Towards systematic conservation planning in the Azores

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Abstract

Several field methodologies, analytical measures and theoretical patterns have been explored for conservation planning for arthropods in native forests of the Azores archipelago. Here, the outcomes are assembled to make recommendations on practical strategies to assess arthropod diversity and to select and manage protected native forests in the Azores. Suggestions are made on how to apply similar plans for conservation of other plant and animal groups in these forests. Potential threats to the Azorean native forest are described and measures to minimize them are proposed. Future studies are also suggested that would improve the present knowledge of arthropod diversity and distribution in Azorean native forests and could assist in the identification of suitable conservation strategies.

Keywords: Azores; arthropods; conservation planning; diversity; inventory; management; monitoring; native forest; protection

Introduction

The remote islands of the Azores archipelago are located in the North Atlantic Ocean (37-40ºN, 25-31ºW). The archipelago has a recent volcanic origin (0.30 - 8.12 million years old) and has frequent volcanic and seismic activities. The climate is temperate humid at sea level, and cold oceanic at higher altitudes. The atmospheric humidity is high with small temperature fluctuations throughout the year.

The Azorean islands have a particular type of forest, Laurisilva, composed of mainly endemic evergreen tree and shrub species (the most dominant being *Juniperus brevifolia* (Seub.) Antoine, *Laurus azorica* (Seub.) Franco, *Ilex perado* Aiton subsp. *azorica* (Loes.) Tutin, *Vaccinium cylindraceum* Sm. and *Erica azorica* Hochst. (ex Seub.). The native forest in the Azores is characterised by a dense tree and shrub cover of small stature, closed canopy, extensive overlay of bryophytes, high levels of humidity and low understorey light.

Manuscripts from the 15th century document that the islands were completely covered by a dense forest when they were discovered (Martins, 1993). Within 550 years, the human population reached 245,000 inhabitants on 2,244 km^2 of land surface, and the overall cover of Laurisilva decreased by more than 90%. Whilst volcanic eruptions, earthquakes, heavy rain and strong winds occurring over this period destroyed patches of vegetation, it is evident that human activities were mainly responsible for this extensive loss (Connor et al., 2012). Native vegetation at low and middle altitudes became gradually extinct or highly modified and a large number of exotic plants and animals were intentionally or accidentally introduced. At present, native forest is mainly restricted to high and steep areas, covering only 2.6% of the overall territory of the archipelago (Gaspar et al., 2008). And still, the small area of forest habitat that remains sustains most of the terrestrial endemic plant and animal species of the archipelago (Triantis et al., 2010).

In 1988, the importance of this biotope was recognized and some of the native forest fragments were included in partial Natural Forest Reserves (NFRs), managed by the Regional Directorate for Forest Resources. Later, in 2004, some parts of the native forest areas were included into Sites of Community Interest (SCIs), to be converted in Special Areas for Conservation (SACs), and into Special Protection Areas (SPAs). The SACs and SPAs would then contribute to the Natura 2000 network. The SACs and SPAs would have their own statutory laws that would differ from those approved for the NFRs even for the areas that overlapped. While some fragments showed overlapping protection, others were not included under any of the designations. In order to overcome the multiple definitions, aims, priorities and laws applied to each area, the Regional Secretariat for the Environment and the Sea (RSES) and the University of the Azores discussed in 2007 a reclassification of the protected areas according to the widely used IUCN category system (Dudley et al., 2010). Most of the forest fragments are now included in Island Nature Parks. The managers of each Island Nature Park (from the RSES) have been recently appointed but the management plans, taking into account the protection categories within each area, will still take several years to be defined and to put into practice.

In this contribution we make recommendations on practical strategies to assess arthropod diversity and to select and manage protected native forests in the Azores. Suggestions are also made on how to apply similar plans for conservation of other plant and animal groups in these forests. Potential threats to the Azorean native forest are described and measures to minimize them are proposed.

Methods

Eighteen native forest fragments distributed across seven islands of the archipelago were considered in this contribution (Figure 1; Table 1). This corresponds to most of the native forest extent of the Azores. The areas excluded are small patches of less than five hectares, highly fragmented, at low altitudes and/or strongly disturbed by cattle and invasive plants.

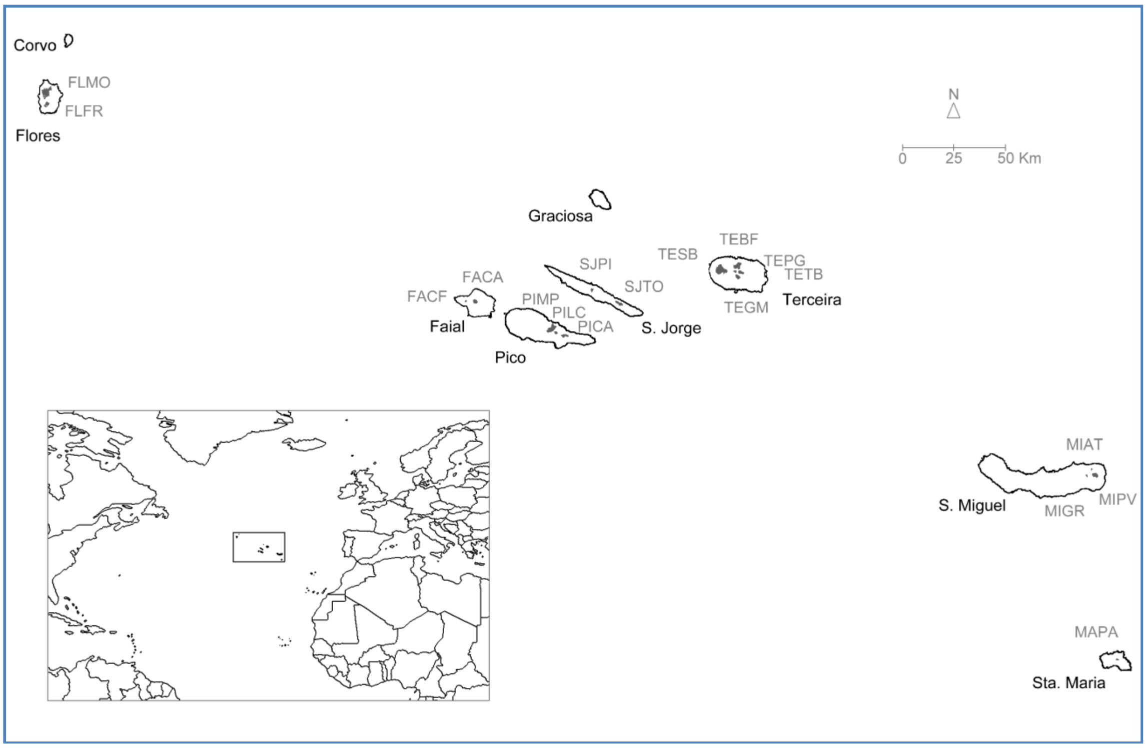

Figure 1. Location of islands and native forest fragments of the Azores archipelago.

Table 1. Main characteristics of the Azorean islands (bold) and native forest fragments considered in this study, including the area (Area, hectares), the highest point (Altitude, metres), distance to the nearest island/fragment (Isolation, kilometres) and the oldest geological age of the soil (lava) substrate (Age, million years BP) (adapted from Gaspar et al., 2008).

Island	Fragment	Code	Area (ha)	Altitude (m)	Isolation (km)	Age (my)
Flores		**FL**	**14102**	**911**	**236.43**	**2.16**
	Morro Alto e Pico da Sé	FLMO	1331	911	6.02	2.16
	Caldeiras Funda e Rasa	FLFR	240	773	6.02	2.16
Faial		**FA**	**17306**	**1043**	**34.26**	**0.73**
	Caldeira do Faial	FACA	190	934	4.67	0.73
	Cabeço do Fogo	FACF	36	597	4.67	0.60
Pico		**PI**	**44498**	**2350**	**32.42**	**0.30**
	Mistério da Prainha	PIMP	689	881	2.92	0.26
	Caveiro	PICA	184	1077	4.61	0.27
	Lagoa do Caiado	PILC	79	945	2.92	0.28
S.Jorge		**SJ**	**24365**	**1053**	**32.42**	**0.55**
	Topo	SJTO	220	946	15.13	0.55
	Pico Pinheiro	SJPI	73	717	15.13	0.55
Terceira		**TE**	**40030**	**1021**	**71.67**	**3.52**
	S. Bárbara e M. Negros	TESB	1347	1021	7.20	1.24
	Biscoito da Ferraria	TEBF	557	809	3.03	0.10
	Guilherme Moniz	TEGM	223	487	2.70	0.41
	Terra Brava	TETB	180	726	2.70	0.10
	Pico do Galhardo	TEPG	38	655	2.79	0.10
S. Miguel		**MI**	**74456**	**1105**	**97.53**	**4.01**
	Pico da Vara	MIPV	306	1105	3.42	3.20
	Graminhais	MIGR	15	930	4.02	3.20
	Atalhada	MIAT	10	500	3.42	4.01
S. Maria		**MA**	**9689**	**587**	**97.53**	**8.12**
	Pico Alto	MAPA	9	579	92.21	8.12

The project BALA (Biodiversity of Arthropods of Laurisilva of the Azores; http://www.gba.uac.pt/projetos/ver.php?id=3) is a research initiative to quantify the spatial distribution of arthropod biodiversity in native forests of the Azores. An extensive standardised sampling protocol was applied in most of the remnant forest fragments of the archipelago. Arthropods were collected using a combination of two techniques, targeting epigean and canopy arthropods. A total of 114 transects distributed amongst 18 forest fragments in seven of the nine Azorean islands were established during the summers of 1999–2004. Along each transect of 150m long and 5m wide, a pitfall trap was placed in the soil every 5m (30 traps in total) and beating samples were taken from the three most dominant tree and shrub species every 15m (30 samples in total). A detailed description of the sampling methods applied is presented by Gaspar et al. (2008) (see also Borges et al., 2005 and Ribeiro et al., 2005). All Araneae, Opiliones, Pseudoscorpiones, Myriapoda and Insecta (excluding Diptera and Hymenoptera) were considered. Several taxonomists (see Acknowledgements) checked the identifications made.

The BALA project was launched in 1998 and since then has contributed considerably to the overall knowledge of diversity and distribution of arthropods in the Azores (see Gaspar et al., 2008 and Borges et al., 2011 for a review of the research developed on arthropods in the Azores).

Results and Discussion

Identifying threats to the Azorean native forest

The field work developed during more than a decade across the 18 native forest fragments allowed researchers to identify the major threats to biotic integrity of native forest in the Azores (Table 2). A similar, although more detailed, exercise was made for the sites studied in Terceira Island, in order to define an Index of Biotic Integrity (IBI; Cardoso et al., 2007). The IBI for the 18 native forest fragments is presented in Gaspar et al. (2011). The smallest forest fragment of Flores Island (FLFR) and the only fragment in Sta. Maria island (MAPA) may be considered, at present, to be those that are most vulnerable to the threats defined. These two fragments are also the ones identified with the lowest IBI (Gaspar et al., 2011). Suggested measures to minimize the identified threats are also proposed in Table 2.

Table 2. Major threats to biotic integrity of native forest in the Azores archipelago. Codes and main characteristics of the forest fragments are presented in figure 1 and table 1.

Threat	Direct impacts	Extent of threat	Measures to minimize threat
Invasion of exotic plant species: - *Hedychium gardneranum* Sheppard ex Ker-Gawl. - *Hydrangea macrophylla* (Thunb.) Ser. - *Rubus ulmifolius* Schott - *Cryptomeria japonica* (L. fil.) D. Don - *Pittosporum undulatum* (Vent.) - *Clethra arborea* Aiton	- Change in the structure and composition of plant communities (loss of endemic and native plant species with slower growth rates, unable to compete with exotic species with higher dispersal and reproductive abilities)	- Margins of all fragments - Core of smaller fragments: FLFR, TEPG, TEGM, TEBF, SJPI, SJTO, FACA, FACF, PILC, MIAT, MIGR, MAPA	- Creation of buffer margins around fragments, where it is possible, and clearing of exotic plant species - Cut and control of exotic plant species inside smaller fragments
Damage by cattle	- Grazing of herbaceous species - Destruction of shrub species - Change in soil organic matter and pH	- Margins of some fragments: FLFR, PILC, PICA, SJTO, SJPI, TEGM, TEPG, TEBF	- Set electrical fences at points where cattle usually gains entry
Unregulated excursions and other tourist activities	- Destruction of herbaceous and shrub species - Fragmentation of forests - Deposition of garbage inside forests	- Core of some fragments: FLFR, FACA, PILC, TEBF, MIPV, MAPA	- Establishment of defined trails in a few fragments - Put information along trail on fauna and flora of native forests emphasising the importance/vulnerability of this habitat - Allow entrance only with nature guides

Suggested steps for systematic conservation planning

Based on results from some extensive research developed recently in the Azores (Borges et al., 2005, 2006, 2011; Ribeiro et al., 2005; Gaston et al., 2006; Cardoso et al., 2007, 2009b; Borges & Wunderlich, 2008; Hortal et al., 2010; Martín et al., 2010; Triantis et al., 2010; Gaspar et al., 2011; Meijer et al., 2011; Fattorini et al., 2012), a step-by-step guide is suggested for systematic conservation planning of arthropods in Azorean native forests. A similar general approach could be applied for other plant and animal groups in these forests. All steps are applicable to other groups except the section *"Results obtained from previous studies for arthropods"*.

Systematic conservation planning in native forests of the Azores (a step-by-step guide):

1. Map native forest
   1.1. Acquire the most recent aerial photographs for all islands using remote sensing technology (*e.g.* Gil et al., 2011a). Consider the application of more advanced tools to measure the "quality" of the

forests with full-waveform LiDAR data and multispectral imagery
1.2. Delimit all patches of native forest using GIS software
1.3. Verify limits of forest patches in the field and identify contiguous land uses
1.4. Demarcate private and public land
(steps being conducted in Natura 2000 projects - *e.g.* Gil et al. (2011b) and current IUCN Islands Parks in the Azores)

2. Inventory diversity
2.1. Select the target groups to inventory diversity
Results obtained from previous studies for arthropods:
-preference for groups that can be readily assigned to morphospecies (Gaspar et al., 2008)
-immatures may be used when a reference collection from several locations is available (Gaspar et al., 2008)
2.2. Compile all information available for those groups
2.3. From the information available, create reference collections for the groups (if required) with replicates found in different forest fragments
2.4. Test alternative standardised sampling methods applicable to Azorean native forests for the target groups (if not developed yet)
Results obtained from previous studies for arthropods:
-pitfall traps, canopy beating samples (Gaspar et al., 2014; COBRA protocol developed by Cardoso et al., 2008 now being applied in the Azores)
2.5. Optimize sampling methods and effort in order to maximize sampling completeness
-select an area and apply several sampling methods
-analyze different combinations of methods and effort
-choose sampling methods and effort that are a compromise between the lowest effort and the highest sampling completeness
Results obtained from previous studies for arthropods:
-establish 150m transects (Gaspar et al., 2008, 2014)
-set 15 Turquin pitfall traps per transect, one every 10m (Gaspar et al., 2014); sample the three most dominant plant species every 15m (30 beating samples per transect; Gaspar et al., 2014)
2.6. Choose the appropriate spatial scale to inventory diversity of those groups
-look for the spatial scale that contributes more to overall diversity
Results obtained from previous studies for arthropods:
-sample the greatest number of islands, focus effort in only one fragment within each island, more transects within each fragment, fewer samples within each transect (Gaspar et al., 2007, 2011, 2014)
-do not restrict sampling to richest islands, fragments or transects (Borges et al., 2005; Gaspar et al., 2007, 2011)

3. Select areas for conservation
(detailed in Gaspar et al., 2011 for any terrestrial habitat of the Azores, excluding coastal areas)
3.1. Define a representation target for the groups studied (presence or proportion of abundance) and constraints for number of areas selected
Results obtained from previous studies for arthropods:
-minimum number of areas so that indigenous species are represented by at least 50% of their overall abundance (Gaspar et al., 2011)
3.2. Determine an integrity index related to disturbance to use as a constraint for selecting areas with the optimization software (step 3.4)
Results obtained from previous studies for arthropods:
-use the Index of Biotic Integrity developed by Cardoso et al. (2007); Gaspar et al., (2011)
3.3. Delimit the private land that can be acquired or used, under agreement, to maintain patches of native forest. If there are financial or other limitations, use them as constraints in the optimization step (next)
3.4. Use optimization software to determine optimal solutions based on targets and constraints

4. Establish management plans
4.1. Identify the potential threats to the selected native forest fragments (see table 2)
4.2. Define practical measures to minimize threats (see table 2)
4.3. If needed, acquire the agreed private land or give compensation to landowners to maintain patches of native forest on their land.
4.4. Plan periodic meetings with landowners of private land and with representatives of each protection

status defined for the selected forest fragments (directors of the Island Natural Parks of the regional secretary of Environment and Sea, Environmental NGOs)
4.5. Combine conservation strategies and sustainable development plans from each entity
4.6. Maintain vigilance for the accomplishment of management plans

5. Monitor diversity
5.1. Select diversity surrogate groups
Results obtained from previous studies for arthropods:
-Araneae and Hemiptera can be used as surrogates of overall alpha species richness and dissimilarity species richness (Gaspar et al., 2010)
5.2. Optimize sampling completeness in order to minimize sampling methods and effort
Results obtained from previous studies for arthropods:
-establish 150m transects (Borges et al., 2005; Gaspar et al., 2008)
-set 15 Turquin pitfall traps per transect, one every 10m; sample the most dominant plant species every 15m; collecting 10 beating samples per transect (Gaspar et al., 2014)
5.3. Choose the appropriate spatial scale to monitor diversity
Results obtained from previous studies for arthropods:
-the same recommendations as for inventorying diversity (see step 2.6; Gaspar et al., 2014)
5.4. Monitor diversity periodically
-look for changes in composition and abundance of species
-rerun the optimization step to look at the effects of changes in species distributions/abundances
-if representation target is not maintained, look if management plans are being correctly applied, change management plans or reconsider the prioritized areas

Future research on conservation planning of Azorean arthropods

Further studies should be developed to improve knowledge on diversity and distribution of Hymenoptera, Diptera, Collembola and Acari species (Borges et al., 2010a, 2011). These groups have not been considered in previous studies referred previously since their assignment to morphospecies is unreliable and the sampling methods applied were not adequate for these arthropods (see discussions in Gaspar et al., 2008). However, being highly diverse and abundant, they are expected to play important functional roles in native forest communities as parasites, saprophages and predators, and to contribute a considerable fraction of endemic species (Borges et al., 2010a). The conservation of these groups should also be important, although much research is required in order to find accurate shortcuts to identify them. Sampling methods other than beating and pitfall trapping are needed effectively to capture these groups. The use of Malaise and SLAM traps is a possibility already being implemented by us in Azores (Borges et al., unpublished data). Smaller adhesive and non-adhesive interception traps made with cardboard or acrylic and sustained in the canopy with strings could be alternative options to sample Hymenoptera and Diptera. Similarly, Collembola and Acari do not seem to be effectively sampled with Berlese funnels in Azorean native forests (Gaspar et al., 2008), so other alternative soil and litter extracting methods should be tested, such as centrifugation. The alternative sampling methods require considerably more effort and time, so research is also needed to find strategies to optimize the sampling effort and methods for these groups.

Studies regarding diversity and distribution patterns of arthropods along time scales could be helpful to complement the protocol described above by determining the time scale (hour of the day, season of the year) on which: a) the minimum combination of sampling methods and effort shows the highest sampling completeness (*e.g.* Cardoso et al., 2008), b) the alpha and beta components contribute considerably more to gamma diversity for a given spatial scale (Summerville & Crist, 2003); c) nestedness patterns eventually occur so that assessment of diversity can be restricted to richer areas (Azeria et al., 2006) and d) an arthropod group has the highest significant correlation with the remaining groups (Gaspar et al., 2010).

Assessing diversity on different time scales in Azorean native forests, though, is a difficult exercise. The comparison of the composition and abundance of arthropods between day and night hours requires a considerable additional effort. The uneven volcanic ground with deep fissures and dense vegetation makes progression through the forests during the night more time-consuming and dangerous. However, this effort has been started under the project "NETBIOME ISLANDBIODIV -Understanding biodiversity dynamics in tropical and subtropical islands as an aid to science based conservation action" (http://www.island-biodiv.org/).

Furthermore, the study of arthropod diversity and abundance during other seasons of the year would require an adaptation of the base sampling methods due to the heavy rainfall. The period that pitfall traps were left in the field would need to be reduced or cups should have holes covered with a net in the upper half to drain excess water. Also, beating would need a plastic instead of a cloth tray so that arthropods would fall into the bag. Bags would require a system to drain water as well. These winter adapted methods would require more time in the field and, for beating samples, more effort sorting samples in the laboratory as well. Despite the requirements of additional effort for the comparison of arthropods collected at different hours of the day or in different seasons of the year, such results would greatly improve knowledge on the distribution of arthropods through time in these native forests. The only time scale approach that does not require extra efforts, other than establishing base transects, is the comparison between different years. Preliminary analyses, detailed in Gaspar et al., 2014), showed that resampling a given transect in a different year or adding another transect in another location contributed similarly to the accumulated species found in the fragment. This suggests that sampling in different years adds as much information on arthropod diversity as applying the same effort in the same year in another location. However, these comparisons were made between close years and it is not known what may occur over a longer period of time. Another project entitled "Predicting extinctions on islands: a multi-scale assessment" (http://cita.angra.uac.pt/biodiversidade/projectos/ver.php?id=3), tried to overcome this limitation by comparing two plots per Azorean native forest fragment sampled in 1999-2000 (Borges et al., 2005) with the same plots sampled in 2010 (Rigal et al., 2014).

The type and causes of arthropod rarity in Azorean native forests is an important topic to be studied. The distinction between arthropod species that are truly rare from those that are rare at a given time, using a given sampling protocol, or in the native forest habitat, has major implications for conservation strategies for these forests (see Gaston et al., 2006; Borges et al., 2008; Fattorini et al., 2012; Rigal et al., 2013). Studies recently developed comparing the arthropod diversity and abundance among different habitats in the Azores (Cardoso et al., 2009b, 2010; Meijer et al., 2011; Florencio et al., 2013) gave important indications on the arthropod species that are vagrants in native forests. Also, results related with the addition of alternative sampling methods and time scale described above will be helpful to explore these as potential causes of rarity in Azorean native forests.

The importance of the Azorean Laurisilva is unquestionable, but much still needs to be done to create awareness amongst the general public of the crucial role that the forest plays for the maintenance of the indigenous flora and fauna of the region. Indeed, local populations, with direct economic interests in land for agriculture and pasture, still have a considerable impact on the sustainability of the Azorean native forest alongside the policy makers, managers and conservationists. Information promulgated by several means in the field, at agriculture meetings, and through leaflets and books will offer to local populations the opportunity to better understand their natural patrimony, and hence, to help to preserve it.

Recent efforts towards improving the biodiversity outreach in Azores, increasing public understanding of why value arthropod biodiversity and thus to protect their habitats, include the publication of books for the general public (Borges and Gabriel, 2009; Cardoso et al., 2009a), the implementation of the Azorean Biodiversity Portal (http://www.azoresbioportal.angra.uac.pt/index.php?lang=pt; see also Borges et al., 2010b) and the Azorean Gallery of Biodiversity (http://galeria.azoresbioportal.angra.uac.pt/). One initiative in Facebook "Chama-lhe Nomes" (https://www.facebook.com/Chama.lhe.Nomes) challenged cybernauts to come up with creative common names for insects endemic to the Azores, raising awareness for the unique biodiversity of the archipelago. In addition, an unprecedented urban intervention in the Azores, "Azoreans for millions of years" occurred in the summer of 2013: unique macro photographs of insects were placed in 12 buildings in the main arteries of Angra do Heroísmo, in order to acquaint Azoreans with their unique natural heritage (see more at http://cita.angra.uac.pt/ficheiros/noticias/1364834635.pdf).

Conclusions

Native forests in the Azores harbour most of the terrestrial endemic and native species of the archipelago. However, Laurisilva cover is continuously threatened by human activities that reduce and fragment areas allowing the entrance of exotic and/or invasive species. Conservation of Laurisilva is mandatory, but human and financial resources are limited. In recent years, several efforts have been made and funding became available to select and include Azorean native forest fragments under some protective form of designation. Proposals were firstly made based only on biotopes, rare vascular plants and the few vertebrates occurring in the archipelago, without reference to any of the endemic invertebrate species that compose the largest component of known biodiversity of these forests. However, in the past few years, the information on diversity and distribution of arthropods provided by the BALA project and other studies was taken into account to delimit the Island Nature Parks. The protected areas are now under the same regulation which facilitates their management and supervision. The next steps towards systematic conservation planning in Azores are to establish practical management plans for the protected areas, including the establishment of periodic, cost-effective diversity monitoring plans to determine the effectiveness of the conservation strategies adopted to date.

Acknowledgments

We are grateful to all researchers that collaborated in the field and laboratory during the BALA project funded by Direcção Regional dos Recursos Florestais (Project 17.01-080203): Álvaro Vitorino, Anabela Arraiol, Ana Rodrigues, Artur Serrano, Carlos Aguiar, Catarina Melo, Francisco Dinis, Genage André, Emanuel Barcelos, Fernando Pereira, Hugo Mas, Isabel Rosário, João Amaral, Joaquín Hortal, Lara Dinis, Paula Gonçalves, Sandra Jarroca, Sérvio Ribeiro and Luís Vieira. The Forest Services provided local support in each island. Acknowledgments are due to all the taxonomists who assisted in the identification of the morphotypes: Andrew Polaszek, António Bivar de Sousa, Artur Serrano, Arturo Baz, Fernando Ilharco, Henrik Enghoff, Jordi Ribes, José Quartau, Jörg Wunderlich, Mário Boieiro, Ole Karsholt, Richard Strassen, Volker Manhert and Virgílio Vieira. We thank Jon Sadler and Owen Petchey for helpful discussions and suggestions. CG was funded by a grant (BD/11049/2002) from Fundação para a Ciência e a Tecnologia. PAV Borges worked in a recently improved version of this text under the support of the project NETBIOME/0003/2011 - ISLAND-BIODIV.

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