Chapter 6

Spatial patterns of endemism and the conservation of beetles (Carabidae and Staphylinidae) in Madeira Island

Mário Boieiro, Dília Menezes, Carla Rego & Artur R. M. Serrano

Introduction

Island ecosystems have for long fascinated naturalists due to the unique habitats, plants and animals they harbour and the peculiar adaptations that some of these living beings exhibit. Many islands have a high number of exclusive species, which make them disproportional contributors to global species richness. For this reason, many islands and archipelagos worldwide are regarded as living sanctuaries.

A recent update of the fauna and flora of Madeira (Borges *et al.*, 2008a) evidentiated the rich biodiversity and the impressive number of endemic species of this island. The uniqueness of Madeiran Natural Legacy has been for long internationally recognized, but the recent inclusion of this island in the Mediterranean Basin global biodiversity hotspot (Myers *et al.*, 2000) and the integration of Madeiran Laurisilva – the emblematic native forest ecosystem – in the World Heritage List (IUCN, 1999) highlighted the value of Madeira Island for nature conservation on a global scale.

A total number of 6611 taxa have been reported for Madeira of which 1128 occur exclusively on this island (Borges *et al.*, 2008a). Unsurprisingly, the largest fraction of island endemics is composed by terrestrial arthropods, a group where endemism can also be found above the species level. Madeiran endemic terrestrial arthropods provide instructive examples of the ecological and evolutionary forces that shape island life: some genera show impressive radiations, others have long-lasting tightly coevolved interactions with their host plants and many of them exhibit peculiar morphological adaptations (e.g., flightlessness, differences in body size when compared with mainland relatives) (e.g., Darwin, 1859; Carlquist, 1974; Enghoff, this book; Percy, this book). Furthermore, many endemic arthropods play key roles

in Madeira's ecosystems by pollinating plants, recycling nutrients, improving soil fertility and providing food resources to other organisms. However, for most groups of terrestrial arthropods, basic information on endemic species distribution, abundance and ecology is still scarce and no specific conservation measures have been addressed to protect the most endangered species. This situation is particularly worrisome taking in consideration several reports on the progressive reduction of the area occupied by natural habitats, particularly Laurisilva, as a result of human activities (e.g., Silva, 1996; Menezes *et al.*, 2004; Menezes de Sequeira *et al.*, 2007) and the occurrence and spread in Madeira Island of some of the worst invasive species worldwide (Silva *et al.*, 2008). The Archipelago of Madeira was recently identified as a major hotspot of species extinction in Europe due to the high loss of invertebrate taxa (mainly gastropods) since human colonization (Fontaine *et al.*, 2007; but see Goodfriend *et al.,* 1994). Furthermore, the extreme degree of vulnerability of some endemic species has been stressed by experts, who have also predicted several extinctions in the near future, if the causes underlying their decline continue to subsist (Becker, 1992; Assing & Wunderle, 1996; Assing & Schülke, 2006). In order to halt biodiversity loss in Madeira, efforts must be addressed to improve our knowledge on the biology of endemic arthropods and on the major threats they face, as well as in the development and application of conservation policies more clearly based in scientific evidence.

The ground and rove beetles of Madeira – a brief overview

Beetles are the most diverse group of animals in Madeira Island and are by far the one with higher number of endemic life forms (Borges *et al.*, 2008b). Two of the most speciose beetle families are the Carabidae and Staphylinidae (ground and rove beetles respectively) which together comprise a third of the beetle fauna of this island. A brief description of each of these two families is presented in Box 1.

Although there were a few sporadic contributions to the knowledge of these two groups of Madeiran beetles prior to 1850, it is consensual that it was Trevor Wollaston who, with his persistent and devoted efforts, laid the foundations for the knowledge of Madeiran Coleoptera (e.g., Wollaston, 1854, 1857, 1865; see Machado, 2006 for a detailed report on the life and work of Wollaston). Besides the large number of species described and the new findings for these islands, Wollaston was meticulous and accurate in providing additional information associated with the specimens and the sampling sites. This way of proceeding was uncommon

at the time and today proves to be extremely valuable when analyzing historical records. Then, for almost a century, only sporadic contributions were made to the beetle fauna of Madeira and the general idea was that all the work had already been done by Wollaston. It was not until 1935, that a new series of intensive surveys of Madeiran beetle fauna started (see Becker, 1992 and references therein for more details) leading to new findings and successive updates of species records (Jansson, 1940; Lundblad, 1958). A renewed interest on the beetle fauna of Madeira arose in the late 80s/early 90s following the valuable contributions made by Artur Serrano and by Dieter Erber and colleagues, who greatly improved our knowledge on the distribution and ecology of many endemics (e.g., Serrano, 1987, 1988; Erber & Hinterseher, 1988; Erber, 1990; Erber & Aguiar, 1996).

BOX 1 – GROUND AND ROVE BEETLES

Ground beetles (Carabidae) are one of the largest families of beetles and usually occur with high values of species richness and relative abundance in most terrestrial ecosystems. Ground beetle species have variable size (~3-35mm) and although some species have beautiful metallic colours, most of them are black or brownish. Most ground beetles are predators that actively hunt for invertebrate prey. These beetles can be found under stones, fallen logs or beneath the bark of trees and are usually active by night. In Madeira Island 99 species have been recorded, 59 of which are endemic to the archipelago. Some genera (e.g., *Calathus*, *Orthomus*, *Trechus*) show a high number of endemics.

Rove beetles (Staphylinidae) are the second largest family of beetles worldwide and most species are easily recognized for their short elytra. Rove beetles are usually elongated or ovoid, black or brownish and show some variation in size (~2-20mm). They occur in a wide variety of terrestrial habitats and their feeding ecology is diverse, though many species are predators. From the 193 species known to occur in Madeira Island, 59 are exclusive of the archipelago. There is an endemic genus of Madeira (*Madeirostiba*) and another genus (*Geostiba*) has a high number of endemics.

Ground and rove beetles are frequently used as biondicators in studies of biodiversity and ecology.

The last 20 years proved to be extremely fruitful in what concerns the study of Madeiran ground and rove beetles: Volker Assing and colleagues staged a revolution on the knowledge

of Madeiran Staphylinidae biodiversity after describing 20 new species from this island and thoroughly revising previous records (see Assing & Schülke, 2006 and references therein). Other authors improved our knowledge on Madeiran Carabidae after providing major revisions of some of the most speciose genera and by updating species lists (Machado, 1995; Wrase & Jaeger, 1996; Lompe, 1999; Serrano & Boieiro, 2008; Serrano *et al.*, 2009). In the mean time the knowledge on the distribution and ecology of endemic taxa also increased, and for many of them distribution maps were made available (Lompe, 1999; Boieiro *et al.*, 2003; Assing & Schülke, 2006).

The distribution of endemics and the reserve network of Madeira Island

In many island ecosystems the establishment of protected areas proved to be a valuable tool in preventing biodiversity loss and ensuring the protection of native habitats. However, the selection of most of those areas was mostly based in the occurrence of emblematic plant and vertebrate species as well as the need to safeguard pristine areas of native habitats. During the last decade many studies have assessed the effectiveness of the reserves' network design in meeting specific conservation goals (e.g., the representativeness of selected taxonomic groups, endemic and rare species, or peculiar habitats) and as a consequence many recommendations have been made to improve their performance (e.g., Barnard *et al.*, 1998; Serrano, 2002; Brito & Grelle, 2004; Sólymos, 2007; Lemckert *et al.*, 2009).

In Madeira Island there is just one terrestrial protected area, the Natural Park of Madeira (NPM), which covers two-thirds of the island and encloses most of the area covered by native habitats (see Box 2). At the time of its creation the main objectives of the NPM were the protection of Madeiran native habitats and their associated biodiversity, so there was no bias for a specific species or group of living beings. Since then, the lack of basic biological information and the dispersion of the data on the distribution of endemic invertebrates together with the low resources (both human and financial) of this institution has been a serious impediment to the inclusion of this animal group as a target for specific conservation measures in Madeira. However, in the last few years the picture changed considerably with the update on the knowledge of the taxonomic biodiversity of the Madeiran Archipelago (Borges *et al.*, 2008a) and a preliminary settlement of priorities for conservation among the endemic taxa (Martín *et al.*, 2008).

BOX 2 - THE NATURAL PARK OF MADEIRA

The Natural Park of Madeira (NPM) was created in 1982 with the aim of valuing and protecting the Natural Legacy of Madeira Island. Some of the NPM's assignments concern planning and managing the territory, protect natural and cultural values, monitor ecosystem functioning and promote the sustainable use of natural resources.

This protected area comprises two thirds of the island and encloses most of the surface covered by natural habitats. The most emblematic habitat of Madeira – the Laurisilva - is almost totally included in the NPM. The Laurisilva is a relic type of laurel humid forest that originally covered the Mediterranean Basin and nowadays is restricted to Macaronesia. Madeiran Laurisilva is considered the largest surviving area of laurel forest and the best preserved of all. Many endemic species, mostly invertebrates, are exclusive of the Laurisilva. Areas of altitude (mountaintops up to 1862m and the Paúl da Serra plateau) occur at the center of the NPM. These areas show impressive landscapes with a high scenic value and also harbour a large diversity of endemic species.

Within the NPM, there are several spatial categories of protection: Integral Natural Reserve, Partial Natural Reserve, Geologic and high altitude vegetation Reserve, Protected Landscape, Rest and Silence Area, Recreational and Mountain Reserve and Transition Zone, which aim to fulfil distinct objectives (related with nature conservation and human recreation) and require compliance with specific rules. The first three designate areas of high scientific interest and are subjected to tight measures of protection.

In the last decade the NPM developed important projects related with the conservation of endemic birds, restoration of native habitats and control of invasive species (see http://www.pnm.pt/).

Endemic species distribution

The update of the distribution of the endemic ground and rove beetles was made following a thorough survey of the literature, analysis of specimens in entomological collections and identification of specimens recently collected in the framework of a scientific project. An effort was made to use all the available data on the distribution of endemic species, but we are aware that some data may be biased, incomplete and consequently interpretations should be done carefully (Hortal *et al.*, 2007; Struebig *et al.*, 2010). Four taxa were excluded from the analysis since their type localities can not be located accurately and no further findings have

been made since their formal description. Distribution data were mapped in a 1kmx1km grid. Whenever possible historical records were mapped following previous works on the distribution of specific endemic taxa (Erber & Hinterseher, 1988; Lompe, 1999; Assing & Schülke, 2006). Mapping of recent data on endemic species distribution posed no difficulty since the location of sampling sites was precise (GPS collected data). Species were considered "rare" when their distribution was restricted to 5 squares ($1Km^2$ each) or less and no report of its occurrence was made in the last 25 years.

Most of the endemic species are known from a few locations (Fig. 1) and this pattern is more evident for rove beetles, where 16 species are known from a single location. Taking in consideration the species known from only 5 squares or less, we found that 36 are rove beetles and 19 are ground beetles. This difference between the two groups is, in part, due to the fact that historically rove beetles have been less studied than ground beetles, but also reflects the recent description of a larger number of rove beetle species, many of which are known from just a few locations (e.g., Assing & Wunderle, 1995; 1996; Assing, 1997; see also Assing & Schülke, 2006 and references therein). Overall, thirty two species were identified as "rare" (19 rove beetles and 13 ground beetles). On the other hand, two ground beetles – *Scarites abbreviatus* and *Trechus custos* - are relatively widespread and abundant in their habitats. The general pattern of species-range size distribution, where many species are narrow endemics and only a few are widespread, is concordant with findings from other places and from other taxonomic groups (Gaston, 2003).

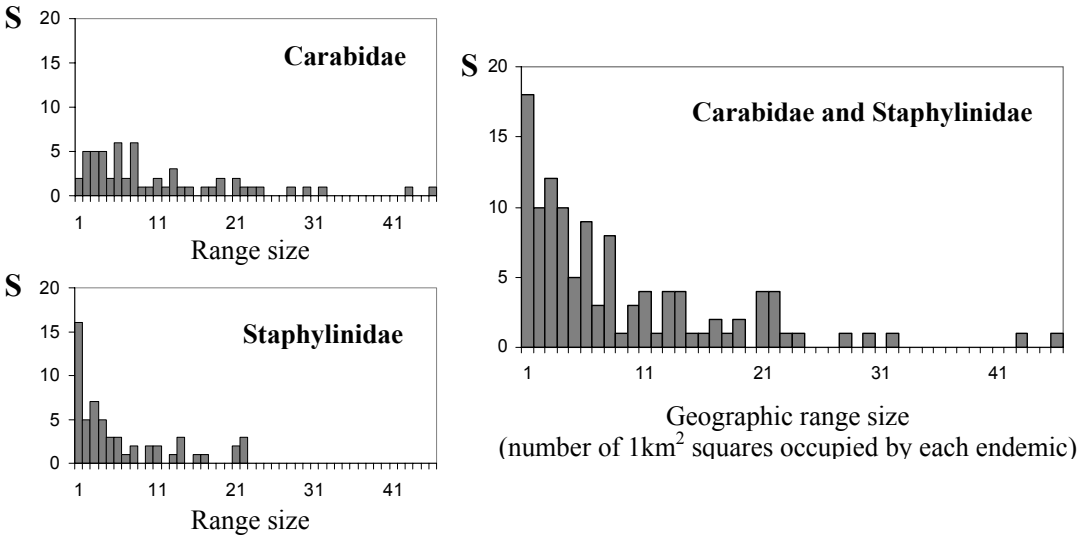

Figure 1. Species-range size distribution for the Madeiran endemic Carabidae, Staphylinidae and to both groups combined.

Correlates of endemic species distribution

The overlap of the endemic species distributions allowed us to identify the areas with high endemism in Madeira (Fig. 2). Those areas are (from left to right): Fanal, Rabaçal/Risco, Caramujo, Madeira peaks (Pico Ruivo/Pico do Areeiro), Fajã da Nogueira and Ribeiro Frio.

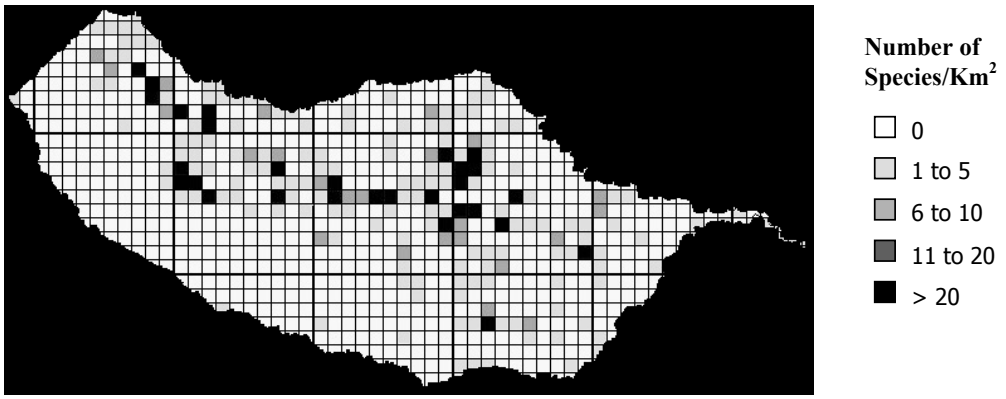

Figure 2. Endemic species richness of Carabidae and Staphylinidae in Madeira Island.

Rabaçal/Risco is the area with highest diversity of endemic ground and rove beetles with 53 species. Other areas (in dark grey), such as Chão da Ribeira, Chão dos Louros/Queimadas and Pico Jorge/Torrinhas, also accommodate a large number of endemics. From one area in the vicinity of Funchal – Monte – 12 endemic species have been reported, but most of these records are historical. During the last decades, the native habitats of this area suffered heavy destruction and are now under severe touristic pressure. So, an assessment of the impact of these changes on the local endemic species richness is of the outmost importance. Surprisingly, in most parts of the island (74.2% of the total number of squares) there is no record of endemic species occurrence. This may be due to a variety of reasons:

- first, there is evidence that most of the endemics are strictly associated with native habitats and these are located in the north and center of the island;

- native habitats have almost been eradicated from the southern half of the island and for centuries these areas have been intensively devoted to agriculture and forestry. Most of the human population (around 84%) is also concentrated on the southern municipalities of Madeira where large areas are occupied with housing, industry, touristic facilities, and logistic services. In the northern part of the island populations are disperse and predominantly located near the coast;

- human-disturbed areas have been avoided as sampling sites by most entomologists since, when having a limited amount of time to conduct sampling, native habitats are usually preferred because they have a higher probability of revealing more interesting findings;

- many areas are of difficult access (they are isolated, have dense plant cover or have very steep slopes) and for this reason have been ignored during sampling surveys;

- some historical records instead of reflecting reliably the place of collection may have been attributed to the best-known neighbouring locality since most collectors (usually foreigners) were unfamiliar with Madeiran localities;

- extensive surveys of Madeiran ground and rove beetles have seldom been implemented.

Most records of endemic species correspond to areas of Laurissilva (762 out of 1010). In fact, many endemic ground and rove beetles (e.g., *Bradycellus* spp., *Calathus* spp., *Geostiba* spp., *Olisthopus* spp., *Orthomus* spp., *Trechus* spp.) are associated with this native habitat which covered a much larger fraction of the island before human colonization. The Laurisilva is the most emblematic native habitat of Madeira and for this reason it has also received more attention from entomologists. Even so, many fragments of Laurisilva forest are still poorly known due to difficulties in accessing them.

The areas of high altitude of Madeira (peaks of Madeira and the Paúl da Serra plateau), located at the center of the island, have also revealed a considerable number of endemic species records (133 out of 1010). Furthermore, some species are exclusive of this habitat (e.g., *Amara superans*, *Atheta leileri, Othius arieiroensis*, *O. ruivomontis, Stenus ruivomontis*, *Syntomus lundbladi* and several *Geostiba* species) where they can usually be found in the litter layer of *Erica* and *Vaccinium* stands or beneath stones. Only a few endemic species seem to occur in a larger variety of habitats. For example, *Nesarpalus gregarius* was recorded from the drier habitats at Ponta de São Lourenço, from some mountaintops and also in various fragments of Laurisilva (e.g., Serrano, 1987; Erber & Hinterseher, 1988).

The distribuition of "rare" endemics

For the endemic species considered "rare", the geographic distribution pattern almost overlapped with the one observed for all the endemics (Fig. 3). The highest number of "rare" species (7 species) was recorded from Cruzinhas (near Ribeiro Frio) and at Risco/Rabaçal (5 species). Most records were found in areas of Laurisilva (58 out of 89) and 11 "rare" species have never been found outside this habitat (p.ex., *Astenus chimaera*, *Calathus pecoudi*, *Orthomus lundbladi*, *O. pecoudi*, *Paraphloeostiba clavicornis*, *Philorhizus vieirai*, *Thalassophilus caecus*, *Trichophya huttoni*).

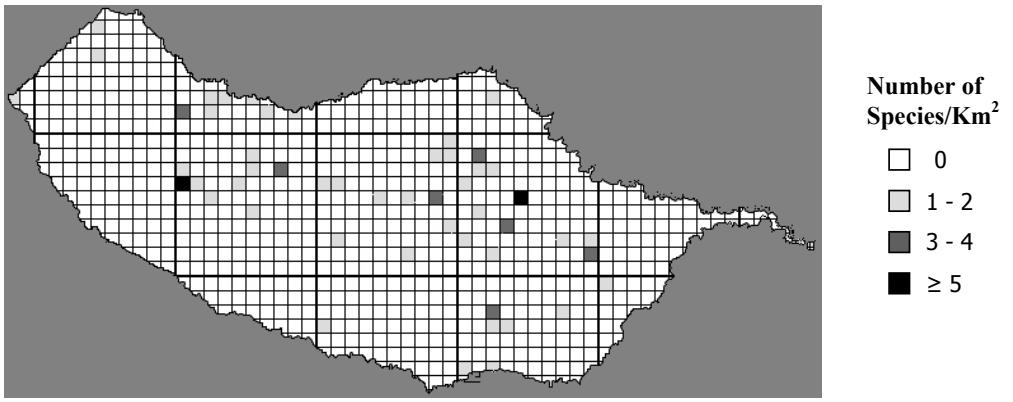

Figure 3. "Rare" endemic species richness of Carabidae and Staphylinidae in Madeira Island.

Representativeness of endemic ground and rove beetles in the Natural Park of Madeira

The large majority of endemic ground and rove beetle species (106 species) have been found in areas included in the NPM. Only nine endemic species are not known to occur within the NPM. Among these nine species, two occur in caves (the troglobitic *Medon vicentensis* and *Thalassophilus pieperi*) and may be vulnerable due to touristic activities taking place in their habitat (i.e., cave visiting at Gruta dos Cardais). Another five species (*Cypha reducta*, *Dromius angustus alutaceus*, *Myrmecopora maritima*, *Pselaphus myniops*, *Xylostiba tricolor*) are considered "rare" since they are only known from a few localities and have not been recorded for more than a century. There is a high probability that some of these species are now extinct (e.g., Becker, 1992; Assing & Schülke, 2006). The remaining two species (*Holobus ignoratus* and *Stenomastax madeirae*) have been recently described from localities in southern Madeira and are most probably introductions from the Oriental region (Assing, 2003). These species were found in human disturbed areas from southern Madeira, in some cases associated to greenhouses and banana cultures.

From the 106 endemic species known to occur within the NPM, 91 species (including 20 "rare" endemics) can be found in the areas with higher protection value. These areas, classified as Integral Natural Reserve, Partial Natural Reserve or Geologic and High Altitude Vegetation Reserve, receive low or no human disturbance and benefit from regular patrols by the nature wardens. Fifteen other endemic species (including seven "rare") can be found within the NPM, but in areas with lower protection (classified as Protected Landscape, Rest and Silence Area, Recreational and Mountain Reserve and Transition Zone). In these areas human disturbance is usually low or moderate, but can be high in specific periods as a result of recreational, sportive or touristic activities. Nevertheless, activities that may result in habitat destruction or damage to animals and plants are not allowed. During the last decade,

some of these areas have been the subject of ecological restoration activities (e.g., control of exotic plant species, recovery of areas previously subjected to intensive grazing) with considerable benefit to the ecosystems' health.

Taking in consideration the distribution of the endemic ground and rove beetles in Madeira Island and the design of the NPM, we found that the large majority of the endemic species have populations within its limits, thus benefiting from the general conservation rules applied in this protected area. The commitment of the NPM to continue the development of initiatives of habitat restoration or improvement is also a guarantee that suitable habitat will be made available in the future and some of the threats faced by Madeiran endemics will be under control. However, efforts should also be addressed to improve habitat connectivity between the areas with high conservation value since many endemic species are forest specialists and forest edges have proved to be effective barriers for their dispersal and colonization (unpublished data). The development of biological surveys focused on endemic taxa, coupled with the application of modelling techniques, should also be carried out, in order to collect valuable information to support decision-making for the adoption of more effective conservation measures.

Beetle conservation on islands: beyond protected areas boundaries

Island ecosystems are probably the places where the biodiversity crisis is more acute. Islands are well known for having suffered high levels of extinction of plants, molluscs and vertebrates, and many endemic species of these groups are critically endangered (Groombridge, 1992; Régnier *et al.*, 2009; Vié *et al.*, 2009). Despite the low number of documented insect extinctions (Vié *et al.*, 2009), there is evidence that thousands of species went extinct in island ecosystems during the last centuries (Asquith, 1995; Brook *et al.*, 2003; Dunn, 2005; Hanski *et al*., 2007).

Many island endemic insects are particularly prone to extinction due to their low range and to the fact that many of them are habitat specialists. The higher vulnerability of these insects may also result from the fact that some species show specific adaptations to island life (e.g., fligthlessness) and lack defensive mechanisms against alien predators and competitors (Gibbs, 2009). Furthermore, insects are one of the most susceptible groups to a particular kind of extinctions – coextinctions (Koh *et al.*, 2004; Dunn, 2005).

In Madeira, the destruction and fragmentation of native habitats since human colonization has probably led to the extinction of some endemic beetles. Evidence comes from the fact that during this period another invertebrate group (gastropods) suffered a high number of extinctions (Goodfriend *et al.,* 1994; Fontaine *et al.*, 2007) and many beetle species have never been recorded since their formal description, more than 100 years ago (Becker, 1992; Assing & Schülke, 2006). Among the endemic ground and rove beetles, 19 species have not been recorded since XIXth century. However, the record of extinctions among insects is an extremely difficult task since basic information on species biology is lacking for most of them and the tiny size, cryptic habits and peculiar life-cycles of some species pose additional difficulties. Only the extinction of large, conspicuous or human-related species is too obvious to go unnoticed. This was the case of the vanished Madeiran Large White (*Pieris brassicae wollastoni*), the only insect known to went extinct in Madeira.

Alien species

Some of the most invasive species worldwide are known to occur in Madeira, but their effects on the endemic insect fauna have not been addressed. There are some reports of the impact of mice, rats and cats on the endemic seabirds (Zino *et al.*, 2008) and efforts have been addressed to control their populations near bird nesting areas. Although it is known that these invasive species also feed upon large-bodied insects (mostly Coleoptera) (Gibbs, 2009; Traveset *et al.*, 2009) nothing is known about their impact on the Madeiran insect fauna. Other mammals, such as goats and rabbits, are known to inflict dramatic changes to island ecosystems through overgrazing, occasionally leading to the local extinction of plants and associated insect species (Asquith, 1995). In the last decade, efforts have been made by the NPM to reduce significantly the area allowed for grazing in Madeira Island and to eradicate wild goats from the neighbouring uninhabited islets (Desertas islands). The natural cover is now recovering but information on the impact suffered by endemic invertebrates is still lacking.

The most problematic invasive plants in Madeira have been identified (Silva *et al.*, 2008) and considerable efforts have been addressed by the legal authorities, in cooperation with the local populations, to recover native habitats and control invasive plant species (e.g., *Ageratina adenophora, Carpobrotus edulis*, *Hedychium gardnerianum*, *Ulex europaeus*). These plants limit the regeneration of native species, interfere in the natural processes of pollination and seed dispersal and consequently promote drastic changes in the community structure and

composition. Nevertheless, nothing is known about the direct and indirect effects of invasive plants on the endemic insect fauna of Madeira.

The introduction of alien invertebrates poses a serious problem to the endemic biodiversity of island ecosystems (Asquith, 1995; Causton *et al.*, 2006; Wagner & Driesche, 2010), but it has been a neglected issue in Madeira (Pombo *et al.*, this book). The noxious effects of alien invertebrate species on the native biodiversity may be severe and without effective measures to prevent their arrival, establishment and to control their populations, they may remain unnoticed for long … until it may be too late. At this stage we must remember the "sudden" extinction of the emblematic Madeiran Large White, an endemic butterfly once relatively widespread in Madeira Island (Wakeham-Dawson *et al.*, 2002). This conspicuous species probably went extinct as an indirect result of the introduction of its congener *Pieris rapae.* According to several authors, *Pieris rapae* might have brought with it a specific parasitoid (*Cotesia* sp.) or a strain of the granulosis virus disease, against which *P. brassicae wollastoni* may have had no resistance (Wakeham-Dawson *et al.*, 2002; Gardiner, 2003; Lozan *et al.*, 2008).

Climate and land-use changes

A number of studies have highlighted the degree of specialization of some insect species and how local extinctions may have taken place even with minor changes in native habitats (Dunn, 2005). In island ecosystems this situation is even more delicate since many species have a narrow distribution and habitat modifications may lead to their extinction. For these reasons, conservation managers should be aware of endemic species distribution and their conservation status, and decisions on interventions on their habitats should be carefully evaluated (particularly those aimed to occur within protected areas). Climate change is also a key threat for Madeiran biodiversity. Recent reports stress the changes in sea level, temperature, rainfall and its consequences for Madeiran ecosystems (Cruz *et al.*, 2008; Petit, 2008). Surprisingly, the conclusions drawn from these studies differ substantially, particularly in what concerns the changes in the distribution of Laurisilva. Nevertheless, both studies agree that many Madeiran endemics will face critical danger of extinction.

Valuing and protecting the endemic beetles of Madeira – time for action!

With the last two sections of this chapter, we intended to highlight the fact that although some species occur in protected areas, this is not *per se* a guarantee of species survival in the long term. Many insect species are extremely sensible to habitat changes and many of those

changes are too subtle to be perceived by man without a regular monitoring of the ecosystems. Furthermore, the high number of reported invertebrate extinctions in Madeira turned evident the urgent need to drive specific conservation measures to this group of living beings which have been systematically neglected as conservation targets.

A serious impediment for the development of specific conservation measures focused on beetles follows from the fact that basic information on the biology of many species is lacking and the extant literature dealing with some of the other species remains dispersed. Madeiran authorities should take advantage of the recent involvement of a large number of specialists in the production of a reference book on the taxonomic biodiversity of Madeira (Borges *et al*., 2008a) to obtain valuable information (on species distribution, abundance, ecology) to be used in conservation planning and management. Furthermore, the development of inventorying/monitoring programs aiming to update the knowledge on poorly known endemic and alien species should also be considered a priority. These programs should be designed with great care (see details in Samways, 2005; New, 2009) in order to provide answers to key aspects related with the conservation of Madeiran endemic invertebrates.

The recent identification of two Madeiran insects (a beetle - *Chrysolina fragariae* - and a butterfly - *Gonepteryx maderensis*) among the most threatened taxa of Macaronesia (Martín *et al.*, 2008) has put in evidence the need to start developing conservation efforts addressed to groups other than plants and vertebrates. We are confident that that study has also provided a stimulus to start developing a conservation strategy to value, study and protect Madeiran invertebrate fauna where those priority insect species can be used as flagships. Both species are attractive (colourful and large), easily identified and have a common name, reasons that may be helpful to get the involvement of the local populations and the general public in their safeguard. Furthermore, the use of the most recent information and communication technologies will allow a more effective and efficient implementation of conservation actions (like it is presently being done in the Azores and in the Canaries) and will play a key role in education and in raising awareness for the need to value and protect the unique biodiversity of Madeira.

Conclusions

The Natural Park of Madeira plays a key role in conserving the biological diversity of Madeira Island, but little is known about its effectiveness in protecting endemic invertebrates.

We used two speciose beetle groups – the ground and rove beetles – both with a high number of endemics and considered good biodiversity indicator groups, to determine the representation of these taxa in the NPM.

The large majority of endemic beetle species occurs within the area covered by the NPM and most of them can also be found in areas with higher protection status. Only a few "rare" endemic beetle species are not known to occur within the area of the NPM and efforts should be addressed to locate more populations of these species and to evaluate their conservation status.

Despite the efforts drove by the NPM to restore and improve habitat quality with benefits for the whole community of native species, a conservation strategy aiming to value, study and protect Madeiran endemic invertebrates is still lacking and should be considered an immediate priority.

Acknowledgements

We thank the finantial support provided by Fundação para a Ciência e a Tecnologia through project "Áreas de elevado endemismo no Arquipélago da Madeira – identificação de prioridades para a conservação da fauna endémica de insectos" - PDCT/BIA-BDE/59202/2004 and grant SFRH/BPD/39998/2007 to CR. We also thank all the team members involved in the above mentioned project, namely Carlos Aguiar, Fernando Pereira, Isabel Amorim, Israel Silva, Paulo Borges, Pedro Cardoso and Sérvio Ribeiro, for their help during field work and the Parque Natural da Madeira, particularly to Susana Fontinha and the nature wardens Herculano and Martinho, for their support.

References

Asquith, A. (1995) Alien species and the extinction crisis of Hawaii's invertebrates. *Endangered Species Update* **12**: 6-12.

Assing, V. (1997) A revision of the Madeiran species of *Geostiba* (Coleoptera: Staphylinidae). Supplement I. *Rev. Suisse Zool.* **104**: 345-355.

Assing, V. (2003) A new species of *Stenomastax* from Madeira (Coleoptera: Staphylinidae, Aleocharinae). *Linzer biol. Beitr.* **35**: 539-542.

Assing, V. & Schülke, M. (2006) Systematic catalogue of the entomofauna of the Madeira Archipelago and Selvagens Islands. Staphylinoidea, Staphylinidae, (Coleoptera). Vol. 2, Part 2. *Bol. Mus. Mun. Funchal, Sup.* **11**: 5-167.

Assing, V. & Wunderle, P. (1995) A revision of the Madeiran species of the genus *Othius* Stephens (Coleoptera: Staphylinidae). *Bol. Mus. Mun. Funchal* **45**: 53-65.

Assing, V. & Wunderle, P. (1996) A revision of the Madeiran species of the genus *Geostiba* Thomson, 1858 (Col.: Staphylinidae). *Rev. Suisse Zool.* **103**: 119-150.

Barnard, P., Brown, C.J., Jarvis, A.M., Robertson, A. & van Rooyen, L. (1998) Extending the Namibian protected area network to safeguard hotspots of endemism and diversity. *Biodivers. Conserv.* **7**: 531-547.

Becker, P. (1992) Colonization of islands by carnivorous and herbivorous Heteroptera and Coleoptera: effects of island area, plant species richness, and "extinction" rates. *J. Biogeogr.* **19**: 163-171.

Boieiro, M., Serrano, A., Pombo, D., Menezes, D. & Capela, R. (2003) The endemic species of Staphylinidae of Madeira Island: spatial distribution and areas of high endemism. *Acta Entomol. Ibérica e Macaronésica* **1**: 51-57.

Borges, P.A.V., Abreu, C., Aguiar, A.M.F., Carvalho, P., Jardim, R., Melo, I., Oliveira, P., Sérgio, C., Serrano, A.R.M. & Vieira, P. (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.

Borges, P.A.V, Aguiar, A.M.F., Boieiro, B.; Carles-Tolrá, M. & Serrano, A.R.M. (2008b) The arthropods (Arthropoda) of Madeira and Selvagens archipelagos. In: *A list of the terrestrial fungi, flora and fauna of Madeira and Selvagens archipelagos* (eds P.A.V. Borges, C. Abreu, A.M.F. Aguiar, P. Carvalho, R. Jardim, I. Melo, P. Oliveira, C. Sérgio, A.R.M. Serrano & P. Vieira) pp. 245-356. Direcção Regional do Ambiente da Madeira and Universidade dos Açores, Funchal and Angra do Heroísmo.

Brito, D. & Grelle, C.E.V. (2004) Effectiveness of a reserve network for the conservation of the endemic marsupial *Micoureus travassosi* in Atlantic Forest remnants in southeastern Brazil. *Biodivers. Conserv.* **13**: 2519–2536.

Brook, B.W., Sodhi, N.S. & Ng, P.K.L. (2003) Catastrophic extinctions follow deforestation in Singapore. *Nature* **424**: 420-423.

Carlquist, S. (1974) *Island Biology*. Columbia University Press, New York.

Causton, C.E., Peck, S.B., Sinclair, B.J., Roque-Albelo, L., Hodgson, C.J. & Landry, B. (2006) Alien insects: threats and implications for conservation of Galápagos Islands. *Ann. Entomol. Soc. Am.* **99**: 121-143.

Cruz, M.J., Santos, F.D., Aguiar, R., Oliveira, R.P., Correia, A., Tavares, T. & Pereira, J.S. (2008) Impactos das Alterações Climáticas nos Ecossistemas Terrestres da Ilha da Madeira. In: *CLIMA 2008 – I Congresso Nacional sobre Alterações Climáticas*. Universidade de Aveiro, Portugal.

Darwin, C.R. (1859) *On the origin of species by means of natural selection, or the preservation of favoured races in the struggle for life*. John Murray, London.

Dunn, R.R. (2005) Modern insect extinctions, the neglected majority. *Conserv. Biol.* **19**: 1030–1036.

Enghoff, H. (this book) The millipede genera *Cylindroiulus* and *Dolichoiulus* as examples of Macaronesian species swarms.

Erber, D. (1990). New and little known coleoptera from Madeira. Results of excursions to Madeira in the years 1986-1990. *Bol. Mus. Mun. Funchal* **42**: 147-181.

Erber, D. & Aguiar, F. (1996) New and remarkable species of the coleopterous fauna of Madeira. *Bol. Mus. Mun. Funchal* **48**: 41- 62.

Erber, D. & Hinterseher, W. (1988) Contribution to the knowledge of the Madeira beetles. *Bol. Mus. Mun. Funchal,* **40**: 139-214.

Fontaine, B., et al. (2007) The European union's 2010 target: Putting rare species in focus. *Biol. Conserv.* **139**: 167-185.

Gardiner, B.O.C. (2003) The possible cause of extinction of *Pieris brassicae wollastoni* Butler (Lepidoptera: Pieridae). *Entomol. Gaz.* **54**: 267-268.

Gaston, K.J. (2003) *The structure and dynamics of geographic ranges*. Oxford University Press, Oxford.

Gibbs, G.W. (2009) The end of an 80-million year experiment: a review of evidence describing the impact of introduced rodents on New Zealand´s 'mammal-free' invertebrate fauna. *Biol. Invasions* **11**: 1587-1593.

Goodfriend, G.A., Cameron, R.A.D., & Cook, L.M. (1994) Fossil evidence of recent human impact on the snail fauna of Madeira. *J. Biogeogr.* **21:**309–320.

Groombridge, B. (1992) *Global biodiversity: status of the Earth's living resources.* World Conservation Monitoring Centre. Chapman and Hall, New York.

Hanski, I., Koivulehto, H., Cameron, A. & Rahagalala, P. (2007) Deforestation and apparent extinctions of endemic forest beetles in Madagascar. *Biol. Lett.* **3**: 344–347.

Hortal, J., Lobo, J.M. & Jiménez-Valverde, A. (2007) Limitations of biodiversity databases**:** case study on seed-plant diversity in Tenerife (Canary Islands). *Conserv. Biol.* **21**: 853-863.

IUCN (1999) The Laurisilva of Madeira (Portugal). In: *IUCN evaluation of nominations of natural and mixed properties to the World Heritage List,* pp. 93-97. Report to the 23rd ordinary session of the World Heritage Commitee, Marrakesh, Morocco.

Jansson, A. (1940). Die Arthropodenfauna von Madeira nach den Ergebnissen der Reise von Prof. Dr. O. Lundblad Juli-August 1935. XXIX. Coleoptera: Sämtliche Familien unter Ausschluss der Familie der Carabidae, Dytiscidae, Hydrophilidae und der Gattung *Cryptrophagus* Herbst aus der Familie Cryptophagidae. *Ark. Zool.* **32**: 1-64.

Koh, L.P., Dunn, R.R., Sodhi, N.S., Colwell, R.K., Proctor, H.C. & Smith, V.S. (2004) Species coextinctions and the biodiversity crisis. *Science* **305**: 1632–1634.

Lemckert, F., Rosauer, D. & Cameron, S. (2009) A comparison of Australia's anuran records against the reserve system. *Biodivers. Conserv.* **18**: 1233–1246.

Lompe, A. (1999) Revision der *Trechus*-Arten Madeiras und Porto Santos (Coleoptera, Carabidae). *Ent. Bl.* **95**: 93–143.

Lozan, A.I., Monaghan, M.T., Spitzer, K., Jaroš, J., Žurovcová, M. & Brož, V. (2008) DNA-based confirmation that the parasitic wasp *Cotesia glomerata* (Braconidae, Hymenoptera) is a new threat to endemic butterflies of the Canary Islands. *Conserv. Genet*. **9**: 1431–1437.

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. *Ark. Zool.* **11**: 461-524.

Machado, A. (1995) Ground beetles of Macaronesia, an overview (Coleoptera, Carabidae*). Bol. Mus. Mun. Funchal, Sup*. **4:** 395-410.

Machado, A. (2006) *T. Vernon Wollaston (1822-1878). Un entomólogo en la Macaronesia*. Taro de Tahiche: Fundación César Manrique, Canárias.

Martín, J.L, Arechavaleta, M., Borges, P.A.V. & Faria, B. (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.

Menezes, D., Freitas, I., Gouveia, L., Mateus, G., Domingues, M., Oliveira, P. & Fontinha, S. (2004) *A Floresta Laurissilva da Madeira, Património Mundial*. Parque Natural da Madeira, Secretaria do Ambiente e Recursos Naturais, Governo Regional da Madeira.

Menezes de Sequeira, M., Jardim, R. & Capelo, J. (2007) A Chegada dos portugueses às ilhas – o antes e o depois – Madeira. In: *"Árvores e Florestas de Portugal". Volume 6, Açores e Madeira – A Floresta das Ilhas* (ed Joaquin Sande Silva), pp. 165-196. Edição da Fundação Luso Americana para o Desenvolvimento, Público e Liga para a Protecção da Natureza.

Myers, N., Mittermeier, R.A., Mittermeier, C.G., Fonseca, G.A.B. & Kent, J. (2000) Biodiversity hotspots for conservation priorities. *Nature* **403**: 853–858.

New, T.R. (2009) *Insect species conservation.* Cambridge University Press, New York.

Percy, D. (this book) Insect-plant interactions on islands: codiversification of legume-feeding psyllids (Psylloidea) and their Fabaceae hosts.

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.

Pombo, D.A., Aguiar, A.M.F. & Nunes, E. (this book) Exotic insects in Macaronesia: vectors, pathways, control measures and global trade.

Régnier, C., Fontaine, B. & Bouchet, P. (2009) Not knowing, not recording, not listing: numerous unnoticed mollusk extinctions. *Conserv. Biol*. **23**: 1214-1221.

Samways, M. (2005) *Insect diversity conservation.* Cambridge University Press, New York.

Serrano, A.R.M. (1987) Contribution à la connaissance des coléoptères de l'archipel de Madére. I. *Coleoptera: Carabidae, Dytiscidae, Hydraenidae, Hydrophilidae, Histeridae* et *Staphylinidae*. *Bol. Mus. Mun. Funchal* **39**: 141-155.

Serrano, A.R.M. (1988) Contribution à la connaissance des Coléoptères de l`Archipel de Madère. II. *Coleoptera: Cerambycidae*. *Bolm Mus. Mun. Funchal* **40**: 235-238.

Serrano, A.R.M. (2002) Os Coleópteros Carabóides Endémicos da Península Ibérica em Portugal (Coleoptera: Caraboidea): Padrões de distribuição e Tentativa de Ordenação das Áreas Protegidas. In: *Proyecto de Red Iberoamericana de Biogeografia y Entomologia Sistemática PrIBES 2002.* (eds C. Costa, S.A. Vanin, J.M. Lobo & A. Melic) pp. 277-293. Monografias Tercer Milenio, vol 2, SEA & Cyted, Zaragoza.

Serrano, A.R.M., Aguiar, C.A.S., Boieiro, M.C., Borges, P.A.V., Rego, C., Rosário, I.A., Ribeiro, S.P. & Pereira, F. (2009) 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. & Boieiro, M. (2008) Carabidae. In: *A list of the terrestrial fungi, flora and fauna of Madeira and Selvagens archipelagos* (eds P.A.V. Borges, C. Abreu, A.M.F. Aguiar, P. Carvalho, R. Jardim, I. Melo,

P. Oliveira, C. Sérgio, A.R.M. Serrano & P. Vieira) pp. 310-313. Direcção Regional do Ambiente da Madeira and Universidade dos Açores, Funchal and Angra do Heroísmo.

Silva, C. (1996). *O problema dos Altos-Chãos da Madeira. Floresta ou pastorícia ?* Direcção Regional dos Assuntos Culturais, Funchal.

Silva, L., Land, E.O. & Rodríguez Luengo, J.L. (eds) (2008) *Invasive Terrestrial Flora & Fauna of Macaronesia. TOP 100 in Azores, Madeira and Canaries.* ARENA, Ponta Delgada.

Sólymos, P. (2007) Are current protections of land snails in Hungary relevant to conservation? *Biodivers. Conserv.* **16**: 347–356.

Struebig, M.J., Christy, L., Pio, D. & Meijaard, E. (2010) Bats of Borneo: diversity, distributions and representation in protected areas. *Biodivers. Conserv.* **19**: 449-469.

Traveset, A., Nogales, M., Alcover, J.A., Delgado, J.D., López-Darias, M., Godoy, D., Igual, J.M. & Bover, P. (2009) A review on the effects of alien rodents in the Balearic (Western Mediterranean Sea) and Canary Islands (Eastern Atlantic Ocean). *Biol. Invasions* **11**: 1653–1670.

Vié, J.-C., Hilton-Taylor, C. & Stuart, S.N. (eds.) (2009) *Wildlife in a changing world – an analysis of the 2008 IUCN Red List of threatened species*. IUCN, Gland, Switzerland.

Wagner, D.L. & Van Driesche, R.G. (2010) Threats posed to rare or endangered insects by invasions of nonnative species. *Ann. Rev. Entomol.* **55**:547-568.

Wakeham-Dawson, A., Franquinho Aguiar, A.M.F. & Martin, G. 2002. The distribution of endemic butterflies (Lepidoptera) on the island of Madeira, Portugal since 1850 with comments on their current conservation status. *Entomol. Gaz.* **53**:153-180.

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. (1865) *Coleoptera Atlantidum, being an enumeration of the coleopterous insects of the Madeiras, Salvages and Canaries.* London.

Wrase, D.W. & Jaeger, B. (1996) Revision der *Bradycellus*-Arten der Atlantischen Inseln aus der verwandtschaft des *Br. excultus* Woll. (Coleoptera, Carabidae, Harpalini). *Linzer biol. Beitr.* **28**: 497-515.

Zino, F., Hounsome, M.V., Buckle, A.P. & Biscoito, M. (2008) Was the removal of rabbits and house mice from Selvagem Grande beneficial to the breeding of Cory's shearwaters *Calonectris diomedea borealis*? *Oryx* **42**: 151-154.