (bars) and its cumulative value across time (diamonds). Three landmarks are signaled in the graph: the description of one of the first endemics, *Pararge xiphia* (Fabricius, 1775); the publication of *Insecta Maderensia* by Wollaston in 1854 and the recent publication of the checklist of fauna and flora from Madeira and Selvagens archipelagos (photo by AMF Aguiar).

The eminent Portuguese aphidologist Fernando Albano Ilharco, a researcher of the National Agronomic Station (Portugal), organized two expeditions in 1966 and 1980 with financial support from the Calouste Gulbenkian Foundation. During these expeditions the main inhabited islands of Madeira and Porto Santo were visited as well as Deserta Grande on the second trip. The material collected is deposited in the National Agronomic Station and the results of the study were published in several papers in the journals *Agronomia Lusitana*, *Boletim da Sociedade Portuguesa de Entomologia* and *Boletim do Museu Municipal do Funchal.*

Also in 1980, the first multidisciplinary Portuguese scientific expedition to both Madeira and Selvagens archipelagos was organized by a team of Portuguese zoologists from the Lisbon Faculty of Sciences and from the National Museum of Natural History and Science. The so called “Zoological Mission”, was held between April and May, and was directed to sample insects and birds. Several hundreds of specimens from 15 insect orders were sampled during this expedition and the results were mainly published in the journals *Bocagiana*, *Boletim do Museu Municipal do Funchal* and *Arquivos do Museu Bocage* during the following decade. Until 1980, various taxonomic experts across Europe like Reinhard Remane, Rauno Linnavuori and Richard Strassen, received specimens for study from Madeira and have collaborated in the hard task of describing and cataloguing the terrestrial arthropod fauna of these islands.

During the following decades, both the growing interest on Madeira biodiversity and the relative ease in traveling to these islands, potentiated the visit of many taxonomic experts. As a consequence, the knowledge on the terrestrial arthropod biodiversity of Madeira increased considerably. Thus, among others, we want to highlight the extraordinary contributions made by Dieter Erber (Coleoptera), Henrik Enghoff (Diplopoda), Joerg Wunderlich (Araneae), Luis Subías (Acari), Marcos Báez (Diptera), Ole Karsholt (Lepidoptera), Volker Assing (Coleoptera) and their colleagues. Further, it should be stressed that during this period a few entomological expeditions were also carried out to Selvagens archipelago leading to new findings: a Manchester University expedition in 1984 and the scientific expedition “Macaronesia 2000”, organized by the Natural History Museum of Tenerife in 1999. The first results of this latter expedition were published in the 2001 volume of *Revista de la Academia Canaria de Ciencias*.

The description of new endemic terrestrial arthropods from Madeira and Selvagens has been relatively high since 1980, although it may seem less impressive if compared with the outstanding work of Thomas Wollaston during the 1850s (Fig. 4).

Nevertheless, only as recently as 2008 did the global knowledge on the terrestrial arthropods of the archipelagos of Madeira and Selvagens become available in one source, which lists 3891 species and subspecies. This was the result of a team effort of more than 70 entomologists coordinated by one of us (P.A.V. Borges) in a project led by the Azores University and funded by the Madeira environmental entities. The checklist of Madeira and Selvagens taxonomic biodiversity was followed by two important works where conservation priorities were identified within the context of Macaronesia aiming to simultaneously protect native species and to control invasive species (Martín *et al*., 2008; Silva *et al*., 2008). Four endemic arthropods - *Chrysolina fragariae*, *Deucalion oceanicum*, *Gonepteryx maderensis*, *Paradeucalion desertarum* - were identified as in urgent need for conservation measures in Madeira and Selvagens, and it was stressed the haste to foster population control of several noxious introduced arthropods. More recently, our team coordinated a book with contributions from 26 authors where some recent findings on Madeira and Macaronesia terrestrial arthropods were discussed and prospects for future work on biodiversity, ecological and evolutionary issues were presented (Serrano *et al*., 2010).

In the field of applied entomology, Madeira has experienced a steady sequence of biological control attempts of insect pests through the introduction of exotic predators and parasitoids. Although not always successful, these events were very important as technology transfer occurrences. In the final of 1930's, the coccinellid *Rodolia cardinalis* was locally bred in captivity to be released by the local farmers against the exotic coccid *Icerya purchasi* a serious pest of citrus on those days. The predator is still active today and the coccid populations are controlled to the point of being considered an unimportant plant pest. In the 1970's, the local Agricultural Services imported from France (Antibes Research Station – INRA) a small quantity of the eulophid parasitoid *Cales noacki* for an attempt (successful) of innoculative release against the Citrus Woolly Whitefly, *Aleurothrixus floccosus*. In the middle 1990´s, under a EU funded IPM program against several citrus insect pests, another successful introduction was made, this time from Israel: the encyrtid parasitoid *Ageniaspis citricola* was released to control the Citrus Leaf Miner, *Phyllocnistis citrella*. Some years later, downtown Funchal struggles with severe infestations of the decorative blue jacarandas by the lantana bug *Insignorthezia insignis*. It is decided to implement a new biological control program and contacts are made with the Commonwealth Agricultural Bureau International through which was imported from Kenya, in 2002, a small quantity (<200 adult specimens) of the coccinellid predator *Hyperaspis pantherina*. Part of this sample was released and the remaining specimens were used to initiate a breeding colony for mass creation. Locally-implemented changes to the breeding methodology of this coccinellid led to a 75% increase in the production of adult beetles. The new breeding facility created for this purpose remained active for 3 years and during this period more than 110,000 coccinellids were released in Funchal and its surroundings (Félix *et al*., 2004, 2005).

Perhaps the most complex and expensive program developed in Madeira against an insect pest was the application of SIT (Sterile Insect Technique) to control the Mediterranean Fruit Fly, *Ceratitis capitata*. Also funded by the EU under the Program POSEIMA/Madeira, a factory was constructed and started the production of sterilised fruit flies in 1996. The success of this technique requires a massive production of insects at relative low cost for which, at the time, this was the first and only factory in Europe with a weekly production capacity of 50 million sterilised males. This factory was the first to use a genetically improved strain of *C. capitata*, the *tsl* strain (temperature sensitive lethal), that enables the elimination of the females in the egg or neonate larva states and consequently the production of only sterilised males (Pereira, 1999). The factory stayed in production for 15 years sustaining area-wide releases in Madeira and Porto Santo islands and also exported surplus pupae to Israel and Morocco.

Finally, it is also worth mentioning that three insect groups, aquatic macroinvertebrates, ground beetles and *Drosophila* species, have also been studied with some detail from the perspectives of applied ecology and evolutionary ecology, showing the usefulness of Madeira arthropods as model organisms. Aquatic macroinvertebrates were used as bioindicators to evaluate water quality of Madeira Island streams contributing to a better understanding of the ecological integrity of the hydrographic network and leading to interesting taxonomic findings (Hughes *et al*., 1998; Hughes & Furse, 2001; Hughes, 2006). Ground beetles have been used as biodiversity and ecological bioindicators to assess the value of different Laurisilva patches for nature conservation (Serrano & Aguiar, 1997, 1998; Boieiro *et al*., 2013b). On the other hand, various genetic, ecological and ethological studies on two sister species of *Drosophila* - the endemic *D. madeirensis* and the native *D. subobscura* – have shed light on the mechanisms of species diversification and reproductive isolation in closely related species (Khadem & Krimbas, 1996; Rego *et al*., 2006).

Any entomologist engaged or interested in studying insects from these islands must be aware that presently at least four institutional insect collections exist in Madeira. In Funchal we can find the collection of the Natural History Museum of Funchal where a small selection of insects includes the public exhibition, but the main collection has limited access. The Biology Department of Madeira University located in the Penteada Campus has its own entomological collection resulting from the samples gathered in a variety of projects carried throughout the archipelago. The remains of the historical Seminary Museum collection, which resulted from the dedicated work of several priests, were recently recovered and catalogued and are now preserved in a small natural history museum housed at the Funchal Botanical Gardens. The fourth entomological collection is that of the Madeira Agricultural Laboratory, located near Camacha, which contains nearly 30,000 specimens, and in spite of its general value, is a major reference for information on species with economic impact. Other institutions, both in Continental Portugal and abroad, also have arthropod collections from Madeira and Selvagens archipelagos, including type material, that resulted from individual or collective expeditions, or were given away or sold by their owners.

3. The biodiversity of terrestrial arthropods

The archipelagos of Madeira and Selvagens, as a whole, present a considerable diversity in species and endemic life forms. The checklist of terrestrial arthropods of theses archipelagos was recently updated following a thorough survey of literature, revision of specimens from natural history collections and also included unpublished information (Borges *et al*., 2008a). This task could only be accomplished through the cooperation of many taxonomic experts and is now a major reference on the biodiversity of Madeira and Selvagens archipelagos.

The number of terrestrial arthropod taxa reported from Madeira and Selvagens archipelagos is respectively 3801 and 201, among which there is a significant number of endemics (Borges *et al*., 2008b) (see Table I; Fig. 5; Plate II). Madeira, the largest island, with a complex orography and highest number of habitat-types, clearly stands out both in species richness and in number of endemic taxa from the other islands of the two archipelagos. Nevertheless, we must also take in consideration that Madeira's biodiversity has been studied in more detail since this island has been a target for several natural history expeditions and many visits from worldwide taxonomic experts (see above section).

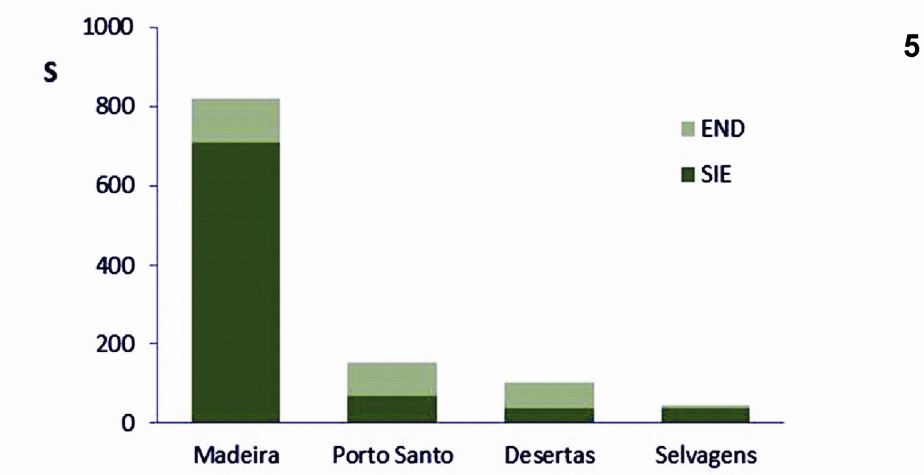
Table I. Number of terrestrial arthropod taxa from different taxonomic groups in the islands of Madeira and the Selvagens, and for both archipelagos (Total). The total number of terrestrial arthropod taxa is presented at the bottom. In specific situations, taxa were reported to Madeira archipelago without indication of the island where the collection was made.

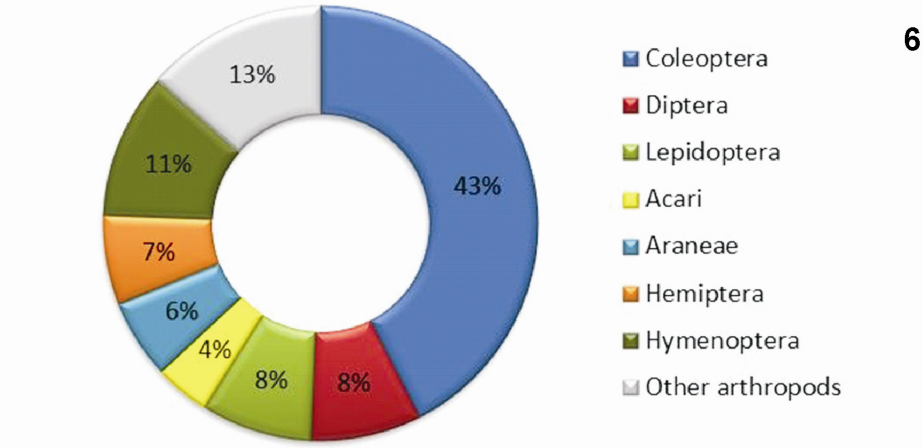
Class/Order	**Madeira**	**Porto Santo**	**Desertas**	**Selvagens**	**Total**
Arachnida	**301**	**54**	**15**	**47**	**338**
Acari: Astigmata	3	0	0	0	3
Acari: Ixodida	2	0	0	0	9
Acari: Mesostigmata	5	0	0	0	5
Acari: Oribatida	48	0	0	2	50
Acari: Prostigmata	62	0	0	0	62
Araneae	164	48	11	38	183
Opiliones	2	0	0	1	3
Pseudoscorpiones	15	6	4	6	23
Malacostraca	**50**	**3**	**2**	**1**	**57**
Maxillopoda	**4**	**0**	**0**	**0**	**4**
Ostracoda	**4**	**0**	**0**	**0**	**4**
Chilopoda	**19**	**4**	**6**	**2**	**21**
Diplopoda	**54**	**7**	**3**	**2**	**60**
Pauropoda	**10**	**0**	**0**	**0**	**10**
Symphyla	**3**	**0**	**0**	**0**	**3**
Collembola	**75**	**24**	**0**	**0**	**87**
Diplura	**1**	**0**	**0**	**0**	**1**
Protura	**9**	**0**	**0**	**0**	**9**
Insecta	**3.019**	**676**	**279**	**149**	**3.297**
Blattodea	14	2	1	0	14
Coleoptera	881	274	130	66	1040
Dermaptera	12	4	1	4	12
Diptera	538	48	16	9	555
Embioptera	1	2	2	0	2
Ephemeroptera	3	0	0	0	3
Hemiptera	481	124	47	14	522
Hymenoptera	593	28	28	9	610
Isoptera	3	0	0	0	3
Lepidoptera	315	137	26	24	331
Mantodea	1	0	0	0	1
Microcoryphia	2	1	0	0	3
Neuroptera	14	4	1	0	15
Odonata	5	5	1	2	6
Orthoptera	26	6	5	5	28
Phthiraptera	8	4	9	5	13
Psocoptera	40	6	0	4	45
Siphonaptera	6	9	1	2	11
Strepsiptera	1	0	0	0	1
Thysanoptera	57	19	10	2	62
Trichoptera	13	0	0	0	13
Zygentoma	5	3	1	3	7
Terrestrial arthropods	**3.549**	**768**	**305**	**201**	**3.891**

The terrestrial arthropod fauna of Madeira and Selvagens presents a high proportion of native taxa (68%), but the number of introduced species is already considerable and it is expected to keep rising due to the increasing transportation of people and goods from various points of the world (Pombo *et al*., 2010a). The percentage of endemic taxa is appreciable, and it is worth mentioning that many endemic taxa of Madeira and Selvagens archipelagos are single-island endemics (i. e., species restricted to just one island) or are restricted to a group of a few small islands and islets (Desertas or Selvagens) (Fig. 5). Further, there is a considerable number of native species that besides occurring in Madeira or Selvagens archipelagos can only be found in Azores and/or Canaries (i.e., they are exclusive of Macaronesia).

In spite of the high number of species reported to Madeira and Selvagens archipelagos, the current knowledge on the taxonomic biodiversity of these islands is far from complete as was stressed in a recent study (Lobo & Borges, 2010). New findings (even in well studied arthropod groups) made in the last few years confirm this assumption (Caldara & Aguín-Pombo, 2008; Donabauer, 2008; Esser, 2008; Schimmel, 2008; Serrano *et al*., 2009; Wrase, 2010; Machado, 2012; Kratochvil & Scheuchl, 2013; Crespo *et al*., 2014; Reboleira & Enghoff, 2014; Rego *et al*., 2014; Rota *et al*., 2014). So, major efforts should be endorsed to survey less explored habitats and regions, and to focus on still understudied hyperdiverse arthropod groups like Acari, Araneae, Diptera and Hymenoptera (Lobo & Borges, 2010).

Among the different groups of terrestrial arthropods recorded in Madeira and Selvagens archipelagos, the Coleoptera clearly dominate in number of species and endemics followed by Hymenoptera,





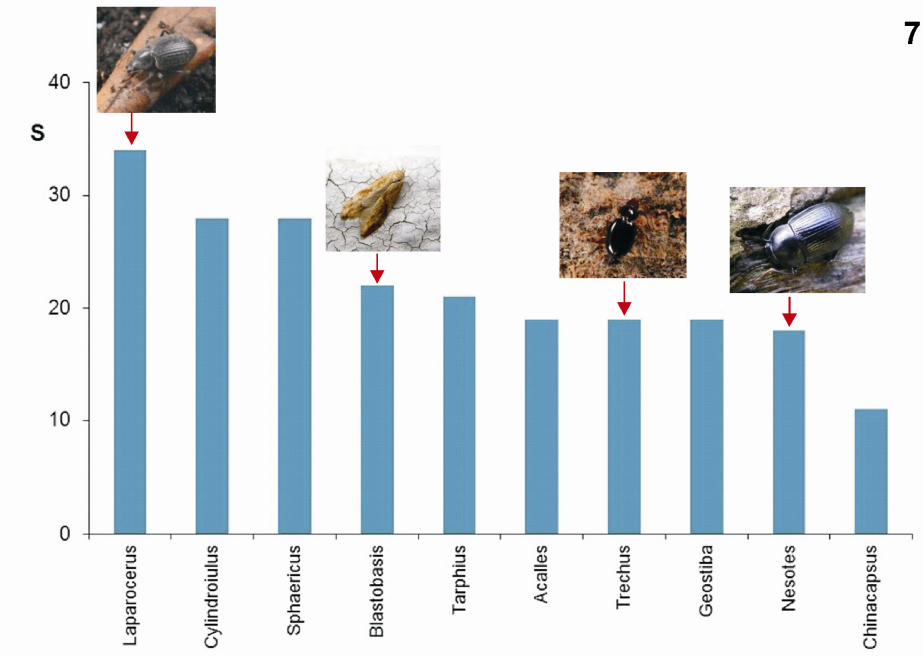


Figure 5. Number of endemic taxa of terrestrial arthropods in islands of the Madeira and Selvagens archipelagos. Endemics restricted to each island or island group (SIE) are highlighted in dark green. **Figure 6.** Proportion of endemic taxa from the different terrestrial arthropod groups. **Figure 7.** The number of endemic taxa (S) of terrestrial arthropod genera that have diversified (> 10 taxa) in Madeira and Selvagens archipelagos (photos by A.M.F. Aguiar and A.R.M. Serrano).

Plate II. Endemic arthropods of Madeira archipelago: **A**. the termite *Postelectrotermes praecox*; **B**. the mayfly *Cloeon peregrinator*; **C**. the butterfly *Hipparchia maderensis*; **D**. the bee *Amegilla maderae*; **E**. the ground beetle *Eurygnathus latreillei*; **F**. the darkling beetle *Hadrus* sp. A, C, E, F: © A.R.M. Serrano; B; © A.M.F. Aguiar; D: © C. Rego.

Diptera, Lepidoptera and Hemiptera (Table I; Fig. 6). Together these hyperdiverse insect groups represent nearly 77% of the terrestrial arthropod endemic taxa diversity, but both Araneae and Acari are also well represented.

It is important to highlight that a large fraction of Madeira and Selvagens endemics correspond to lineages that have diversified. The thirty one genera which have 5 or more endemic taxa contribute with over a third of the total endemic taxa. Among those genera, *Laparocerus, Cylindroiulus, Sphaericus*, *Tarphius, Blastobasis*, *Acalles*, *Geostiba, Trechus*, *Nesotes* and *Chinacapsus* are particularly speciose (Fig. 7). Curiously, some of these genera have also radiated in Azores (e.g., *Tarphius*, *Trechus*) and in the Canaries (e.g., *Acalles*, *Blastobasis*, *Laparocerus*, *Nesotes*, *Sphaericus*, *Tarphius*, *Trechus*) (Emerson & Oromí, 2005; Contreras-Diaz *et al*., 2007; Arechavaleta *et al*., 2010; Borges *et al*., 2010; Amorim *et al*., 2012). Other terrestrial arthropod taxa included in endemic genera, like the monotypic *Cymoptus*, *Deucalion*, *Ellipsodes*, *Esuridea*, *Eurygnathus*, *Frontiphantes*, *Macrostethus*, *Madeirostiba*, *Paradeucalion*, *Ploeosoma*, *Ramblinus*, *Rhinothripiella* and the polytypic *Chinacapsus* and *Hadrus*, represent unique evolutionary lineages that have differentiated genetically and morphologically from their ancestors or became restricted to these archipelagos.

A characteristic feature of oceanic island ecosystems is the absence of species of terrestrial arthropod groups that are well represented in the mainland. This phenomenon, designated as taxonomic disharmony, results from the obstacles faced by individuals during colonization and establishment on islands, which affect differently the set of potential colonizers. Consequently, the species/groups that succeed to establish are a small set of the potential colonizers and in the new environment they may evolve to fill vacant ecological niches. In Madeira and Selvagens archipelagos there are several terrestrial arthropod groups missing, in spite of being common in the nearest mainland. For example, there are no representatives of hesperiid butterflies and notodontid moths in these islands (Aguiar & Karsholt, 2006). Further, among others, cicindelid and lampyrid beetles, mutillid wasps, tabanid flies, and many families of aquatic insects are also lacking.

The colonization of Madeira and Selvagens archipelagos by organisms started millions years ago following island formation and is still an ongoing process. In spite of many arthropod species having a high dispersal capability being able to cover large distances by flight, many other species were passively transported by winds, sea currents or, more recently, with the aid of man (Ashmole & Ashmole, 1988; Brunton & Hurst, 1998; Edwards & Thornton, 2001; Kelly *et al*., 2001). In fact, during the last century, a high number of exotic species associated to cultivated plants as well as cosmopolitan invasive species have become established in this way in Madeira. Among the worst invasive insect species worldwide, four – the ants *Linepithema humile* and *Paratrechina longicornis*, the fly *Ceratitis capitata*, and the whitefly *Bemisia tabaci* - are already established in Madeira, but information on their ecological impact is still scarce (Pombo *et al*., 2010b). In addition, four other arthropod species reported from Madeira – the millipede *Ommatoiulus moreletti*, the woodlice *Armadillidium vulgare* and *Eluma purpurascens*, and the spider *Dysdera crocata* – were identified as invasive in Macaronesia and some principles to develop monitoring and control efforts have been outlined (Silva *et al*., 2008).

The colonization history of Madeira and Selvagens by terrestrial arthropods can only be clearly understood if we take in consideration the biogeographical history of these archipelagos and the dynamics of sea-level changes and ocean circulation since Oligocene (Fernández-Palacios *et al*., 2011). Besides the extant archipelagos of Macaronesia, other islands which are now seamounts composed the so-called Palaeo-Macaronesia. These former islands, with ages up to 60 Ma, were distributed between the present-day islands and Southwest Europe (forming the Madeiran volcanic province) and North Africa (forming the Canarian volcanic province) and seemed to have played a crucial role in the colonization of Macaronesia archipelagos by acting as stepping-stones. Thus, the routes of colonization of Madeira and the Selvagens were either via these older islands of Palaeo-Macaronesia through a stepping-stone process or directly from mainland, particularly North Africa and Southwest Europe.

Studies on island arthropods have provided crucial information for the advancement of scientific knowledge on diverse areas such as adaptation, speciation, community assembly and the impact of invasive species (Carson & Kaneshiro, 1976; O´Dowd *et al*., 2003, Whittaker & Fernández-Palacios, 2007; Serrano *et al*., 2010; Hembry *et al*., 2013). The terrestrial arthropod biodiversity of Madeira and the Selvagens is unique and includes excellent animal models that are suitable for the study of ecological and evolutionary patterns and processes that structure the diversity of life.

4. Perspectives and challenges for the knowledge and conservation of terrestrial arthropods

Oceanic islands are known to contribute disproportionately to global biodiversity since they present a high number of exclusive species for their small area. However, island ecosystems have been severely affected by today's biodiversity crisis with plenty of examples of species extinctions as a consequence of human activities (Blackburn *et al*., 2004; Régnier *et al*., 2009; Connor *et al*., 2012; Rando *et al*., 2012, 2013). In Madeira archipelago the panorama has not been much different since some species have been reported as extinct following human colonization, including the recent extinction of a butterfly – the Madeiran Large White (Pieper, 1985; Goodfriend, 1994; Gardiner, 2003; Fontaine *et al*., 2007; Rando *et al*., 2012; Fig. 8). Furthermore, other invertebrate organisms are also presumed extinct due to the lack of records for decades and the observation of drastic direct and indirect changes on their habitats (Boieiro *et al*., 2010).

The conservation of the terrestrial arthropods of Madeira and Selvagens archipelagos is a challenge that needs to be faced under multidisciplinary and interdisciplinary approaches. Important steps have been taken during the last decade to better know, protect and value the terrestrial arthropod biodiversity of these archipelagos:

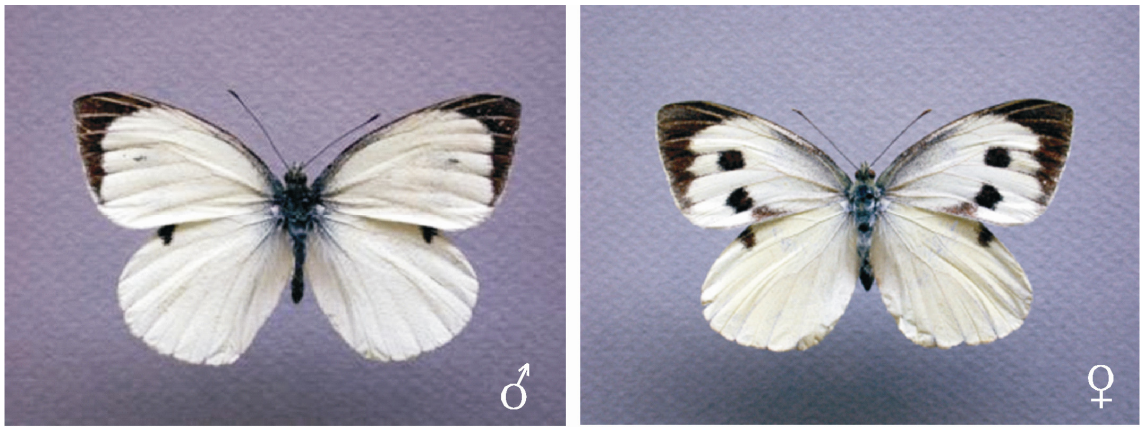


Figure 8. Male and female specimens of the extinct Madeiran Large White (*Pieris wollastoni*) (photos by A.M.F. Aguiar).

● The checklist of terrestrial arthropods has been compiled and published (Borges *et al*., 2008a,b). This impressive work is now a major reference on Madeira biodiversity by listing all extant taxa, their geographic distribution and colonization status, and by putting Madeira biodiversity in a Macaronesian and Global context. However, another merit of this work was the identification of taxonomic and geographic lacunae on the knowledge of Madeira and the Selvagens' terrestrial arthropods, which can now be progressively addressed.

The lack of knowledge on basic information about terrestrial arthropod species is a serious impediment for their effective conservation (Cardoso *et al*., 2011), thus it is crucial to have as priority the development of inventorying and monitoring programs targeting these animals.

In recent years, two projects funded by the Fundação para a Ciência e a Tecnologia (FCT projects - POCTI/BIA-BDE/59202/2004 and PTDC/BIA-BEC/099138/2008) surveyed native and man-made habitats of Madeira, Porto Santo and Desertas using standardized protocols with the aim to investigate spatial patterns and processes of diversity in spiders and ground beetles (Boieiro *et al*., 2013a, 2014). However, projects targeting other arthropod groups and habitat-types should also be carried in the short term to obtain data on species distribution and abundance since these are essential for conservation status assessment.

● Several works have highlighted the urgent need to protect some threatened terrestrial arthropods of Madeira and the Selvagens (see Plate III). A recent identification of conservation priorities in Madeira/Selvagens and Macaronesia listed four rare endemic arthropod species among the most endangered species (Martín *et al*., 2008). Further, sets of taxonomic experts have produced European red lists of selected arthropods groups where several Madeiran endemics were classified as "Threatened" or "Near Threatened" (Kalkman *et al*., 2010; Nieto & Alexander, 2010; Van Swaay *et al*., 2010). Several other works call attention to the urgent need of protection of taxa threatened of extinction, like the endemic beetle *Geostiba brancomontis* (Assing & Schülke, 2006). Recently, some authors worried about the conservation of the narrow endemic Desertas wolf spider (*Hogna ingens*) took this concern a step forward; they collected data on the abundance and distribution of this species, on its habitat characteristics and on the major threats to its survival and proposed its classification as Critically Endangered to the IUCN (Crespo *et al*., 2014).

The set of terrestrial arthropod species already recognized as in peril should be the target of action plans aiming to collect data on their biology, population status and distribution as well as to identify and control the threats to their survival. On the other hand, the development of inventorying and monitoring programs focused on terrestrial arthropods coupled with the analysis of historical records and with the advice of experts may also lead to the identification of conservation priorities among other arthropod taxa that have been neglected hitherto.

● Legal authorities are aware of the uniqueness of Madeira archipelago's natural legacy and share the general growing concern for the conservation of invertebrate organisms. In the past, despite invertebrate conservation being not a priority for regional authorities due to lack of funding and specialized human resources, there was always support from these authorities for conservation and research projects focused on this animal group. In the last few years, the Madeira Natural Park (MNP) has begun to include specific studies and conservation actions targeting endemic invertebrates (particularly endangered land snails) in the projects under its coordination. Further, mostly during the last decade, there has been an effort of invertebrate representation in MNP publications and dissemination activities. Even so, the general public remains unaware of the high relevance of terrestrial arthropods in Madeira ecosystems and there is still little perception of the reasons to protect them.

A major challenge faced by Madeira environmental authorities is thus to engage the population to value and protect the invertebrate biodiversity of Madeira and Selvagens archipelagos. Efforts have been and are being made to achieve this goal by the technical staff of the MNP and, quite recently, following a collaborative project, a book on the biodiversity of Madeira and highlighting the uniqueness of its insects and spiders has been published aimed at the general public (Boieiro *et al*., 2013b). However, there is still

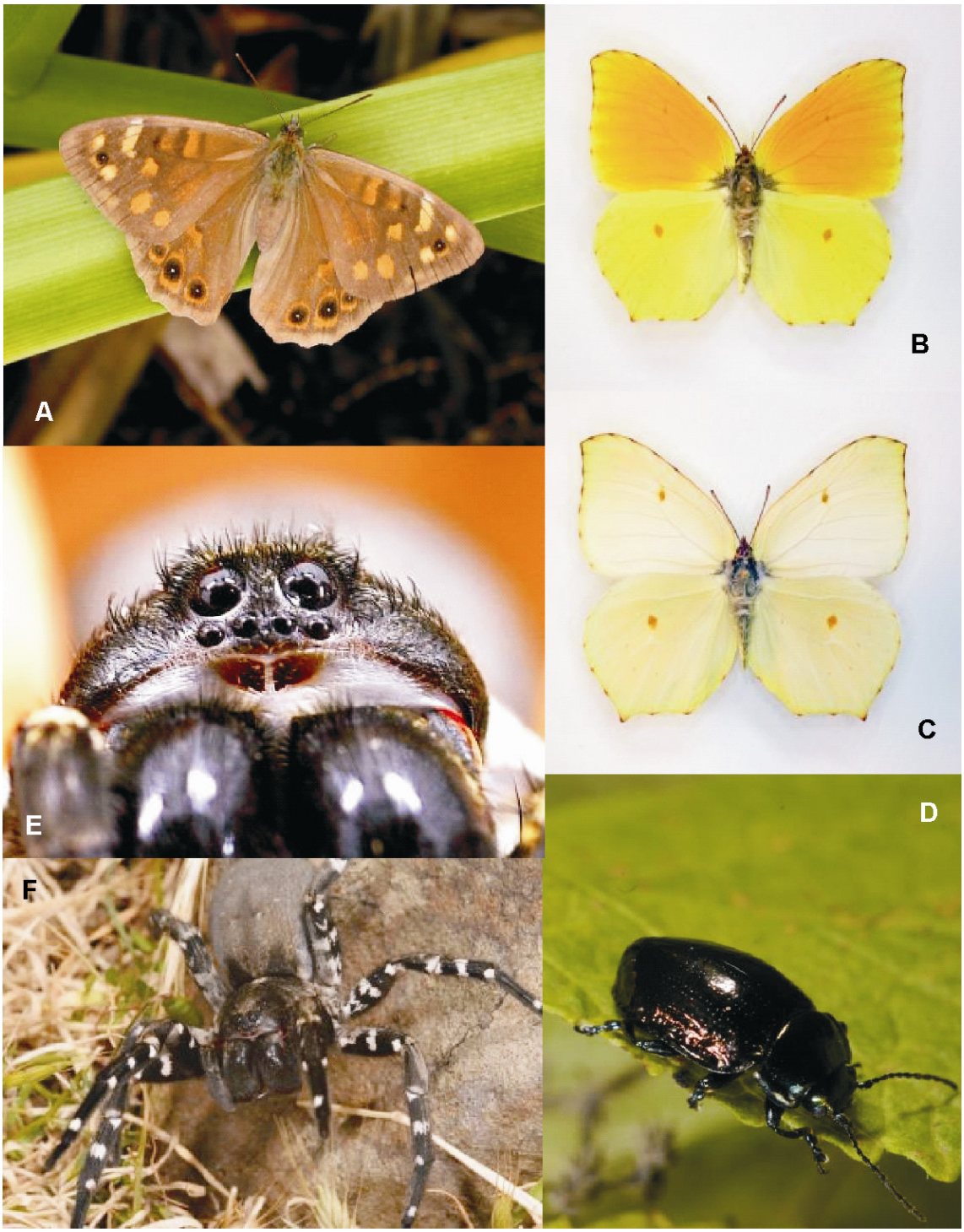


Plate III. Endangered endemic arthropods of Madeira archipelago: **A**. the butterfly *Pararge xiphia*; **B-C**: the butterfly *Gonepteryx maderensis* (**B**: male and **C**: female); **D**. the leaf beetle *Chrysolina fragariae*; **E-F**: the Desertas tarantula *Hogna ingens* (**E**: head detail and **F**: adult specimen). A-C: © A.M.F. Aguiar; D-F: © A.R.M. Serrano.

much to be done on this subject, and other national and international programs engaging the public for invertebrate conservation may also provide stimulus and guidance for future initiatives (Oberhauser & Prysby, 2008; Braschler, 2009; Braschler *et al*., 2010; New, 2010; see also https://repositorio.uac.pt/bitstream/10400.3/2377/1/Chama-lhe_Nomes.pdf; http://cita.angra.uac.pt/ficheiros/noticias/1364834635.pdf).

A critical issue that should deserve the commitment of legal entities is the development of a Madeira and Selvagens biodiversity online database. The recent approval the E-Infrastructure PORBIOTA by FCT will create an opportunity for Madeira to join the Azorean Biodiversity Portal in a national biodiversity online database. This achievement will serve the multiple purpose of:

–centralize the information on biodiversity to help conservation management and decision process;

–make public the diversity of species of the Madeira and Selvagens archipelagos to a large audience, aiming to engage people to value and protect this natural heritage;

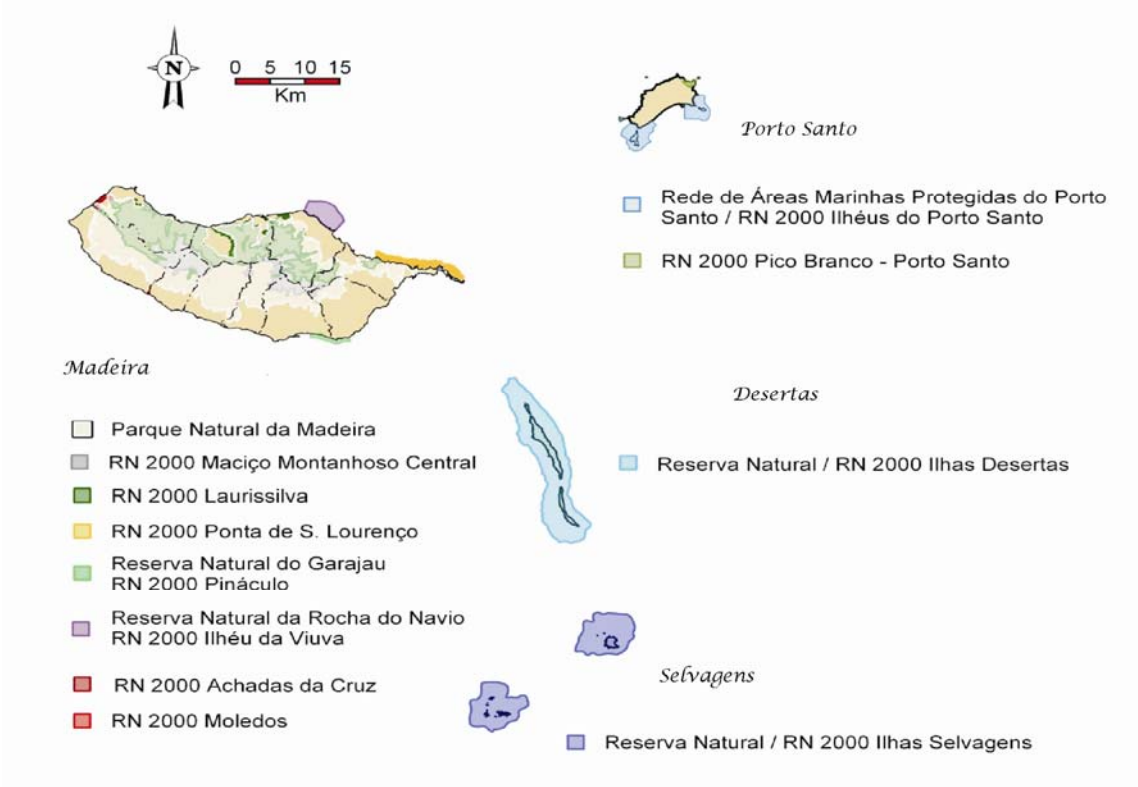


Figure 9. Protected areas of Madeira and Selvagens archipelagos, including Natura 2000 network sites (RN 2000) (adapted from http://www.pnm.pt/).

–collect, organize and make public the information dealing with Madeira biodiversity, including scientific literature and natural history collections.

Online biodiversity databases have proved to be important tools both for research and education by easily and visually providing valuable information on species identification, ecology and distribution. Further, some of them are regularly updated with interesting news and scientific data and may also provide some interaction with the general public, a key aspect in biodiversity conservation. The Azorean Biodiversity Portal online database (http://www.azoresbioportal.angra.uac.pt/) is an extraordinary example on how biodiversity databases can be very helpful for stakeholders, the scientific community and the general public by sharing different sorts of information on the Azorean animal and plant species (Borges *et al*., 2010).

The conservation of Madeira and Selvagens terrestrial arthropods is threatened by a variety of factors such as habitat destruction and fragmentation, invasive species and climate change.

Natural habitat destruction is a major cause of arthropod population extinction and has led to drastic changes in species composition in many areas of Madeira archipelago since human colonization. The growing awareness of public for nature conservation, the development of governmental and non-governmental institutions devoted to protect biodiversity and the creation of legislative instruments have been important factors when it comes to halting biodiversity loss in Madeira. Nowadays, the network of protected areas of Madeira and Selvagens archipelagos covers a large fraction of the territory (Fig. 9) and sets within its limits a number of restrictions aiming to maintain natural habitat integrity and to protect biodiversity. Nevertheless, both the creation of microreserves and the change in spatial protection category within protected areas should be considered in order to safeguard populations of endangered arthropod species.

Species introductions in Madeira and Selvagens archipelagos have had a severe impact on biodiversity, taking in consideration the changes in species composition and structure of natural communities. Despite the scarcity of data on this issue, it is known that invasive mammals and plants have impacted protected seabird species reproduction, contributed to the decline of endemic plants and affected the survival of endemic invertebrates (Oliveira *et al*., 2010; Crespo *et al*., 2014). The MNP has a large experience in the population control of invasive vertebrate and plant species in Madeira and the Selvagens archipelagos. The MNP has successfully eradicated invasive mice and rabbits from Selvagens archipelago, mice, rats, rabbits and goats from Bugio (Desertas Islands) and more recently mice, rats and rabbits from the islets of Porto Santo (Oliveira *et al*., 2010); in Madeira Island the MNP coordinates periodic campaigns for population control of invasive plants (e.g., *Ageratina adenophora*, *Carpobrotus edulis*, *Hedychium gardnerianum*, *Nicotiana glauca*, *Passiflora mollissima*, *Pittosporum undulatum*) and the nesting grounds of endangered seabirds are every year protected from the attack of feral cats and rats. Nevertheless, a considerable number of species, particularly invertebrates, arrive each year to Madeira, some of which succeed to establish and may pose a threat to environmental security, public health or local economy as it happened with the recent introductions of the mosquito *Aedes aegypti* (vector of Dengue fever) and the longhorn beetle *Monochamus galloprovincialis* (vector of the pine wilt disease) (see Plate IV). However, many invasive invertebrates have discrete, but severe impacts on natural communities by leading to extinction

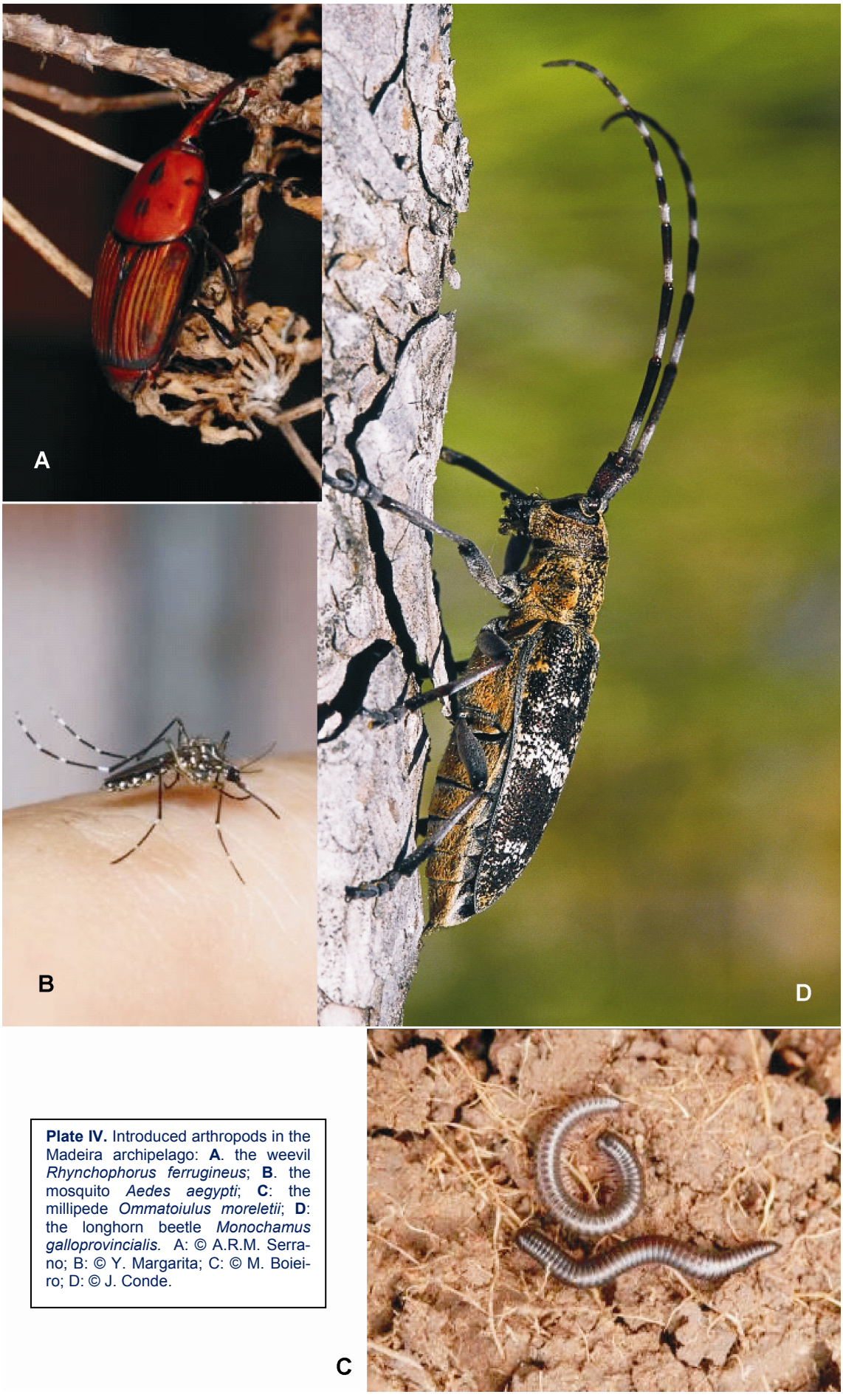


Plate IV. Introduced arthropods in the Madeira archipelago: **A**. the weevil *Rhynchophorus ferrugineus*; **B**. the mosquito *Aedes aegypti*; **C**: the millipede *Ommatoiulus moreletii*; **D**: the longhorn beetle *Monochamus galloprovincialis*. A: © A.R.M. Serrano; B: © Y. Margarita; C: © M. Boieiro; D: © J. Conde.

other invertebrates or significantly reducing their populations and having noxious effects on ecological processes (Clarke *et al*., 1984; O'Dowd *et al*., 2003; Jackson *et al*., 2014). Population control programs are mandatory for the invasive arthropod species established in Madeira and the Selvagens (Silva *et al*., 2008) and monitoring programs should be regularly carried to assess ecosystem health (i.e., identify changes in species composition and structure of natural communities) in order to evaluate in time the need to adopt specific conservation measures.

Changes in climate are expected to strongly affect oceanic islands ecosystems worldwide. In Madeira, climate change may lead to significant changes in the distribution of species and natural habitats having as a direct consequence the extinction of populations and species (Santos & Aguiar, 2006; Cruz *et al*., 2009). For example, the natural habitats of higher altitude (heathland and altitude grassland) will have a drastic reduction in area and will probably disappear from lower altitudes to become restricted to mountaintops. Presumably, sea-level will also rise (up to 60cm until 2099, according to different scenarios) leading to changes in coastal areas' habitats and threatening plant and animal populations of low altitude islets. Actions to mitigate the effects of climate change should be put forward as well as the development of adaptation strategies aiming to deal with some of the expected consequences.

The conservation of terrestrial arthropods in Madeira and Selvagens archipelagos is a daunting and urgent task that needs to be addressed as a priority goal, following a specific conservation strategy targeting this group of animals, and not as a side effect of mainstream conservation activities. The main objectives of that strategy should be clear, achievable and aimed to solve both general and specific conservation issues, some of which have been raised in the last few years and for which baseline information is available. Funding for inventorying and monitoring programs and to hire specialized personnel is a main issue here, but a solution has to be encountered.

The conservation strategy of Madeira and the Selvagens' terrestrial arthropods should pursue the involvement of the scientific community, stakeholders and the general public and develop several guidelines to:

–improve the knowledge on the terrestrial arthropod species (by data collection, analysis and management);

–identify, prioritize and protect the most vulnerable species and natural habitats (by data collection, analysis and modelling, decision-making, legislative initiatives and wildlife protection activities)

–make public the unique terrestrial arthropod biodiversity and engage the public to value and safeguard Madeira Natural Heritage (by providing appealing information online and on paper and digital formats, organizing conferences and exhibitions, developing environmental education programs in collaboration with schools).

Madeira and Selvagens archipelagos have a unique biodiversity, recognized worldwide and identified as part of a Global Biodiversity Hotspot, where terrestrial arthropods play an important role due to their richness in species and endemics, but also considering their evolutionary history and their ecological role in natural ecosystems. The growing knowledge we have on the abundance, distribution and ecology of terrestrial arthropods together with the information on the threats to their survival has highlighted the need to develop a conservation strategy targeting this animal group as a way to prevent biodiversity loss in the today's fast changing and relatively vulnerable environment of oceanic islands.

5. Acknowledgments

The authors want to thank Enésima Mendonça and Clara Gaspar for their help in providing the maps and to Dília Menezes for the informations concerning the conservation activities developed by the Madeira Natural Park. Carlos Viveiros, José Conde and Ysabel Margarita kindly allowed us to use their photos. We also thank the financial support provided by Fundação para a Ciência e a Tecnologia (FCT, Portugal) through grants SFRH/BPD/91357/2012 (to C. Rego) and SFRH/BPD/86215/2012 (to M. Boieiro).

6 Recommended bibliography

AGUIAR, A.M.F. & O. KARSHOLT 2006. Systematic catalogue of the entomofauna of the Madeira archipelago and Selvagens islands. Lepidoptera Vol. 1. *Boletim do Museu Municipal do Funchal (História Natural)* Suppl., **9**: 5-139. http://publications.cm-funchal.pt/bitstream/100/1409/1/Bolmmf_s09_2006_pp005-140.pdf

AMORIM, I., B.C. EMERSON, P.A.V. BORGES & R.K. WAYNE 2012. Phylogeography and molecular phylogeny of Macaronesian island *Tarphius* (Coleoptera: Zopheridae): why so few species in the Azores? *Journal of Biogeography*, **39**: 1583-1595. http://cita.angra.uac.pt/ficheiros/projectos/5_1355677776.pdf

ANDRADA, E.C. 1990. *Repovoamento florestal no arquipélago da Madeira (1952-1975).* Ministério da Agricultura, Pescas e Alimentação, Lisboa.

ARECHAVALETA, M., S. RODRÍGUEZ, N. ZURITA & A. GARCÍA (Eds.) 2009. *Lista de especies silvestres de Canarias (hongos, plantas y animales terrestres).* Gobierno de Canarias, Tenerife. http://www.gobiernodecanarias.org/medioambiente/piac/descargas/Biodiversidad/Listas-Especies/Lista_Especies_Silvestres.pdf

ASHMOLE, N.P. & M.J. ASHMOLE 1988. Insect dispersal on Tenerife, Canary Islands: high altitude fallout and seaward drift. *Arctic and Alpine Research,* **20**: 1-12.

ASSING, V. & M. SCHÜLKE 2006. *Systematic catalogue of the entomofauna of the Madeira Archipelago and Selvagens Islands. Staphylinoidea, Staphylinidae (Coleoptera).* Supl. 11, 167 pp. http://publications.cm-funchal.pt/bitstream/100/1407/1/Bolmmf_s11_2006_pp005-168.pdf

BLACKBURN, T.M., P. CASSEY, R.P. DUNCAN, K.L. EVANS & K.J. GASTON 2004. Avian extinction and mammalian introductions on oceanic islands. *Science,* **305**: 1955-1958.

BOIEIRO, M., D. MENEZES, C. REGO & A.R.M. SERRANO 2010. Spatial patterns of endemism and the conservation of beetles (Carabidae and Staphylinidae) in Madeira Island. In: Serrano, A.R.M., Borges, P.A.V., Boieiro, M. & P. Oromí (Eds.) (2010). *Terrestrial arthropods of Macaronesia – biodiversity, ecology and evolution*. Sociedade Portuguesa de Entomologia, Lisboa, Pp. 115-132. http://cita.angra.uac.pt/ficheiros/publicacoes/1310498562.pdf

BOIEIRO, M., J.C. CARVALHO, P. CARDOSO, C.A.S. AGUIAR, C. REGO, I. FARIA E SILVA, I.R. AMORIM, F. PEREIRA, E.B. AZEVEDO, P.A.V. BORGES & A.R.M. SERRANO 2013a. Spatial factors play a major role as determinants of endemic ground Beetle Beta diversity of Madeira Island Laurisilva. *Plos One*, **8**(5): e64591. http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0064591

BOIEIRO, M., A.F. AGUIAR, C.A.S. AGUIAR, P.A.V. BORGES, P. CARDOSO, L. CRESPO, D. MENEZES, F. PEREIRA, C. REGO, I. SILVA, P.M. SILVA & A.R.M. SERRANO 2013b. *Madeira, the biodiversity pearl - valuing the native habitats and endemic life forms*. Sociedade Portuguesa de Entomologia, Lisboa, 80 pp.

BOIEIRO, M., A. AGUIAR, C. AGUIAR, P.A.V. BORGES, P. CARDOSO, L. CRESPO, A. FARINHA, J. HORTAL, P.M. SILVA, D. MENEZES, C. PALMA, F. PEREIRA, C. REGO, P.R. SILVA, A.M.C. SANTOS, I. SILVA, J.P. SOUSA, A.R.M. SERRANO, C. PRADO & E. CASTRO 2014. Conflito entre actividades humanas e a conservação de endemismos insulares numa área de elevada biodiversidade à escala mundial. *Ecologi@*, **7**: 85-88. http://speco.fc.ul.pt/revistaecologia_7_art_2_11.pdf

BORGES, P.A.V., C. ABREU, A.M.F. AGUIAR, P. CARVALHO, R. JARDIM, I. MELO, P. OLIVEIRA, C. SÉRGIO, A.R.M. SERRANO & P. VIEIRA (Eds.) 2008a. *A list of the terrestrial fungi, flora and fauna of Madeira and Selvagens archipelagos*. Direcção Regional do Ambiente da Madeira and Universidade dos Açores, Funchal and Angra do Heroísmo. 438 pp. http://cita.angra.uac.pt/ficheiros/publicacoes/1258117277.pdf

BORGES, P.A.V., A.M.F. AGUIAR, M. BOIEIRO, M. CARLES-TOLRÁ & A.R.M. SERRANO 2008b. List of arthropods (Arthropoda). In: Borges, P.A.V., Abreu, C., Aguiar, A.M.F., Carvalho, P., Jardim, R., Melo, I., Oliveira, P., Sérgio, C., Serrano, A.R.M. & P. Vieira (Eds). *A list of the terrestrial fungi, flora and fauna of Madeira and Selvagens archipelagos.* Direcção Regional do Ambiente da Madeira and Universidade dos Açores, Funchal and Angra do Heroísmo. http://cita.angra.uac.pt/ficheiros/publicacoes/1258375719.pdf

BORGES, P.A.V., A. COSTA, R. CUNHA, R. GABRIEL, V. GONÇALVES, A. FRIAS MARTINS, I. MELO, M. PARENTE, P. RAPOSEIRO, P. RODRIGUES, R. SERRÃO SANTOS, L. SILVA, P. VIEIRA & V. VIEIRA 2010a. *Listagem dos organismos terrestres e marinhos dos Açores*. Princípia Editora, Lda. 429 pp. http://www.azoresbioportal.angra.uac.pt/files/publicacoes_Listagem_ml.pdf

BORGES, P.A.V., R. GABRIEL, A. ARROZ, A. COSTA, R. CUNHA, L. SILVA, E. MENDONÇA, A.F. MARTINS, F. REIS & P. CARDOSO 2010b. The Azorean Biodiversity Portal: an internet database for regional biodiversity outreach. *Systematics and Biodiversity*, **8**: 423-434. https://repositorio.uac.pt/bitstream/10400.3/1709/1/P118_Borges2010_Portal.pdf

BRASCHLER, B. 2009. Successfully implementing a citizen-scientist approach to invertebrate monitoring in a resource-poor country. *BioScience*, **59**: 103-104. http://www.bioone.org/doi/pdf/10.1525/bio.2009.59.2.2

BRASCHLER, B., K. MAHOOD, N. KARENYI, K.J. GASTON & S.L. CHOWN 2010. Realizing a synergy between research and education: how participation in ant monitoring helps raise biodiversity awareness in a resource-poor country. *Journal of Insect Conservation*, **14**: 19-30.

BRUNTON, C.F.A. & G.D.D. HURST 1998. Mitochondrial DNA phylogeny of Brimstone butterflies (genus *Gonepteryx*) from the Canary Islands and Madeira. *Biological Journal of the Linnean Society,* **63**: 69-79.

CALDARA R. & D. AGUÍN-POMBO 2008. A new synonym and new records of Tychiini (Coleoptera, Curculionidae) from Madeira Archipelago and Selvagens Islands. *Zootaxa*, **1781**: 63-66.

CAPELO, J. 2004. A paisagem vegetal da ilha da Madeira. *Quercetea*, **6**: 3-200.

CARDOSO, P, T.L. ERWIN, P.A.V. BORGES & T.R. NEW 2011. The seven impedements in invertebrate conservation and how to overcome them. *Biological Conservation,* **144**: 2647-2655. http://cita.angra.uac.pt/ficheiros/noticias/1318530000.pdf

CARSON, H.L. & K.Y. KANESHIRO 1976. *Drosophila* of Hawaii - systematics and ecological genetics. *Annual Review of Ecology and Systematics,* **7**: 311-345.

CHINA, W.E. 1938. Arthropodenfauna von Madeira nach den Ergebnissen der Reise von Prof. Dr. O. Lundblad 1935. III. Terrestrial Hemiptera. *Arkiv för Zoologi*, **30**: 1-68.

CLARKE, B., J. MURRAY & M.S. JOHNSON 1984. The Extinction of Endemic Species by a Program of Biological Control. *Pacific Science,* **38**: 97-104. http://scholarspace.manoa.hawaii.edu/bitstream/handle/10125/844/v38n2-97-104.pdf

CONNOR, S.E., J.F.N. VAN LEEUWEN, T.M. RITTENOUR, W.O. VAN DER KNAAP, B. AMMANN & S. BJÖRCK 2012. The ecological impact of oceanic island colonization – a palaeoecological perspective from the Azores. *Journal of Biogeography*, **39**: 1007-1023.

CONTRERAS-DIAZ, H.G., O. MOYA, P. OROMI & C. JUAN 2007. Evolution and diversification of the forest and hypogean ground-beetle genus *Trechus* in the Canary Islands. *Molecular Phylogenetics and Evolution,* **42**: 687-699.

CRESPO, L.C., M. BOIEIRO, P. CARDOSO, C.A.S. AGUIAR, I.R. AMORIM, C. BARRINHA, P.A.V. BORGES, D. MENEZES, F. PEREIRA, C. REGO, S. RIBEIRO, I.F. SILVA & A.R.M. SERRANO 2014. Spatial distribution of Madeira Island Laurisilva endemic spiders (Arachnida: Araneae). *Biodiversity Data Journal,* **2**, e1051, 1-60. http://biodiversitydatajournal.com/browse_journal_articles?journal_id=1

CRUZ, M.J., R. AGUIAR, A. CORREIA, T. TAVARES, J.S. PEREIRA & F.D. SANTOS 2009. Impact of climate change on the terrestrial ecosystems of Madeira. *International Journal of Design & Nature and Ecodynamics,* **4**: 1-10.

DONABAUER, M. 2008. Zwei neue Arten der Gattungen *Nesorthomus* und *Eutrichopus* (Coleoptera: Carabidae: Pterostichini). *Zeitschrift Arbeitsgemeinschaft Österrreichischer Entomologen*, **60**: 117-120.

DREM 2014. *Estatísticas demográficas da Região Autónoma da Madeira*. Direção Regional de Estatística da Madeira, Funchal, Portugal. http://estatistica.gov-madeira.pt/jdownloads/Social/Populao%20e%20Condies%20Sociais/Demografia/Demografia%20%20Publicaes/pdf_-_estatsticas_demogrficas_2013.pdf

EDWARDS, J.S., & I.W.B. THORNTON 2001. Colonization of an island volcano, Long Island, Papua New Guinea, and an emergent island, Motmot, in its caldera lake. VI. the pioneer arthropod community of Motmot. *Journal of Biogeography*, **28**: 1379-1388.

EMERSON, B.C., & P. OROMÍ 2005. Diversification of the forest beetle genus *Tarphius* in the Canary Islands, and the evolutionary origins of island endemics. *Evolution*, **59**: 586-598.

ESSER, J. 2008. Systematic Catalogue of the Cryptophagidae of the Madeira Archipelago and Selvagens Islands (Coleoptera: Cucujoidea). *Mitteilungen des Internationalen Entomologischen Vereins* **33**(1-2): 31-43. http://www.orion-berlin.de/bibl/esser/51.pdf

FÉLIX, A.P., J. VASCONCELOS, C. BRAZÃO & A.M.F. AGUIAR 2004. Aspectos bioecológicos de *Hyperaspis pantherina* Fürsch (Coleoptera: Coccinellidae) predador de *Orthezia insignis* Browne (Homoptera: Ortheziidae). *Boletin Sanidad Vegetal – Plagas*, **30**(2): 347–354. http://www.magrama.gob.es/ministerio/pags/biblioteca/revistas/pdf_plagas%2FBSVP-30-02-347-354.pdf

FÉLIX, A.P., P. ROCHA, C. BRAZÃO & A.M.F. AGUIAR 2005. Criação laboratorial e aspectos morfológicos de *Hyperaspis pantherina* Fürsch (Coleoptera: Coccinellidae) predador de Orthezia insignis Browne (Homoptera: Ortheziidae). *Boletin Sanidad Vegetal – Plagas*, **31**(3): 473-481. http://www.magrama.gob.es/ministerio/pags/biblioteca/plagas/BSVP-31-04-473-481.pdf

FERNÁNDEZ-PALACIOS, J.M. 2010 The islands of Macaronesia. In: Serrano, A.R.M., Borges, P.A.V., Boieiro, M. & P. Oromí (Eds) (2010). *Terrestrial arthropods of Macaronesia – biodiversity, ecology and evolution*. Sociedade Portuguesa de Entomologia, Lisboa, Pp 1-30. http://jmferpal.webs.ull.es/Book_Chapters_files/Cap.1%20The%20islands%20of%20Macaronesia.pdf

FERNÁNDEZ-PALACIOS, J.M., L. DE NASCIMENTO, R. OTTO, J.D. DELGADO, E. GARCÍA DEL REY, J.R. ARÉVALO & R.J. WHITTAKER 2011. A reconstruction of Palaeo-Macaronesia, with particular reference to the long-term biogeography of the Atlantic island laurel forests. *Journal of Biogeography*, **38**: 226-246.

FERNÁNDEZ-PALACIOS, J.M. & R.J. WHITTAKER 2010. El ciclo de la isla. In: *Atlas de la Biodiversidad de Canarias* (ed. J.L. Martín Esquivel), pp. 18-27. Turquesa Ediciones, Santa Cruz de Tenerife. http://jmferpal.webs.ull.es/Book_Chapters_files/El%20ciclo%20de%20la%20isla%20Atlas%20de%20biodiversidad%20de%20Canarias.pdf

FONTAINE, B., *et al*. 2007. The European union's 2010 target: Putting rare species in focus. *Biological Conservation,* **139**: 167-185.

FREITAS, C., L. GOUVEIA, P. OLIVEIRA, R. PIRES & S. FONTINHA 2004. *As Reservas Marinhas da Ilha da Madeira.* Serviço do Parque Natural da Madeira. http://issuu.com/parquenaturalmadeira/docs/reservas-marinhas

FREITAS, C., C. SANTOS, C. MEDEIROS, D. MENEZES, G. MATEUS, I. FREITAS, L. GOUVEIA, M. DOMINGUES, N. JARDIM, P. OLIVEIRA, P. SEPÚLVEDA, R. PIRES & S. FONTINHA 2011. *Madeira Paraíso Natural*. Serviço do Parque Natural da Madeira. http://issuu.com/parquenaturalmadeira/docs/madeira_par_natural_2011

FREY, R. 1949. Die Dipterenfauna der Insel Madeira. *Commentationes biologicae*, **8**: 1-47.

GARDINER, B.O.C. 2003. The possible cause of extinction of *Pieris brassicae wollastoni* Butler (Lepidoptera: Pieridae). *Entomologist's Gazette,* **54**: 267-268.

GOODFRIEND, G.A., R.A.D. CAMERON & L.M. COOK 1994. Fossil evidence of recent human impact on the snail fauna of Madeira. *Journal of Biogeography,* **21**: 309-320.

HEMBRY, D.H., T. OKAMOTO, G. MCCORMACK & R.G. GILLESPIE 2013. Phytophagous insect community assembly through niche conservatism on oceanic islands. *Journal of Biogeography,* **40**: 225-235.

HUGHES, S.J. 2006. Temporal and spatial distribution patterns of larval trichoptera in madeiran streams. *Hydrobiologia,* **553**(1): 27-41.

HUGHES, S.J. & M.T. FURSE 2001 Development of a biotic score for the assessment of the ecological quality of the rivers and streams of Madeira. *Arquipelago - Life and Marine Sciences*, Supplement **2** (Part B): 19-32. http://www.db.uac.pt/pdf/fauna/5_biotic.pdf

HUGHES, S.J., M.T. FURSE, J.H. BLACKBURN & P. LANGTON 1998. A Checklist of Madeiran Freshwater Macroinvertebrates. *Boletim do Museu Municipal do Funchal,* **50**(284): 5-41. http://publications.cm-funchal.pt/bitstream/100/883/1/Bolmmf-1998-art284.pdf

IUCN 1999. The Laurisilva of Madeira (Portugal). In: *World Heritage Committee. IUCN evaluation of nominations of natural and mixed properties to the World Heritage List*. Marrakesh, pp. 93-97.

JACKSON, M., T. JONES, M. MILLIGAN, D. SHEATH, J. TAYLOR, A. ELLIS, J. ENGLAND & J. GREY 2014. Niche differentiation among invasive crayfish and their impacts on ecosystem structure and functioning. *Freshwater Biology*, **59**: 1123-1135.

KALKMAN, V.J., J.-P. BOUDOT, R. BERNARD, K.-J. CONZE, G. DE KNIJF, E. DYATLOVA, S. FERREIRA, M. JOVIĆ, J. OTT, E. RISERVATO & G. SAHLEN 2010. *European Red List of Dragonflies*. Luxembourg: Publications Office of the European Union. http://ec.europa.eu/environment/nature/conservation/species/redlist/downloads/European_dragonflies.pdf

KELLY, L.C., D.T. BILTON & S.D. RUNDLE 2001. Population structure and dispersal in the Canary Island caddisfly *Mesophylax aspersus* (Trichoptera, Limnephilidae). *Heredity,* **86**: 370-377.

KRATOCHVIL, A. & & E. SCHEUCHL 2013 *Andrena (Micrandrena) dourada* nov.sp. from Porto Santo, Madeira Archipelago, Portugal. *Linzer Biologische Beiträge,* **45**: 755-774.

LOBO, J.M. & P.A.V. BORGES 2010. The provisional status of terrestrial arthropod inventories in the macaronesian islands. In: Serrano, A.R.M., Borges, P.A.V., Boieiro, M. & P. Oromí (Eds) (2010). *Terrestrial Arthropods of Macaronesia – biodiversity, ecology and evolution.* Sociedade Portuguesa de Entomologia, Lisboa, Pp. 33-47. http://cita.angra.uac.pt/ficheiros/publicacoes/1310498271.pdf

LINDBERG, H. 1961 Hemiptera Insularum Maderensium. *Commentationes biologicae,* **24**: 1-109. http://research.amnh.org/pbi/library/0541_1.pdf

LUNDBLAD, O. 1942 Die Arthropodenfauna von Madeira nach den Ergebnissen der Reise von Prof. Dr. O. Lundblad Juli-August 1935. XXXI. Die Hydrachnellae. *Arkiv för Zoologi*, **5**: 1-121.

LUNDBLAD, O. 1958. Die Arthropodenfauna von Madeira nach den Ergebnissen der Reise von Prof. Dr. O. Lundblad Juli-August 1935. XXXV. Die Käferfauna der Insel Madeira. *Arkiv för Zoologi*, **11**: 461-524.

MACHADO, A. 2006. *T. Vernon Wollaston (1822-1878). Un entomólogo en la Macaronesia*. Taro de Tahiche: Fundación César Manrique, Canarias. http://www.fcmanrique.org/recursos/publicacion/tvernonwollaston.pdf

MACHADO, A. 2012. Two new *Tarphius* species from Macaronesia (Coleoptera, Zopheridae). *Journal of Natural History*, **46**: 637-643.

MARTÍN, J.L, M. ARECHAVALETA, P.A.V. BORGES & B. FARIA (Eds.) 2008. *TOP 100 - As cem espécies ameaçadas prioritárias em termos de gestão na Região Europeia Biogeográfica da Macaronésia*. Consejería de Medio Ambiente y Ordenación Territorial, Gobierno de Canarias, 500 pp. http://cita.angra.uac.pt/ficheiros/publicacoes/1258124693.pdf

MEDEIROS, A., C. SANTOS, D. MENEZES, L. GOUVEIA, P. OLIVEIRA & R. PIRES 2010. *Ponta de São Lourenço*. Serviço do Parque Natural da Madeira. http://issuu.com/parquenaturalmadeira/docs/livroslourenco

MENDES. L.F. 1981. Nova nota e descrições de Tisanuros (Microcoryphia e Zygentoma: Apterygota) da Macaronésia. *Arquivos do Museu Bocage*, Série A, **I**(9): 143-164.

MENEZES, D., I. FREITAS, L. GOUVEIA, M. MATEUS, M. DOMINGUES, P. OLIVEIRA & S. FONTINHA 2005a. *A floresta Laurissilva da Madeira Património Mundial*. Serviço do Parque Natural da Madeira. http://issuu.com/parquenaturalmadeira/docs/floresta-laurissilva

MENEZES, D., I. FREITAS, L. GOUVEIA, P. OLIVEIRA, R. PIRES & S. FONTINHA 2005b. *As Ilhas Desertas*. Serviço do Parque Natural da Madeira. http://issuu.com/parquenaturalmadeira/docs/ilhas-desertas

MENEZES, D., L. GOUVEIA, M. DOMINGUES, N. JARDIM, P. OLIVEIRA & S. FONTINHA 2004. *As Ilhas Selvagens*. Serviço do Parque Natural da Madeira. http://issuu.com/parquenaturalmadeira/docs/ilhas_selvagens

NEVES, H., A. VALENTE, B. FARIA, I. SILVA, J. MARQUES, N. GOUVEIA, P. SILVA & P. OLIVEIRA 1996. *Laurissilva da Madeira – caracterização quantitativa e qualitativa*. Funchal: Parque Natural da Madeira, Grafimadeira. 192 pp.

NEW, T.R. 2010. Butterfly conservation in Australia: the importance of community participation. *Journal of Insect Conservation*, **14**(3): 305-311.

NIETO, A. & K.N.A. ALEXANDER 2010. *European Red List of Saproxylic Beetles*. Luxembourg: Publications Office of the European Union. http://ec.europa.eu/environment/nature/conservation/species/redlist/downloads/European_saproxylic_beetles.pdf

OBERHAUSER, K.S. & M.D. PRYSBY 2008. Citizen science: creating a research army for conservation. *American Entomologist*, **54**(2): 103-105. http://monarchnet.uga.edu/GetInvolved/Oberhauser_and_Prysby.pdf

O´DOWD, D.J., P.T. GREEN & P.S. LAKE 2003. Invasional 'meltdown' on an oceanic island. *Ecology Letters*, **6**: 812-817.

OLIVEIRA, P., D. MENEZES, R. TROUT, A. BUCKLE, P. GERALDES & J. JESUS 2010. Successful eradication of the European rabbit (*Oryctolagus cuniculus*) and house mouse (*Mus musculus*) from the island of Selvagem Grande (Macaronesian archipelago), in the Eastern Atlantic. *Integrative Zoology,* **5**: 70-83.

PEREIRA, R. 1999. Subprograma de Luta Autocida contra *Ceratitis capitata*. In: *Contribuição para a Protecção Integrada na Ilha da Madeira*, ed JP de Carvalho, pp. 177-210. Funchal: DRA/Sec. Reg. Agr. Florestas e Pescas

PETIT, J. 2008. Madeira. In: *Climate Change and Biodiversity in the European Union Overseas Entities* (eds. J. Petit & G. Prudent), pp. 130-132. UICN, Brussels.

PIEPER, H. 1985. The fossil land birds of Madeira and Porto Santo. *Bocagiana,* **88**: 1-6. http://publications.cm-funchal.pt/bitstream/100/1477/1/Boc088-1985.pdf

POMBO, A.D., A.M.F. AGUIAR & E. NUNES 2010a. Exotic arthropods in Macaronesia: vectors, pathways, control measures and global trade. In: Serrano, A.R.M., Borges, P.A.V., Boieiro, M. & P. Oromí (Eds). *Terrestrial arthropods of Macaronesia – biodiversity, ecology and evolution.* Sociedade Portuguesa de Entomologia, Lisboa. Pp. 145-168.

POMBO, A.D., A.M.F. AGUIAR & E. NUNES 2010b. Exotic arthropods in Macaronesia: invasiveness, ecological impact and effects of climate change. In: Serrano, A.R.M., Borges, P.A.V., Boieiro, M. & P. Oromí (Eds) (2010). *Terrestrial arthropods of Macaronesia – biodiversity, ecology and evolution*. Sociedade Portuguesa de Entomologia, Lisboa, Pp. 169-196.

QUARTAU, J.A. 1981. Missão zoológica aos Arquipélagos da Madeira e das Selvagens. *Arquivos do Museu. Bocage* (Série C), **1**(1): 1-29.

REBOLEIRA, A.S.P.S. & H. ENGHOFF 2014. Insular species swarm goes underground: two new troglobiont *Cylindroiulus millipedes* from Madeira (Diplopoda: Julidae). *Zootaxa,* **3785**: 481-489.

RANDO, J., J. ALCOVER, S. OLSON & H. PIEPER 2013. A new species of extinct scops owl (Aves: Strigiformes: Strigidae: *Otus*) from São Miguel Island (Azores Archipelago, North Atlantic Ocean). *Zootaxa,* **3647**: 343-357.

RANDO, J.C., H. PIEPER, J.A. ALCOVER & S.L. OLSON 2012. A new species of extinct fossil scops owl (Aves: Strigiformes: Strigidae: Otus) from the Archipelago of Madeira (North Atlantic Ocean). *Zootaxa,* **3182**: 29-42.

RÉGNIER, C., B. FONTAINE & P. BOUCHET 2009. Not knowing, not recording, not listing: numerous unnoticed mollusk extinctions. *Conservation Biology,* **23**: 1214-1221.

REGO, C., M. BOIEIRO, Y. GONÇALVES, D. MENEZES, D. AGUIN-POMBO & R. CAPELA 2014. The drosophilids (Diptera: Drosophilidae) from a Laurisilva patch in Madeira with two new records for this Island. *Bocagiana*, **238**: 1-8. http://publications.cm-funchal.pt/bitstream/100/1658/1/Boc238-2014.pdf

ROTA, J., A. AGUIAR & O. KARSHOLT 2014. Choreutidae of Madeira: review of the known species and description of the male of *Anthophila threnodes* (Walsingham, 1910) (Lepidoptera). *Nota Lepidopterologica*, **37**: 91-103.

SANTOS, D. & R. AGUIAR (Eds.) 2006. *Impactos e medidas de adaptação às alterações climáticas no Arquipélago da Madeira* - Projecto CLIMAAT II, Direcção Regional do Ambiente da Madeira, Funchal.

SCHIMMEL, R. 2008. The genus *Coptostethus* Wollaston from the Selvage Islands, with descriptions of two new species (Coleoptera: Elateridae). *Stuttgarter Beiträge zur Naturkunde, A (Biologie), Neue Serie*, **1**: 351-355.

SERRANO, A.R.M. 1987a. Contribution à la connaissance des Coléoptères de l'archipel de Madère. I. Coleoptera: Carabidae, Dytiscidae, Hydraenidae, Hydrophilidae, Histeridae et Staphylinidae. *Boletim do Museu Municipal do Funchal,* **39**(192): 141-155. http://publications.cm-funchal.pt/bitstream/100/1166/1/Bolmmf-1987-art192.pdf

SERRANO, A.R.M. 1987b. Contribution à la connaissance des Coléoptères (Insecta, Coleoptera) de l'archipel des Sauvages. *Bocagiana,* **111**: 1-3. http://publications.cm-funchal.pt/bitstream/100/1447/1/Boc111-1987.pdf

SERRANO, A.R.M. 1988. Contribution à la connaissance des Coléoptères de l'archipel de Madère. II. Coleoptera: Cerambycidae. *Boletim do Museu Municipal do Funchal,* **40**(204): 235-238. http://publications.cm-funchal.pt/bitstream/100/1149/1/Bolmmf-1988-art204.pdf

SERRANO, A.R.M. & C.A.S. AGUIAR 1997. An approach to the ground beetles (Coleoptera, Carabidae) of two fragments of laurel forest (Madeira Island). *Portugaliae Zoologica,* **4**: 9-19.

SERRANO, A.R.M. & C.A.S. AGUIAR 1998. Diversity and habitat preference of carabid beetles (Coleoptera, Carabidae) in Encumeada de S. Vicente (Madeira). *Boletim do Museu Municipal do Funchal,* Supl. **5**: 399-408. http://publications.cm-funchal.pt/bitstream/100/900/1/Bolmmf_s05B_1998_pp399-408.pdf

SERRANO, A.R.M., C.A.S. AGUIAR, M.C. BOIEIRO, P.A.V. BORGES, C. REGO, I.R. AMORIM, S.P. RIBEIRO & F. PEREIRA 2008. A new species of *Orthomus* Chaudoir, 1838 (Coleoptera: Carabidae) from Madeira island (Macaronesia) and notes on related species. *Zootaxa,* **1972**: 20-34.

SERRANO, A.R.M., P.A.V. BORGES, M. BOIEIRO & P. OROMÍ (Eds.) 2010. *Terrestrial arthropods of Macaronesia – biodiversity, ecology and evolution.* Sociedade Portuguesa de Entomologia, Lisboa, 327 pp.

SILVA, L., E.O. LAND & J.L. RODRÍGUEZ LUENGO (Eds.) 2008. *Invasive terrestrial flora & fauna of Macaronesia. TOP 100 in Azores, Madeira and Canaries*. ARENA, Ponta Delgada, 546 pp. http://www.azoresbioportal.angra.uac.pt/files/publicacoes_Part1_Inicio.pdf

ULBRICH, H.J. 2014. *An illustrated bibliography of the Ilhas Selvagens (recorded 2000-*2014). Institutum Canarium. Special Publication 1, Wien, 157 pp. http://www.almogaren.org/ic-digital/ICDigital_Selvagens_Bibliography_2014.pdf

UVA, J.S. 2008. *IFRAM1 – 1º Inventário Florestal da Regiao Autónoma da Madeira*. Direcção Regional de Florestas, Funchal, 120 pp.

VAN SWAAY, C., A. CUTTELOD, S. COLLINS, D. MAES, M. LOPEZ MUNGUIRA, M. ŠAŠIĆ, J. SETTELE, R. VEROVNIK, T. VERSTRAEL, M. WARREN, M. WIEMERS & I. WYNHOF 2010. *European Red List of Butterflies* Luxembourg: Publications Office of the European Union. http://ec.europa.eu/environment/nature/conservation/species/redlist/downloads/European_butterflies.pdf

WHITTAKER, R.J. & J.M. FERNÁNDEZ-PALACIOS 2007. *Island biogeography: ecology, evolution, and conservation*, 2nd ed. Oxford University Press, Oxford.

WOLLASTON, T.V. 1854. *Insecta Maderensia, being an Account of the Insects of the Islands of the Madeiran Group*. London.

WOLLASTON, T.V. 1857. *Catalogue of the Coleopterous Insects of Madeira in the collection of the British Museum.* London.

WOLLASTON, T.V. 1864 *Catalogue of the coleopterous insects of the Canaries in the collection of the British Museum.* British Museum. Taylor and Francis, London, 648 pp.

WOLLASTON, T.V. 1865. *Coleoptera Atlantidum, being an enumeration of the coleopterous insects of the Madeiras, Salvages and Canaries*. London.

WOLLASTON, T.V. 1867 *Coleoptera Hesperidum, being an enumeration of the Coleopterous insects of the Cape Verde Archipelago*. London: John van Voorst, 255 pp.

WOLLASTON, T.V. 1877. *Coleoptera Sanctae Helenae*. J. van Voorst, London, 256 pp.

WRASE, D.W. 2010 A new species of genus *Zargus* Wollaston 1854 from Madeira (Coleoptera, Carabidae, Licinini). *Linzer biologische Beiträge*, **42**: 325-334.