

Arthropods and other Biota associated with the Azorean Trees and Shrubs: *Juniperus brevifolia*

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This work aims to characterize the arthropods and other biota (lichens, bryophytes, vascular plants and birds) associated with the Azorean endemic tree, *Juniperus brevifolia*. This is the first of a series of publications that will (i) provide a comprehensive list of all the biota associated with the main Azorean endemic trees and shrubs, (ii) describe in detail the diversity, abundance and spatial patterns of canopy arthropods, and (iii) whenever possible, to extend biodiversity assessments to communities of bryophytes, lichens, vascular plants and vertebrates. We use standardized sampled data from BALA project for canopy arthropods and for the remaining taxa we surveyed literature data and the Herbarium of University of Azores. *Juniperus brevifolia* occurs in a wide range of elevation belts in Azores and accommodates a remarkable large number of taxa: besides canopy arthropods (161 species) it is also an important substrate to other vascular species (six species), bryophytes (105 species), lichens (106 species) and also birds (four species). In addition, the species richness and particularly the abundance of endemics are dominant, and the number of conservation concern species for bryophytes is noteworthy (30 out of 70). The complexity of the tree and the high diversity of micro-habitats created the conditions for epiphytic species to easily colonize all parts of the tree, from the bottom, trunk and branches. The communities associated with the Azorean cedar are consequently of a high conservation value and should be further investigated in their ecological dynamics.

Key words: Arthropods, Azorean cedar, bryophytes, host plant, species composition

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INTRODUCTION

Azores are known by their low number of indigenous species (endemic and native non-endemic) of most taxonomic groups, in comparison with the other Macaronesian archipelagos. Moreover, the Azores are probably the archipelago of Maca-

ronesia where the damages caused by historical anthropogenic ecosystem changes are the most apparent (Borges & Hortal 2009; Cardoso et al. 2010; Triantis et al. 2010a,b; Connor et al. 2012, 2013; Rando et al. 2013). Such changes are thought to have caused already the extinction of numerous endemic species, particularly in the

most disturbed islands, where few and minute native forest patches remain (Cardoso et al., 2010; Rando et al. 2013; Terzopoulou et al. 2015). As a consequence, the knowledge of the current distribution and abundance of terrestrial Azorean biotas is a critical step to set conservation programs on the native forest ecosystem (see e.g. Gaspar et al. 2011). Due to the work of several research groups from the University of the Azores in the last twenty years, many archipelagic studies on both indigenous and exotic species have been carried out, such as exhaustive species inventories (Borges et al. 2005b; Borges et al. 2010a), comprehensive biogeographical studies (Whittaker et al. 2008, 2014; Borges & Hortal 2009; Cardoso et al. 2010; Santos et al. 2010; Triantis et al. 2010a,b; Cameron et al. 2013; Aranda et al. 2014; Carvalho & Cardoso 2014; Carvalho et al. 2015) and phylogenetic and evolutionary studies (Ferreira et al. 2011; Schaefer et al. 2011; Amorim et al. 2012; Rodrigues et al. 2013). In addition, there are several ecological studies at smaller spatial scales focusing on the communities of particular organisms, namely bryophytes (e.g. Gabriel & Bates 2005; Aranda et al. 2015), vascular plants (e.g. Elias & Dias 2009; Rumeu et al. 2011; Marcelino et al. 2013) and arthropods (e.g. Borges et al. 2006; Meijer et al. 2011; Florencio et al. 2013; Raposeiro et al. 2013).

However, there are very few studies so far dealing in detail with the biotic communities associated with each of the indigenous host tree species that structure the extant Azorean forests. Among them we emphasise the works on arthropod canopy community biodiversity and structure (Markin et al. 1995; Ribeiro et al. 2005; Gaspar et al. 2008; Borges et al. 2008; Ribeiro & Borges 2010) and those dealing with the effects of herbivory on a specific indigenous host tree species (Vieira et al. 1993; Silva et al. 1995; Ribeiro et al. 2003). Despite these works, there is still insufficient knowledge regarding the biodiversity assessment and the spatial structure of the biotas associated with Azorean host trees, which hinders biodiversity conservation and sustainable resource management (Summerville et al. 2003; Cardoso et al. 2011).

We propose to do a series of publications reviewing the existing knowledge on the biotic communities associated with structurally important native trees and shrubs of the Azores archipelago, namely *Juniperus brevifolia* (Seub.) Antoine, *Ilex perado* Aiton subsp. *azorica* (Loes.) Tutin; *Laurus azorica* (Seub.) Franco, *Erica azorica* Hochst. ex Seub., *Vaccinium cylindraceum* Sm. and *Myrsine africana* L.. Our main objectives are: i) to provide a comprehensive list of all the biota associated with the main Azorean endemic trees and shrubs, ii) to describe in detail the diversity, abundance and spatial patterns of canopy arthropods, since there is already a bulk of standardized data collected with the BALA project – fieldwork: 1992-2002 and 2003-2004 (e.g. Ribeiro et al. 2005; Gaspar et al. 2008), and iii) whenever possible, to extend our biodiversity assessment to communities of bryophytes, lichens, vascular plants and vertebrates. Given the current rates of biodiversity loss due to global changes (e.g. invasive species, habitat erosion and fragmentation, climatic changes), with all their impacts on the ecosystems and associated communities (Butchart et al. 2010, Hooper et al. 2012) we feel that this will be a valuable asset for future researchers and conservation practitioners, offering a baseline that may be used to compare and evaluate future changes in the native Azorean ecosystems and associated species composition.

We will start this series of works with the Azorean endemic gymnosperm, *Juniperus brevifolia* (Seub.) Antoine, since this is the most common and widespread endemic tree in the extant Azorean native forests (Fig. 1).

THE TARGET SPECIES: *JUNIPERUS BREVIFOLIA* (SEUB.) ANTOINE

Juniperus brevifolia, the Azorean cedar or Short leafed juniper, is a dioecious shrub or tree, with a trunk bark brown-purple, exfoliating in strips. Leaves are acicular, closely set, with two broad, white stomatiferous bands on the adaxial surface. Seed cones are subglobose, green and pruinose while young, dark copper-brown when mature. Seeds are free, ovoid and triquetrous (Adams 2014). Sequences from nuclear and chloroplast DNA (trnC-trnD spacer) have placed *J. brevifolia* in a clade with *Juniperus navicularis* Gandoger, that is endemic to western coastal areas of main-

land Portugal and it seems possible that seeds of *J. navicularis*-like plants or their ancestor were brought to the Azores by birds from the Iberian Peninsula (Adams 2014). A study by Rumeu et al. (2011) suggested that a single introduction event

likely occurred from Europe and that genetic differentiation of *J. brevifolia* post-dated the emergence of the oldest island (Santa Maria, 8.12 Ma, [França et al. 2003]).



Figure 1. *Juniperus brevifolia* (Seub.) Antoine with details of a female branch, with seed cones, and a male branch with male cones. Ilustrações científicas: Fernando Correia (www.efecorreia-artstudio.com). With permission of Azorina – S.A.

Presently, two subspecies are recognized (Elias & Dias 2014): (1) *J. brevifolia* subsp. *maritima* is an erect shrub or small tree, with (inverted) pyramidal crown; leaves: 5.6–7.6 × 1.4–1.8 mm; seed cones: 7.9–9.5 mm, ripening in the first year; seeds: 1–3 per seed cone, 4.9–6.3 × 3.5–5.1 mm, germinating from February to May; pollination: January–March; distribution: Flores, Terceira, Pico, São Jorge and São Miguel (?), below 100 m

a.s.l.; and (2) *J. brevifolia* subsp. *brevifolia* is a tree or shrub; leaves: 4.5–6.7 × 1.1–1.5 mm; seed cones: 6.9–8.7 mm, ripening in the second year; seeds: 2–3 per seed cone, 3.9–5.3 × 2.1–3.7 mm, germinating from March to June; pollination: March–June; distribution: all islands, except Graciosa, usually between 300 m and 1500 m a.s.l. Two varieties have been recognized from the later subspecies (Elias & Dias 2014): i) *J. brevifolia*

subsp. *brevifolia* var. *brevifolia* (the dominant taxa) a small to medium-sized tree, found mostly between 300 and 1000 m a.s.l., in all Islands (except Graciosa); and ii) *J. brevifolia* subsp. *brevifolia* var. *montanum* a small prostrate shrub, usually found between 850 and 1500 m a.s.l. in the Islands of Flores, Terceira, Pico, São Jorge, Faial and São Miguel. Overall, this species has wide ecological amplitude and it can be found from the coast to 1500 m a.s.l. (in Pico Mountain). Therefore it has the potential to occupy all islands, at all altitude ranges except Pico (which has a maximum altitude of 2350 m a.s.l.).

Presently, according to Elias (2007), *J. brevifolia* reaches higher values of abundance and frequency between 500 and 800 m a.s.l.. Between 800 and 1000 m a.s.l. frequency decreases, and between 1000 and 1500 m a.s.l. abundance also decreases. Low winter temperatures, very high rainfall, strong and frequent winds explain the decreasing abundance. Above 1500 m it is rarely found, possibly due to the frequent snow cover during the winter in Pico Mountain. At lower altitudes, namely between 100 and 500 m (especially up to 300 m) it becomes rarer, not only due to human induced habitat changes but also, in the remaining natural or semi-natural areas due to the competition with tree species with higher stature (e.g. *Morella faya*, *Laurus azorica* and *Picconia azorica*). Furthermore, since *J. brevifolia* is a pioneer species (Elias & Dias 2009), low frequency and intensity of gap creating natural disturbances, at these low altitude ranges, might also explain this pattern. Below 100 m a.s.l. there is a small increase in abundance and frequency due to the presence of subsp. *maritima* in coastal scrubs. Once present in all islands, this species is now extinct in Graciosa and near extinction in Santa Maria. In the islands of São Miguel, São Jorge and Faial, *J. brevifolia* populations have been greatly reduced or highly fragmented. This decline was due to centuries of human exploitation of natural resources. It is well-known that the species was used since human settlement for naval and house construction, for furniture and as fuel (Frutuoso 1978, 1981, 1987). In addition, extensive dairy farming in the last decades led to widespread clearing of forests for pasture, further decreasing populations of *J. brevifolia* (Silveira

2013). Nevertheless, it is still possible to find pristine *Juniperus* forests in Flores, Pico and Terceira (Elias et al. 2011). This species is also found in coastal scrubs, in pioneer and secondary scrubs and in forested peat bogs (Elias & Silva 2008). It is protected both by national and international laws and a few studies have been developed to characterize the genetic variability of the species for conservation and restoration purposes (e.g. Silva 2000; Silva et al. 2011).

METHODS

THE AZOREAN ARCHIPELAGO

The Azores are a volcanic archipelago with nine islands (Figure 2), located on the North Atlantic, on a WNW-ESE axis, between 37° - 40°N and 25° - 31°W. The archipelago extends for 615 km and is located approximately 1300 km west of mainland Portugal, 1600 km east of North America and 800 km NE from Madeira Island. The islands form three distinct groups: the eastern (Santa Maria and São Miguel), the central (Terceira, Graciosa, São Jorge, Pico and Faial) and the western (Flores and Corvo) groups with different geological ages, with Santa Maria as the oldest island (8.12 Ma) and Pico as the youngest (0.27 Ma) (França et al. 2003).

The archipelago's climate is affected by the surrounding ocean, namely the effects of the Gulf Stream, as well as by island topography, being mild and very wet, often reaching an average annual relative humidity of 95% in the high altitude forests. Annual temperature fluctuations are dampened by the ocean, causing low thermal variation throughout the year (Azevedo et al. 2004).

AZOREAN VEGETATION

Most Azorean extant native forests are montane cloud forests (Elias et al. 2011). They are humid, evergreen forests characterised by short tree stature, dense crown foliage and high tree density. In more exposed and wet environments *J. brevifolia* is the dominant tree. Otherwise the canopy is usually dominated by *J. brevifolia* and *I. perado* subsp. *azorica*. At lower altitudes, especially in less exposed areas, *L. azorica* is also a common species (Elias 2007; Elias et al. 2011). Montane

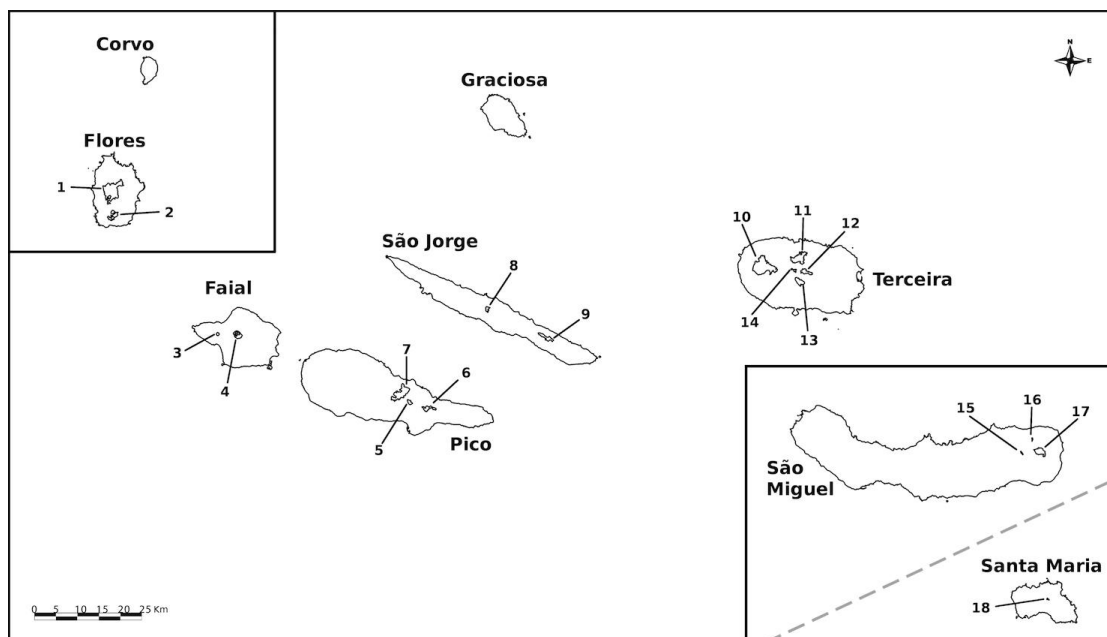


Figure 2. Map of the Azores (distances between the island groups and between São Miguel and Santa Maria are not in scale). Sampled reserves: 1 – Morro Alto e Pico da Sé; 2 – Caldeira Funda e Rasa; 3 – Cabeço do Fogo; 4 – Caldeira; 5 – Lagoa do Caiado; 6 – Caveiro; 7 – Mistério da Prainha; 8 – Pico Pinheiro; 9 – Topo; 10 – Serra de Santa Bárbara; 11 – Biscoito da Ferraria; 12 – Terra Brava; 13 – Caldeira de Guilherme Moniz; 14 – Pico Galhardo; 15 – Graminhais; 16 – Atalhada; 17 – Pico da Vara.

cloud forests are also characterised by a dense cover of mosses and other epiphytes (Gabriel & Bates 2005). In the Azores these forests are shaped by the shallow soil layer, fractured and craggy terrain (Ribeiro et al. 2005) and wind speed.

From the work of Frutuoso (1978, 1981, 1987), compiled from documents, oral tradition and from its own travels to the islands, it is clear that forests dominated the Azorean landscape at the time of discovery and settlement of the archipelago in the 15th Century. Based on the classical proposal of Dansereau (1970) the vegetation of the Azores could be divided in six altitudinal belts, characterized by their dominant species: *Morella faya* (0-300 m); *Laurus azorica* (300-650 m); *Juniperus brevifolia* (450-1100 m); *Erica azorica* (850-1600 m); *Calluna vulgaris* (1600-2200 m) and (6) lichens (2200-2350 m). Palynological studies by Connor et al. (2012, 2013) provided us with some very important information about the recent past and historical native vegetation of two Azorean islands, Pico and Flores. These studies added

more evidence that primitive Azorean vegetation was dominated by trees and that human impact had a strong influence on the native vegetation. In fact, as a result of less than 600 years of human settlement more than 95% of the native forest was destroyed by human action (Triantis et al. 2010b; Fernández-Palacios et al. 2011; Silveira, 2013), with most coastal, lowland and submontane forests (dominated by *Morella faya*, *Picconia azorica*, *Laurus azorica* and *Prunus azorica*) being replaced, giving way to urban and agricultural areas.

The remaining pristine forest continues under threat due to habitat reduction, fragmentation and invasive plants, with clear impacts on the flora and fauna (Borges et al. 2000; Cardoso et al. 2010; Triantis et al. 2010b; Terzopoulou et al. 2015), and is now restricted to a few dispersed high-altitude fragments, with areas between 4 and 1300 ha (Borges et al. 2005a, 2006; Gaspar et al. 2008), totalling some 6000 ha (Gaspar et al. 2008; Gabriel et al. 2011).

AZOREAN BIODIVERSITY

The Azorean terrestrial biota is currently composed by 6199 species and subspecies (about 6147 species), being 455 (414 species) of these endemic to the archipelago (Borges et al. 2010b, with additional updated data for arthropods). A large component of this biota are recent introductions, with 47% of arthropods (excluding taxa whose colonisation status was not possible to determine) and 81% of vascular plants being exotic (Borges et al. 2010b, with additional updated data for arthropods). There are currently 2333 arthropod *taxa* (269 endemics) reported to the Azores, corresponding roughly to 37% of all terrestrial species. Fungi as a whole are the second most diverse group with 1328 taxa (34 endemics), followed by the vascular plants with 1110 taxa (73 endemics). Bryophytes (*sensu lato*) account roughly for 7.7% of the biota, with 480 taxa, including seven Azorean endemics. Land snails and slugs (Mollusca) are also a diverse group, with 114 taxa, including 49 endemics (Borges et al. 2010b, with additional updated data). Excluding fresh-water fishes (13 taxa), all exotic, there are 58 vertebrate species present in the archipelago: 11 of which are mammals (all introduced, except for three species of native bats and the endemic noctule bat, *Nyctalus azoreum*). Breeding birds are represented by 43 species, including 11 endemic subspecies and two endemic species (*Oceanodroma monteiroi* and *Pyrrhula murina*). Additionally there are also two exotic species of amphibians and two exotic species of reptiles (Borges et al. 2010a).

DATA SETS

Arthropods

The arthropod data set (see Appendix I) consists of the results from the BALA project (Biodiversity of Arthropods of Laurisilva of the Azores), an extensive and standardized sampling protocol applied to native vegetation areas in the years of 1992-2002 and 2003-2004 (Borges et al. 2005a; Ribeiro et al. 2005; Gaspar et al. 2008; see also more details at <http://islandlab.uac.pt/proj ectos/ver.php?id=65>). Each forest fragment included a minimum of four 150 m long transects (the number of transects being dependant on the forest fragment area); besides pitfall traps (not

analysed in this publication, but see Borges et al. 2005a; Gaspar et al. 2008), the two or three most common trees and shrubs per transect were sampled every 15 metres (for a total of 10 replicates per transect), using canopy beating. For that purpose, a stick and a cloth collector tray, in the shape of an inverted pyramid with a bag at the end, was used. Naturally, Juniper was not available on all of the transects, and so, for this particular subset of data, each forest fragment included between one and sixteen transects. For a more detailed description of the sampling protocol see Ribeiro et al. (2005) and Gaspar et al. (2008). A total of 16 forest fragments, mostly natural patches of *Juniperus-Sphagnum* woods, *Juniperus* woods, *Juniperus-Ilex* forests and *Juniperus-Laurus* forests were sampled in six islands (Flores, Faial, Pico, São Jorge, Terceira and São Miguel), for a total of 74 transects and 740 samples made for *Juniperus*. All samples and identified species are deposited in the EDTP – Entomoteca Dalberto Teixeira Pombo, University of Azores, Angra do Heroísmo, Portugal. Occurrence data was digitized in the ATLANTIS database (<http://www.atlantis.angra.uac.pt/>) and available also in the Azores Biportal (<http://azores.biportal.uac.pt/>) for the general public.

Other taxa

Vascular plants

The vascular plants list (see Appendix II.1) includes epiphytic species and one hemiparasite of *J. brevifolia* and was based on the information from Schäfer (2005).

Bryophytes

The bryophyte data set used in this work includes both herbarium and literature records (Appendix II.2). From all the gathered literature references dealing with Azorean bryophytes (see complete list in Gabriel et al. 2011), 21 specifically mentioned *J. brevifolia* as a substrate of either epiphytic (growing on living bark) or epixylic species (growing on dead trunks and branches) (see Appendix III). Moreover, data from the collection of bryophytes deposited at the University of the Azores (Angra do Heroísmo) were also included in the study. Some of the herbarium records came from *ad hoc* inventories, while others, especially

from Terceira (Gabriel & Bates 2005) and Pico Island (Homem 2005) were obtained from community studies, using standard collection protocols on native vegetation areas; bryophyte samples on *J. brevifolia* were obtained from relevés with 30 cm side, placed at different heights on the trees, allowing the estimation of cover and richness of species (further details on Gabriel 2000). All data are included in the ATLANTIS database (<http://www.atlantis.angra.uac.pt/atlantis/common/index.jsf>) and also available in the Azores Bioportal (<http://azoresbioportal.uac.pt/>) for the general public.

Lichens

The lichen data set used in this work includes mainly literature records, although approximately one fifth (22 out of 107 species) of the lichen species associated with *J. brevifolia* referred in Appendix II.3, may also be found on the Collection of Lichens deposited at the University of the Azores (Angra do Heroísmo). Of the 100 lichenological references identified for the Azores, 15 specifically refer *Juniperus brevifolia* as the substrate of the lichens (see Appendix III).

Birds

The bird data set used in this work (Appendix II.4) follows the literature (see Appendix III).

DATA ANALYSES

Arthropods

For this study, we considered all adult and juvenile specimens identified to a given morphospecies, while excluding all individuals that were not possible to identify or whose classification into morphospecies was dubious. The identification of juvenile/immature specimens is possible for the Azorean fauna due to the relatively low species richness of the archipelago and the long standing experience of one of the authors (PAVB) (see also Ribeiro et al. 2005; Gaspar et al. 2008). For some of the analysis the arthropods were grouped into three colonisation categories: endemic (present only in the Azores), native non-endemic (“native” for simplification from now on; including species that, although not endemic, arrived to the islands by natural means), and introduced species, after the criteria of Borges et al. (2010a). We allocated a native status for the taxa without a reliable identification, with the following excep-

tions: i) when the family was known to have only exotic species recorded for the Azores; ii) when the genera was known to be dominated by exotic species in the Azores (based on Borges et al. 2010a). Furthermore, we assigned each species to a functional group (predator, herbivore, saprophyte, fungivore) and a feeding mode (external digestion and sucking, chewing and cutting, piercing and sucking, siphoning, not feeding). Data for trophic guild and feeding mode were collated from an extensive literature search of ecological information, including manuscripts with the first descriptions of the species, first species records for the Azores, brief notes, and ecological studies among others. Information was also obtained from experts who have identified the specimens or from experts of a given taxonomic group when information for a particular species was not available. For the few taxa identified to morphospecies, we have considered the information of the nearest taxonomic resolution (genus, family).

In the case of Terceira island, to avoid pseudo-replication, when transects were sampled in more than one year, replicates were excluded, in a way as to balance the data chronologically. Additionally, Terceira was the only island in which some transects had more than 10 samples due to some additional experiments (see Gaspar et al. 2014). As such, and to standardize with the other islands, when transects had more than 10 samples, all samples past the first ten were excluded from the analysis.

To ascertain potential differences between the islands regarding species richness, abundance, trophic guild composition and feeding mode, statistical comparison tests (Chi-square) were done with R software (R Core Team, 2015) and the respective *post-hoc* tests for which pairs of populations differ were computed with the NCStats package (Ogle 2015) by performing all chi-square tests for all pairs of populations (with Bonferroni adjustment for inflation due to multiple comparisons). In cases where the given classes were present in only one or two islands, these were excluded from the Chi-square tests. To observe the imbalance caused by the unequal sampling effort in the different islands, sample based accumulation curves (not shown), standardized at the minimum common number of 40 samples were per-

formed in EstimateS (Colwell 2009). This software was also used to estimate the Fisher α and the Shannon-Wiener index for each island and for the archipelago as a whole.

To assess the distribution of species abundances, binning of the species into modified Preston's octaves was performed using the third method described in Gray et al. (2006), using the R package gambin (Matthews et al. 2014). This package was also used to calculate the corresponding Alpha GamBin values.

Nonmetric Multidimensional Scaling (Kruskal 1964) was applied to the data at a transect scale using Bray-Curtis similarities, through R software and packages vegan (Oksanen et al. 2015) and ade4 (Dray & Dufour 2007). Statistical significance in the dissimilarity between islands was assessed through an analysis of similarities (ANOSIM) (Clarke 1993). To discern the possible bias in the results caused by the extremely unbalanced sampling effort between the islands, the NMDS ordination was also done using the data standardized at four randomly selected transects per island. As a measure of the error associated with this rarefaction of the data for the standardized NMDS analysis, 999 permutations of ANOSIM R^2 values, using sets of four randomly selected transects per island, were estimated in order to construct a 95% confidence interval.

The number of shared species between the islands and the compositional differences between the islands were assessed using Bray-Curtis similarity, through the EstimateS software. The number of shared species and Bray-Curtis similarity values were calculated by using both the full set of data (unequal numbers of transect per island) and 10 standardized sets of data each with 4 transects per island. These standardized sets of data were obtained by numbering each transect in each individual island from 1 to n (where n is the maximum number of transect in any given island) and then using the R software to generate 10 pseudo-random sets of 4 numbers from 1 to n , for each island.

Other taxa

Excepting Arthropods, which had enough data to allow the performance of comparative macroeco-

logical analyses, other taxa (Bryophytes [Liverworts, Mosses], Lichens, Ferns and Birds) were analysed using a descriptive approach, in order to obtain: i) lists of species occurring on *Juniperus brevifolia* (Appendix II); ii) richness of species per taxonomic group and per island (whenever possible); and iii) richness of endemic, native and exotic species and their proportion regarding the Azorean *taxa*.

RESULTS

ARTHROPODS

Arthropod taxonomical data overview

We collected 36729 specimens, corresponding to 161 species, representing four Classes, 15 Orders and 66 Families (Table 1 and Appendix I). Of all the collected species, 50 (31%) are considered endemic, 62 (39%) are native and 49 (30%) are introduced in the archipelago (Table 2).

Table 1. Summary table of the collected arthropod taxa, listing all classes and orders found, with indication of the number of families, species and individuals in each order.

Order / Class	Fam.	Spp	Indiv.
Arachnida			
Pseudoscorpiones	1	1	13
Opiliones	1	1	14
Araneae	12	40	13619
Diplopoda			
Julida	1	1	177
Chilopoda			
Lithobiomorpha	1	1	1
Insecta			
Microcoryphia	2	2	122
Blattodea	1	1	1509
Psocoptera	7	15	2301
Hemiptera	18	40	8840
Thysanoptera	2	9	22
Neuroptera	1	1	149
Coleoptera	11	24	153
Trichoptera	1	1	51
Lepidoptera	7	23	9370
Hymenoptera	1	1	388

Most of the species are rare in the samples, with 90 (56%) having 10 or less individuals. Quite noticeable is the relatively high proportion of

singletons, either at archipelago level (44 species; 27%) or at island level, with particular emphasis for Terceira Island (39 species), where they account for approximately 37% of the species collected in juniper canopies (Table 2). The same may be said for the number of uniques, with 49 uniques for the Azores as a whole and 42 uniques in Terceira (40%). Only six species (3.7%) had more than 1000 individuals. The endemic moth *Argyresthia atlanticella* (Lepidoptera: Yponomeutidae) was the single most abundant species collected on the juniper canopies, with 8483 individuals (23.1%). The endemic canopy sheet weaver *Savigniorrhypis acoreensis* (Araneae, Lyniphidae) and the native mesh web weaver *Lathys dentichelis* (Araneae, Dytinidae) were the most

abundant spiders, with 5758 (15.7%) and 4089 (11.1%) specimens collected, respectively. The other highly diverse and abundant order, the Hemiptera, are also represented by the native juniper specialist giant conifer aphid *Cinara juniperi* (Hemiptera, Lachnidae) with 3085 individuals (8.4%) and by the endemic planthopper from São Miguel *Cixius insularis* (Hemiptera, Cixiidae) with 1232 specimens (3.4%). The native cockroach *Zetha vestita* ranks as the fifth most abundant species, with 1509 individuals (4.1%) captured. These six species account for 65.8% of all collected individuals (see also Appendix I for further details), and may be considered as the most common canopy dwellers of the Azorean cedar.

Table 2. Summary table with the Arthropod species richness (S), abundance (N), diversity indexes (Fisher α , Shannon-Wiener), number of singletons and doubletons (species present with one and two individuals), uniques and duplicates (species found only in one and two samples) for the total number of individuals and for each colonisation class (Nat, native; End, endemic; Int, introduced), for the entire archipelago and for each individual island. Values in parenthesis indicate the corresponding standardized value, obtained from sample based accumulation curves rarefied at 40 samples. T - Total collected species. FLO – Flores; FAI – Faial; PIC – Pico; SJG – São Jorge; TER – Terceira; SMG – São Miguel.

		Azores	FLO	FAI	PIC	SJG	TER	SMG
S		161	54 (41.1)	50 (50)	73 (56.3)	62 (55.0)	106 (50.9)	67 (58.8)
S_{Nat}		62	20 (13.86)	22 (22)	26 (20.2)	22 (19.87)	38 (17.25)	26 (23.72)
S_{End}		50	27 (21.6)	19 (19)	27 (23.2)	28 (26.3)	35 (20.2)	21 (19.1)
S_{Int}		49	7 (5.7)	9 (9)	20 (12.9)	12 (9.9)	33 (13.5)	20 (17.0)
N		36729	6297	1681	7401	4119	13657	3574
N_{Nat}		11563	655	731	2120	768	6044	1245
N_{End}		24159	5577	882	5036	3300	7152	2212
N_{Int}		1007	65	68	245	51	461	117
Fisher α		-	8.11 ± 0.42	9.69 ± 0.62	11.25 ± 0.51	10.35 ± 0.54	15.65 ± 0.57	11.70 ± 0.60
Shannon-Wiener		-	1.97	2.58	2.71	2.04	2.69	2.25
Species per tree		9.09 ± 3.69	7.64 ± 3.71	9.28 ± 2.92	10.01 ± 4.01	9.47 ± 3.43	9.30 ± 3.29	7.63 ± 4.63
Sampled Trees		739	100	40	140	60	340	59
Singletons	T	44	14 (11.1)	14 (14)	13 (11.1)	16 (14.4)	39 (14.3)	16 (16.7)
	Nat	21	8	7	3	6	14	7
	End	8	5	5	4	4	9	2
	Int	15	1	2	6	6	16	7
Doubletons	T	19	5 (3.8)	4 (4)	3 (5.9)	6 (7.6)	4 (6.0)	14 (16.7)
	Nat	6	2	1	2	4	1	5
	End	3	2	3	0	2	1	6
	Int	10	1	0	1	0	2	3
Uniques	T	49	15 (12.14)	16 (16)	14 (13.35)	18 (16.93)	42 (17.99)	21 (21.41)
	Nat	23	8	8	3	8	15	9
	End	17	6	6	4	4	10	4
	Int	9	1	2	7	6	17	8
Duplicates	T	21	7 (4.30)	4 (4)	4 (8.89)	7 (7.99)	6 (7.12)	12 (10.07)
	Nat	8	3	1	3	4	3	3
	End	10	3	2	0	2	1	6
	Int	3	1	1	1	1	2	3

There is a profound imbalance in the sampling effort, with Terceira Island having the highest number of individuals (13657) and comparatively high species richness, but at the same time it has more than double the number of samples of the second most sampled island (Pico Island, Table 2). When standardizing the number of samples, a more homogeneous set of richness and abundance values was obtained (Table 2).

Rarity patterns

If the species are grouped into modified Preston's octaves, it is possible to observe that for the total number of collected species, for native species and also for the introduced ones it follows a unimodal distribution, with many rare species and few truly abundant species. On the other hand, the endemics present a more complex multi-modal distribution with some rare and abundant species, and also a large proportion of intermediately abundant species (Fig. 3).

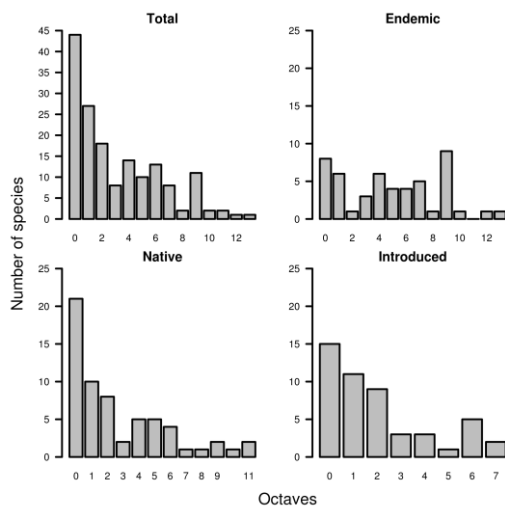


Fig. 3. Modified Preston's octaves histograms for all, endemic, native and introduced species. The three graphs for the three individual colonisation status are scaled equally for the Y axis.

Considering the species in the first quarter of the octaves as truly rare (Gaston 1994), a total of 97 species (or 60% of the total number of species collected on juniper canopies) can be considered as rare in that habitat. If the different colonization classes are considered, 63% of the native species, 36% of the endemic and 53% of the introduced

species are rare in the inventory. If the same binning is done to each island using the total number of species, once again the high number of locally rare species is clear on Faial, São Jorge, Terceira and São Miguel islands. The exceptions are Pico and Flores islands, which show a bimodal distribution with many rare and intermediate species (Fig. 4). Repeating the procedure for the islands using the different colonisation classes results in the broad maintenance of the general class pattern (see Fig. 3) in each island.

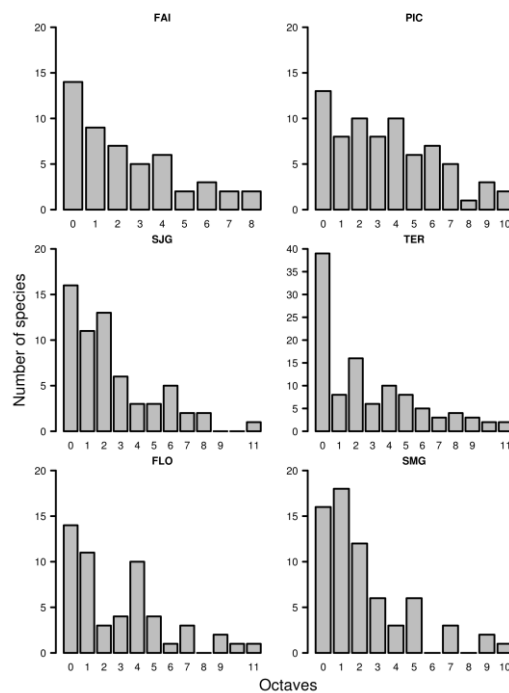


Fig. 4. Modified Preston's octaves histograms for each of the six sampled islands using all species sorted by island groups. FAI – Faial; PIC – Pico; SJG – São Jorge; TER – Terceira; FLO – Flores; SMG – São Miguel. All graphs except the one for Terceira (TER) are scaled equally for the Y axis.

The α GamBin parameter presents a potentially informative ecological diversity metric, because it summarizes the shape of the SAD in a single number. Alpha Gambin values between 0 and 1.5 indicate usually a Log series distribution, between 2 and 2.5 approximates to a Log normal and values higher than 3, more complex multinomial distributions. For deeper explanation of the

GamBin model see Matthews et al. (2014). So, as a simple and intuitive measure of the shape of the SAD's and to better compare the distinct species distributions in Figures 3 & 4, the values of Alpha GamBin and the approximate shape of the distributions as given by the index are presented in Table 3.

Table 3. Alpha GamBin indexes for all, endemic, native and introduced species, as well as for each of the six sampled islands, using all species. FAI – Faial; PIC – Pico; SJG – São Jorge; TER – Terceira; FLO – Flores; SMG – São Miguel.

Colonization Class	Alpha Gam-Bin index	Distribution shape
All	0,99	logseries
Endemic	2,34	lognormal
Native	0,85	logseries
Introduced	1,34	logseries

Island	Alpha Gam-Bin index	Distribution shape
FAI	1,47	logseries
PIC	2,23	lognormal
SGJ	1,08	logseries
TER	0,88	logseries
FLO	1,17	logseries
SMG	1,09	logseries

Species richness

Analysing the proportion of endemic, native and introduced species, we found that both at the Azores archipelago as a whole and at individual island level, species richness is more or less evenly distributed amongst the three colonisation categories (endemic, native and introduced) with the exception of Flores, Faial and São Jorge, where less than 20% of the species are introduced (Fig. 5). Nevertheless, there were no statistically significant differences among the islands ($X^2 = 12.571$, $df = 10$, $p\text{-value} = 0.249$).

Considering the archipelago as a whole, the orders Araneae, Hemiptera, Coleoptera, Lepidoptera and Psocoptera were the most diverse, with both Araneae and Hemiptera registering 40 species each, from the 161 collected.

The most diverse families were Linyphiidae –

Araneae with 14 species (six introduced), Staphylinidae - Coleoptera with nine species (four introduced) and Cixiidae - Hemiptera with a total of seven endemic species.

When each island is considered individually, we find that the previous pattern is similar, with Araneae and Hemiptera accounting, in each island, for roughly 50% of the collected species (Fig. 5), with a Chi-square test showing no significant differences in the proportions of the 5 most species diverse orders between the islands ($X^2 = 12.38$, $df = 25$, $p\text{-value} > 0.05$).

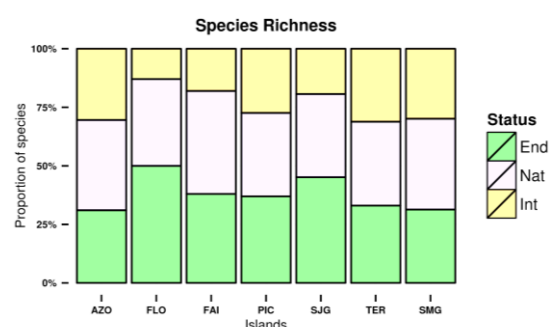


Fig 5. Proportion of species per colonisation status for endemic, native and introduced species at archipelago and island level.

Considering the colonisation status of the species, some deviations from the previous pattern are observed (Fig. 5). For endemics the general pattern is maintained along the archipelago, but with higher proportions of spider and true bug species (particularly spiders). The native Hemiptera account for roughly 40% of the collected native species. As with the case of the total species richness, Chi-square tests showed no significant differences between the islands when considering the share of each Order in the island's species richness (native: $X^2 = 10.30$, $df = 25$, $p\text{-value} > 0.05$; endemic: $X^2 = 9.40$, $df = 25$, $p\text{-value} > 0.05$; introduced: $X^2 = 22.14$, $df = 25$, $p\text{-value} > 0.05$). In the case of the introduced species, Araneae and Coleoptera are the most diverse orders at archipelago level, but when looking at each island there is no discernible transversal pattern as was the case for the endemic and native species, notwithstanding the prevalence of spider species on most islands (Fig. 6).

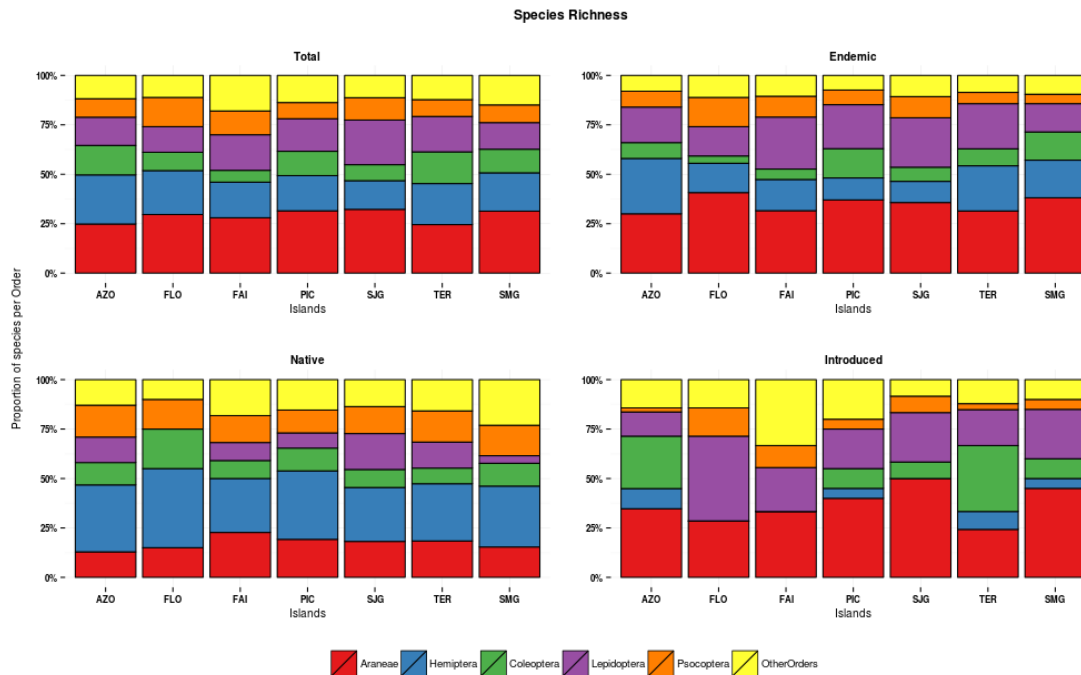


Fig. 6. Proportion of species per order at archipelago and island level, for all species, endemics, natives and introduced species.

Abundance

Taking abundance into consideration, the general patterns change. Native species on all islands account for more than 50% of collected individuals, but nevertheless the proportion of individuals in each colonisation level is significantly different between the islands ($X^2 = 49.84$, $df = 10$, p -value < 0.0001) and samples from Flores are dominated by individuals of endemic species (almost 90%). Also quite strikingly, introduced species account on average for less than 4% of the number of individuals collected on each island (Fig. 7). *Post-hoc* tests show that Flores was significantly different from the remaining islands with the exception of São Jorge. São Jorge was also significantly different from Terceira and Faial (see Appendix IV, Table 1).

Considering the archipelago as a whole, Araneae is the most abundant order, with more than 13500 collected individuals, followed by Lepidoptera and Hemiptera. On the other hand, Coleoptera, despite its relatively high species richness, accounts for much less than 1% of all

collected individuals, with only 153 collected in the entire archipelago. It is also conspicuous the disparity in the proportions of each of the five most abundant orders in each island, with no apparent common pattern, which translates into a significant difference between them ($X^2 = 139.79$, $df = 25$, p -value < 0.0001) (see Fig. 8). *Post-hoc* tests indicate that Terceira and São Miguel were significantly different from most of the other islands (see Appendix IV, Table 2).

In all the islands spiders and true bugs account for roughly 80% of the collected specimens, but the ratio between them varies in each island, with São Jorge and São Miguel being dominated by spiders whereas in Faial and Flores true bugs account for almost half of the collected individuals. There is also a relatively high abundance of the native cockroach *Zetha vestita* in all the islands except Faial and Pico. In the case of endemic species, it is quite conspicuous the high proportion of Lepidoptera individuals collected in the samples from Flores, Faial, Pico and São Jorge, mainly the ermine moth *Argyresthia atlanticella*

as well as the dominance of Hemiptera in São Miguel (roughly 55% of the collected individuals) particularly the single island endemic *Cixius insularis*. Once more, for the introduced species, there is no discernible pattern of abundance for the islands of the archipelago (see Fig. 8). Chi-square tests confirmed this graphical interpretation by showing significant differences between the islands at all colonisation status (native: $X^2 = 112.56$, $df = 25$, $p\text{-value} < 0.0001$; endemic: $X^2 = 203.94$, $df = 25$, $p\text{-value} < 0.0001$; introduced: $X^2 = 182.85$, $df = 25$, $p\text{-value} < 0.0001$). For natives, *post-hoc* tests show that São Miguel and Faial were significantly different from most of the other islands, while for endemics São Miguel was once more significantly different from the remaining islands and Terceira was significantly different from Flores, Faial and São Jorge.

introduced species, only the “Triangle” islands (Faial, Pico and São Jorge) showed no significant differences between them. See Appendix IV, Table 2 for further details.

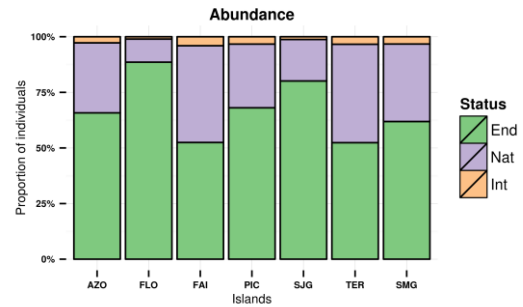


Fig. 7. Proportion of abundance per colonisation status for endemic, native and introduced species at archipelago and island level.

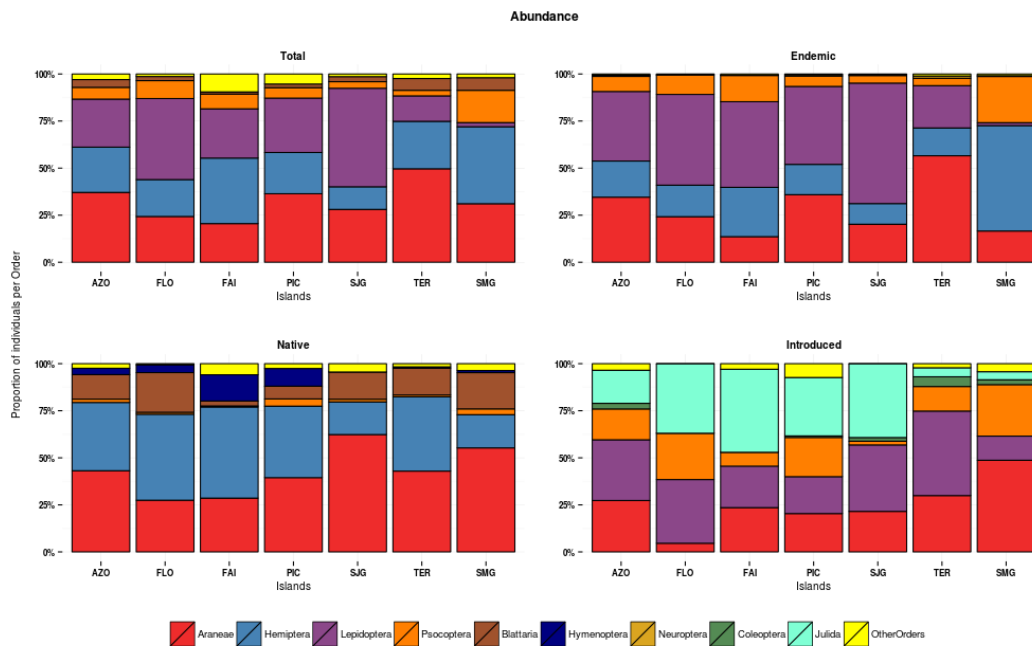


Fig. 8. Proportion of abundance per order at archipelago and island level, for all species, endemics, natives and introduced species.

Functional groups and feeding modes

When considering the functional groups to which the collected individuals belong, 76 species (47%) are herbivores, 60 (37%) are predators (of which 40 are arachnids) and 24 (15%) are saprophytes. There is also one omnivore ant species

and 3 fungivorous species (Fig. 8). Fungivorous arthropods were represented, at archipelago level, by only 10 individuals divided amongst 3 species in Terceira and 2 individuals of one species in São Miguel. We found a great constancy in the proportion of species belonging to each functional

groups across all the islands (Chi-square tests showed no significant differences – $X^2 = 11.56$, $df = 20$, $p\text{-value} > 0.05$). In all the islands almost half the species present in juniper trees are herbivores, and predators (mostly spiders) represent roughly 35% of the species. Only in São Miguel there are slightly more predator than herbivore species. Saprophytes make up the majority of the remaining species.

When looking at the division in functional groups by number of collected individuals (Fig. 9), Chi-square tests showed significant differences between the islands ($X^2 = 64.08$, $df = 15$, $p\text{-value} < 0.0001$). The only common feature is that the herbivores were more abundant than predators and saprophytes combined, with the exception of Terceira, where there were more specimens of predators than those of herbivores in the juniper canopies and in São Miguel, where there is a relatively high proportion of saprophytes. *Post-hoc* tests show that Terceira is significantly different from Faial and Flores, and that São Miguel is significantly different from Faial and São Jorge (see Appendix IV, Table 3).

When the feeding mode is considered (Fig. 10), it is possible to observe a repetition of the previous patterns, with the proportions of each category being more or less conserved across the archipelago where species are concerned (and no significant differences were observed – $X^2 = 13.81$, $df = 35$, $p\text{-value} > 0.05$). Considering the proportion of collected individuals in each category, once again, no common pattern is observable, with the general pattern for each island following the trends for trophic guild and for the orders when considering the total of individuals. Again, a Chi-square test indicates that the islands are significantly different from each other ($X^2 = 151.48$, $df = 35$, $p\text{-value} < 0.0001$). *Post-hoc* tests show that São Miguel was significantly different from the other islands. Terceira was also significantly different from all other islands except Pico (Pico showed no significant differences from the islands of the Central Group nor from Flores). See Appendix IV, Table 4 for further details.

Species community similarity

The islands from the central group have the highest proportion of shared species as shown by the higher number of common species and by the

higher values of Bray-Curtis similarity (Table 4). Pico, Terceira and São Jorge islands also have a high number of shared species with Flores, whereas São Miguel has the lowest values of similarity with the remaining islands. Considering the colonisation status (Table 4), we can say that the previous pattern is probably driven by the endemic species, as these maintain and even exacerbate the trends observed for the complete data set, whereas the native species display higher values of Bray-Curtis similarity, and therefore are not spatially structured. Introduced species are in general present in low numbers, display more or less homogeneous values of Bray-Curtis similarity and do not seem to conform to a particular spatial pattern, appearing spread throughout the islands.

Using the rarefied set of data (Table 5) we can state that the general similarity trends from the observed data are maintained, with the islands from the Central Group being the most similar and with São Miguel and Flores being the most dissimilar. The rarefaction also smoothed down the effects of the sampling bias for Terceira, as these values are more on a par with those from the remaining islands of the Central Group.

To complement our similarity analysis, we ordinated transects according to their similarity values (measured with Bray-Curtis coefficient) using NMDS. The first two axes of the NMDS had a stress value of 0.2 indicating that two dimensions were enough to give an acceptable representation of our data. The NMDS using the full set of data (Fig. 11) reveal that: 1) the islands of the Central Group share many species; 2) in the two dimensional space defined by the NMDS, the dispersion of the transects of each island and particularly for Terceira is noticeably low (i.e. transects within an island share many species); 3) São Miguel Island stands apart from the remaining of the archipelago and the scattering of transects is particularly high (i.e. strong heterogeneity between between transects in terms of species composition); and 4) Flores Island stands slightly apart from the Central Group and diametrically opposite to São Miguel. In general, the configuration of islands on the NMDS plot follows their spatial geographical configuration. As expected, the introduced species break this pattern, in accordance with the results from Tables 4 and 5.

Biota associated with *Juniperus brevifolia*

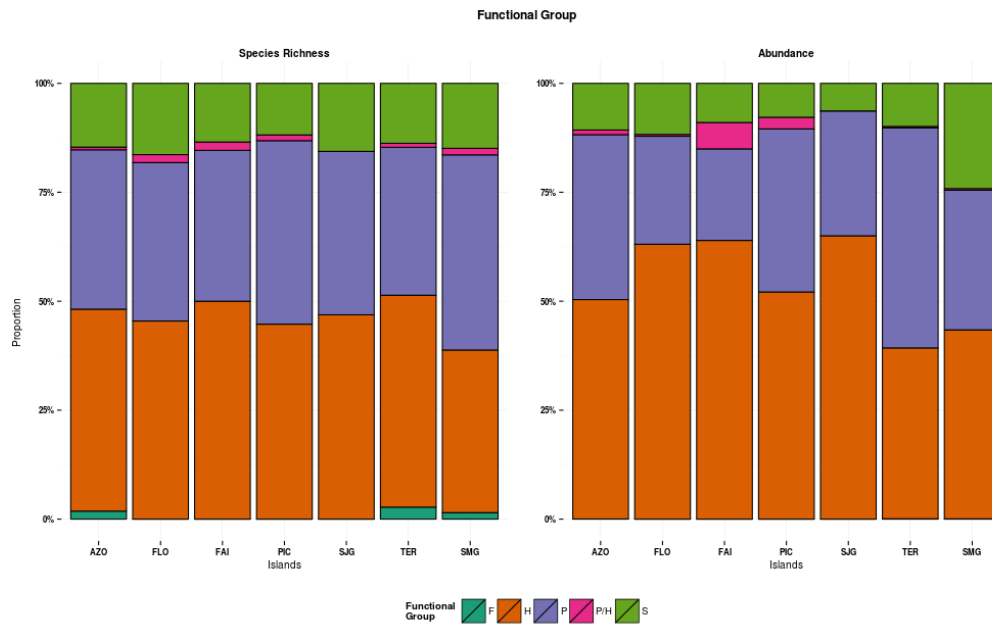


Figure 9. Proportion of species and abundance per different functional groups at archipelago and island level. S - Saprophyte, P/H - Omnivorous; P - Predator; H - Herbivore; F - Fungivore.

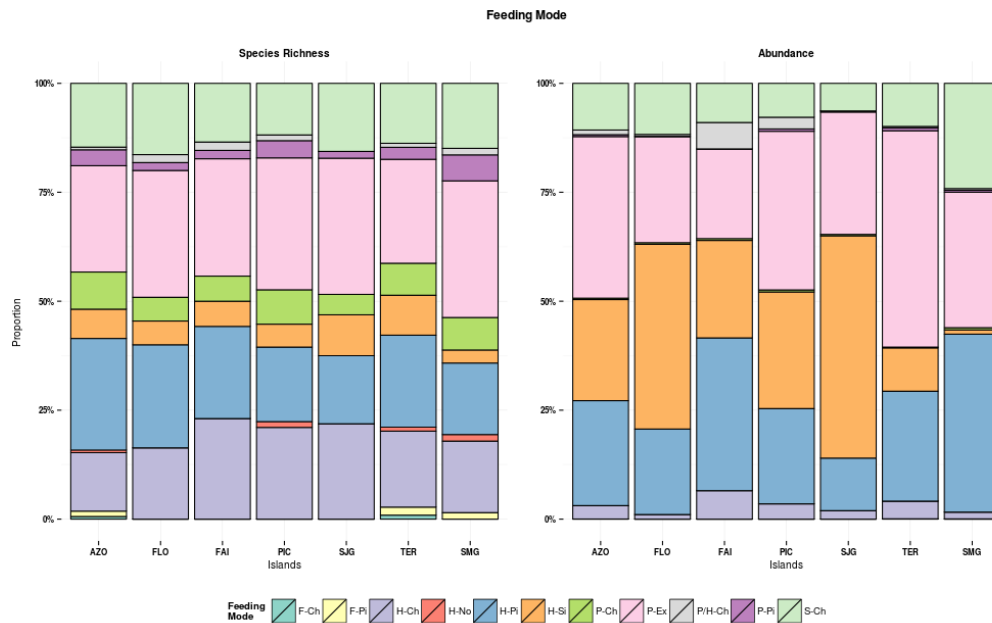


Fig. 10. Proportion of species and abundance per different feeding modes at archipelago and island level. Ex - External digestion and sucking; Ch - Chewing and cutting; Pi - Piercing and sucking; Si - Siphoning; No - Not feeding.

Table 4. Summary of the results of the shared species analysis for the observed data using all species, endemics natives and introduced. Main diagonal – number of species present in the island, upper half – number of shared species between the islands, lower half – Bray-Curtis similarity index values.

Observed							Nat						
Total	TER	FAI	FLO	PIC	SJG	SMG	TER	FAI	FLO	PIC	SJG	SMG	
TER	106	41	41	54	50	45	38	17	13	19	15	16	
FAI	0,18	50	33	42	38	34	0,19	22	12	17	15	16	
FLO	0,36	0,22	54	38	38	32	0,19	0,3	20	14	12	12	
PIC	0,53	0,32	0,6	73	46	43	0,43	0,49	0,36	26	17	16	
SJG	0,33	0,36	0,63	0,64	62	38	0,21	0,438	0,58	0,51	22	14	
SMG	0,19	0,24	0,14	0,27	0,24	67	0,31	0,46	0,3	0,61	0,53	26	
End							Int						
TER	FAI	FLO	PIC	SJG	SMG	TER	FAI	FLO	PIC	SJG	SMG		
TER	35	17	21	22	24	33	7	7	13	11	11		
FAI	0,17	19	15	18	16	0,22	9	6	7	7	6		
FLO	0,45	0,19	27	18	20	0,24	0,68	7	6	6	6		
PIC	0,59	0,23	0,67	27	21	0,47	0,36	0,32	20	8	10		
SJG	0,42	0,33	0,64	0,7	28	0,2	0,71	0,64	0,26	12	7		
SMG	0,09	0,1	0,1	0,12	0,14	21	0,19	0,2	0,34	0,3	0,2	20	

Table 5. Summary with the geometric means of the results from the 10 sets of rarefied shared species analysis using all species, endemics, natives and introduced. Main diagonal – averaged number of species present in the island, upper half – averaged number of shared species between the islands, lower half – averaged Bray-Curtis similarity index values.

Rarefied							Nat						
Total	TER	FAI	FLO	PIC	SJG	SMG	TER	FAI	FLO	PIC	SJG	SMG	
TER	44,6	29,2	23,3	30,2	31,9	24,2	14,7	11,6	7,1	10,4	10,1	9,3	
FAI	0,43	50	25,8	35,9	35,2	28	0,51	22	8,7	14,1	13,5	13,6	
FLO	0,35	0,37	37,6	26,2	27,7	22	0,26	0,22	12,2	8,2	7,9	8,2	
PIC	0,49	0,55	0,51	52,9	35,6	28,5	0,53	0,58	0,32	18,6	11,2	11,7	
SJG	0,42	0,43	0,56	0,56	55,1	28,7	0,61	0,45	0,43	0,53	18,5	11,3	
SMG	0,33	0,23	0,11	0,23	0,19	53	0,59	0,46	0,16	0,43	0,47	20,9	
End							Int						
TER	FAI	FLO	PIC	SJG	SMG	TER	FAI	FLO	PIC	SJG	SMG		
TER	18,2	12,5	11,9	13	15,1	9,3	11,2	4,9	4,1	6,6	6,4	5,3	
FAI	0,37	19	12,3	15,8	15,5	9,6	0,28	9	4,7	6	6,1	4,7	
FLO	0,37	0,43	19,7	13,4	15,5	9,5	0,25	0,46	5,5	4,3	4,1	4,1	
PIC	0,47	0,52	0,56	21,8	18	11	0,3	0,6	0,35	12,4	6,1	5,5	
SJG	0,35	0,41	0,58	0,56	26,2	12,3	0,32	0,53	0,46	0,46	10,3	4,9	
SMG	0,17	0,09	0,09	0,12	0,09	16,3	0,15	0,17	0,23	0,24	0,17	15,4	

Biota associated with *Juniperus brevifolia*

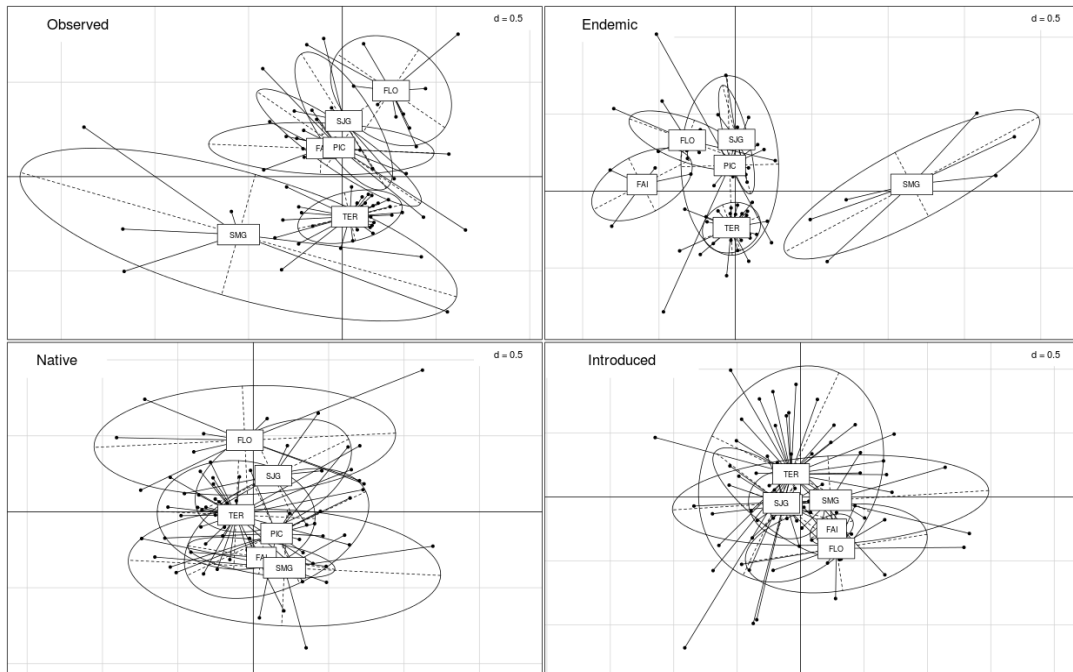


Fig. 11. Nonmetric Dimensional Scaling (NMDS) with Bray-Curtis similarities for the six islands using: Total - the full set of data; endemic native and introduced species data.

This separation of São Miguel from the remaining of the archipelago is even more clear when considering only the endemic species and it is equally clear the dissimilarity between transects. This pattern is contrary to the apparent similarity observed between the remaining islands. The native communities seem to be fairly similar in each island and also across the archipelago, with the groups showing a great overlap, whereas for the introduced species, all the islands have fairly similar species compositions, although with some heterogeneity between transects in each island.

This visual assessment of the NMDS ordination plots can be statistically tested by using the allied statistical method of Analysis of Similarities (ANOSIM). When considering the whole community or only the endemic species, the compositional dissimilarities seen in the ordination plots are confirmed by significantly high R^2 values (Total: $R^2 = 0.76$, $p = 0.001$; endemic: $R^2 = 0.83$, $p = 0.001$) obtained. The analysis of similar-

ities for the native species indicates that there are still significant dissimilarities between the species composition of each island, but the relatively lower R^2 value hints at a more uniform distribution of the species in the archipelago and/or at a higher intra-island dissimilarity ($R^2 = 0.39$, $p = 0.001$). The ANOSIM for the introduced species indicates that there are no significant dissimilarities between islands/clusters and that the intra-island dissimilarity is high ($R^2 = 0.02$, $p = 0.328$). Regarding the standardized data, we can observe that the general patterns shown by the full set of data are broadly maintained either with all the individuals or when divided by colonisation status, as can be seen by the example in Figure 12. In fact, some trends are even more noticeable, such as the differentiation of São Miguel from the remaining of the archipelago or the diametrical opposite position of Flores Island in relation to São Miguel (Fig. 12).

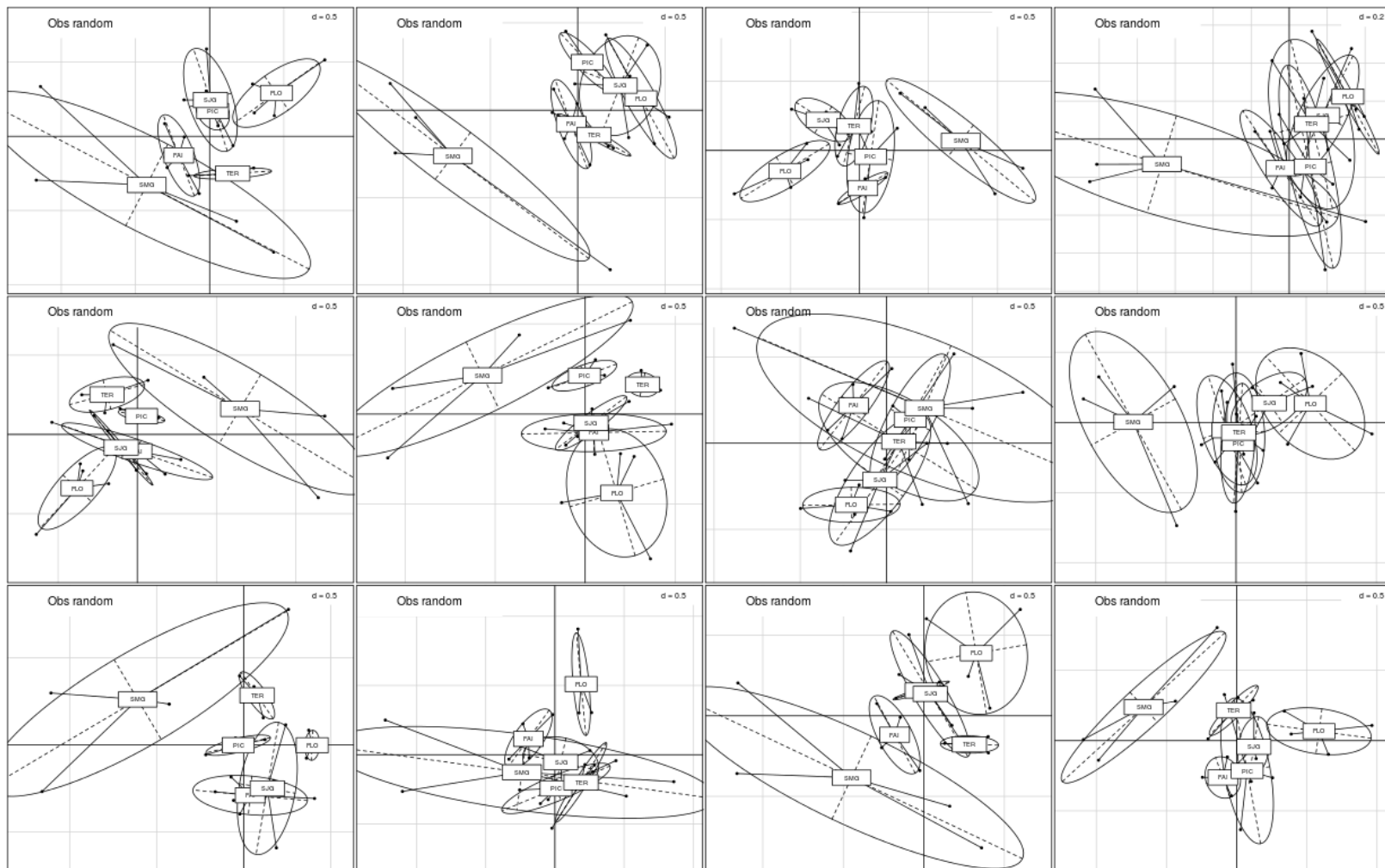


Fig. 12. Examples of Nonmetric Dimensional Scaling (NMDS) with Bray-Curtis distances for the six islands, using four randomly selected transects per island, for the total set of species

Table 6 presents the results for the observed (unrarefied) set of data together with mean R^2 and the 95% confidence interval for the rarefied data. For the total number of species and for the endemic species, the constructed confidence intervals (CIs) are relatively narrow and the observed R^2 value is slightly higher than the upper quantile of the CI. The observed ANOSIM R^2 for native species sits inside the CI for this category. For the introduced species the mean R^2 is also quite low and the observed R^2 actually falls under the lower quantile of the constructed CI.

Table 6. Summary table for ANOSIM results for the total of arthropod species, endemics, natives and introduced and for 999 ANOSIM rarefied replicates with the corresponding mean R^2 and 95% confidence interval for each of the aforementioned categories.

Observed	-	R^2	Signif.
Total	-	0,76	0,001
Endemic	-	0,83	0,001
Native	-	0,39	0,001
Introduced	-	0,02	0,328
Rarefied replicates	CI 95%	Mean R^2	-
Total	0.52 - 0.74	0,63	-
Endemic	0.58 - 0.79	0,69	-
Native	0.09 - 0.41	0,24	-
Introduced	0.04 - 0.31	0,17	-

Other taxa

Juniperus brevifolia, existing in a wide range of elevation belts, accommodates a large number of taxa. Besides Arthropods, it is also an important substrate to other vascular species, to bryophytes (liverworts and mosses), to lichens and also to birds. The list of occurrence of all the documented taxa may be found in Appendix II, while the bibliographic references are mentioned in Appendix III.

The endemic hemi-parasitic *Arceuthobium azoricum* is of particular interest among flowering species, and, among the five fern species preferentially epiphytes on *J. brevifolia*, two are considered very rare, *Ceradenia jungermannioides* and *Grammitis azorica*. In the field, it is sometimes possible to observe other vascular plants growing on *Juniperus brevifolia*, such as *Lactuca watsoniana*, *Erica azorica*, *Myrsine africana* or even seedlings of the *Juniperus brevifolia* itself.

There is a large number of bryophyte species growing on *Juniperus brevifolia* (105; 22.1%) (Appendix II.1). All of these are either endemic of the archipelago (one; 14.3%), the Macaronesia (five; 35.7%), the Iberian Macaronesia (four; 100%), Europe (seven; 58.3%) or native to the Azores (Appendix II).

The proportion of species growing on *Juniperus brevifolia* differs among the islands (c.f. Table 7), but apart from Graciosa (where the tree is no longer present) and Santa Maria (where appropriate references are lacking), all other islands have liverworts and mosses referred to this substrate. The islands of Pico (Homem 2005), São Jorge and Terceira (cf. Gabriel 2000; Gabriel & Bates 2005) present the highest richness values of species growing on this tree. The variation among these values is probably more related to the detail of studies published for each island, than to any real differences of the quality of the substrate. Recently, in inventories made with the Moveclim protocol (cf. Gabriel et al. 2014), many specimens were collected from *Juniperus brevifolia* and later works will probably even out these values.

From the 105 bryophytes growing on *Juniperus brevifolia*, 30 species are considered as Conservation Concern by the IUCN (Dierssen 2001) (cf. Appendix II). Vulnerable species include nine liverworts (*Acrobolbus wilsonii*, *Aphanolejeunea azorica*, *A. sintenisii*, *Cephalozia crassifolia*, *Cheilolejeunea cedercreutzii*, *Leptoscyphus azoricus*, *Pallavicinia lyellii*, *Telaranea azorica*, *Tylimanthus laxus*) and one moss (*Daltonia stenophylla*).

Lichens are another taxonomic group that takes advantage of *Juniperus brevifolia* as a substrate (Appendix II.3). From the 781 lichens referred to the Azores (Aptroot et al. 2010), 106 were described as growing on this tree (Table 8). Apart from *Dictyonema interruptum*, one of the six Basidiomycota referred to the archipelago, the 105 Ascomycota are distributed among the islands in an uneven way, most of the species from Terceira Island (Aptroot et al. 2009), but with the highest proportion in Flores Island, where lichens occurring on *Juniperus brevifolia* bark account for about one third of the species (37; 31.1%). Five lichen species occurring on *Juniperus brevifolia* are considered endemic of the archipelago (*Nephroma hensseniae*; *N. venosum*, *Peltigera*

dissecta, *Peltigera melanorrhiza* and *Thelotrema antoninii*), while three species of the genus *Usnea* are considered Macaronesian endemic (*Usnea geissleriana*, *U. macaronesica* and *U. subflammea*). Besides plants and lichens, also birds use *Juniperus brevifolia* tree. It is possible to find explicit references in literature (Bannerman &

Bannerman 1966; Gabriel 2000; Cabral et al. 2005 and Moura 2014 - Appendix III) to the three subspecies of firecrest (*Regulus regulus azoricus*, *R. r. inermis* and *R. r. sanctaemariae*) and the Azores wood pigeon (*Columba palumbus azorica*) (Appendix II.4). All these subspecies are endemic to the Azores.

Table 7. Number and proportion of bryophyte species occurring in *Juniperus brevifolia* and in all substrata, for each of the nine Azorean Islands and the Azores (total) for liverworts (Division Marchantiophyta) and mosses (Division Bryophyta).

Division	Substrate	Cor	Flo	Fai	Pic	Gra	SJo	Ter	SMi	SMa	Total
Marchantiophyta											
	<i>J. brevifolia</i>	10	10	15	49	0	17	55	7	0	65
		15.2%	9.3%	13.8%	40.5%	0.0%	36.2%	38.2%	5.5%	0.0%	39.6%
	All substrata	66	107	109	121	47	131	144	127	74	164
Bryophyta											
	<i>J. brevifolia</i>	3	7	6	23	0	11	29	2	0	40
		2.7%	4.2%	3.4%	14.4%	0.0%	13.3%	13.6%	0.9%	0.0%	12.9%
	All substrata	110	168	174	160	179	83	214	230	139	311

Table 8. Number and proportion of lichen species occurring in *Juniperus brevifolia* and in all substrata, for each of the nine Azorean Islands and the Azores (total) including Division Ascomycota and Division Basidiomycota.

Division	Substrate	Cor	Flo	Fai	Pic	Gra	SJo	Ter	SMi	SMa	Total
Ascomycota											
	<i>J. brevifolia</i>	0	37	13	29	0	3	85	13	0	105
		(0.0%)	(31.1%)	(6.6%)	(12.8%)	(0.0%)	(2.0%)	(18.9%)	(3.4%)	(0.0%)	(13.5%)
	All substrata	13	119	196	227	149	148	449	384	56	775
Basidiomycota											
	<i>J. brevifolia</i>	0	0	0	0	0	0	1	0	0	1
		(0.0%)	(0.0%)	(0.0%)	(0.0%)	(0.0%)	(0.0%)	(100%)	(0.0%)	(0.0%)	(%)
	All substrata	0	1	1	1	0	2	1	3	0	6

DISCUSSION

There is a large body of studies regarding arthropod canopy communities, encompassing a wide range of habitats and spectrum of host plants (Stork 1991; Winchester 1997; Kuria et al. 2010). In many of these studies there is a remarkable constancy in the proportions of certain functional

groups and orders (Moran & Southwood 1982; Krüger & McGavin 2001) and the most abundant and diverse orders in our study (Araneae, Hemiptera, Lepidoptera) also tend to be amongst the most abundant and diverse in other parts of the world (Stork 1991; Floren & Linsenmair 1997). In our study, Coleoptera are an exception that will be discussed further below. Nevertheless, the fact

that hyperdiverse and biologically important groups like Hymenoptera and Diptera, that can be extremely abundant and diverse on tree canopies (Guilbert 1997; Kitching et al. 1997) were not considered in the BALA protocol (except for ants) can somewhat hamper direct comparisons.

Focusing now on data from the Azores, the overall general patterns regarding species richness and abundance agree with general patterns observed in previous studies for the communities of arthropods in Azorean native forests (see Ribeiro et al. 2005; Gaspar et al. 2008), which is not surprising, since juniper samples are an important component of BALA project data. In all instances Araneae, Hemiptera, Lepidoptera and Coleoptera account for more than 75% of the species recorded.

Spiders were previously reported as the most abundant order overall (Gaspar et al. 2008) and also the one with the highest ratio of juveniles to adults (Gaspar et al. 2008). This is also true in the case of our study. This high abundance and diversity of spiders confirms the propensity of an architecturally complex tree as the *J. brevifolia* to accumulate species in general and spiders in particular (Ribeiro et al. 2005; Ribeiro & Borges 2010). This high number of juvenile spiders, most of them of indigenous species, shows that source populations are building up and completing their life cycle on Juniper, taking advantage of the structural complexity of the host tree to protect their postures and juveniles (see e.g. Borges et al. 2008).

Still regarding the spiders, Linyphiidae was the most diverse family of all the collected orders, something that could be related with the high dispersal capabilities of this family (Thomas et al. 2003) allowing for higher chances of arrival/colonisation from the continental landmasses and for easier dispersal amongst the different islands (Borges & Wunderlich 2008; Cardoso et al. 2010; Carvalho & Cardoso 2014).

The relatively high proportion of singletons found in this study is also in accordance with previous findings (Gaspar et al. 2008). The amount of singletons for Terceira is considerably higher than in aforementioned study, but it is still lower than the values reported for herbivore singletons in canopies given in Ribeiro et al. (2005). Additionally, the percentage of rare species as given

by binning the species into octaves (60%) was similar to the results obtained by Ribeiro & Borges (2010) for juniper trees (60% of rare species), although these authors also present the rarity data pertaining to three feeding classes, with corresponding differences in the proportion of rare species. Our results also support these authors' findings regarding the fact that many rare species accumulate in the canopies of *J. brevifolia*. For native and introduced species, it may also be the case that these species have greater dispersal capabilities and thus, could more easily end up as habitat-tourists (Borges et al. 2008). This is almost certainly the case for most introduced species, which almost invariably present low abundances, indicating that the core populations are outside natural forests. It is also possible that this high number of (most likely) locally rare species could be a result of undersampling and/or a combination of phenological, methodological and spatial edge effects (Scharff et al. 2003; Cardoso et al. 2008).

Concerning the functional groups of the collected specimens, both our study and Gaspar et al. (2008) agree on the dominance of predators and herbivores, in terms of abundance and species richness, with these accounting, on all instances, for more than 80% of the individuals or species (respectively) and, mainly in terms of species richness being the proportions of the different functional groups being quite constant through the archipelago. This is not dissimilar from the figures given by Winchester (1997) for temperate coniferous forests or by Krüger & McGavin (2001) for tropical savannah's, and agrees with patterns of functional group proportion constancy in other parts of the world (Moran & Southwood 1982; Stork 1987, 1991). Herbivores were slightly more diverse and abundant than predators, but in our study, Terceira (for abundance) and São Miguel (for richness) deviate from this pattern. On the other hand, Borges et al. (2008) also found more predator than herbivore species on their samples from Terceira. One of the possible reasons might be the aforementioned propensity of juniper to accumulate spiders (Ribeiro & Borges 2010). For herbivores, especially chewers, lower diversity might also be related with the reduced number of food choices available on *Juniperus* (see Winchester 1997).

Also as previously reported (Borges et al. 2008; Gaspar et al. 2008), fungivores were the least well represented group, with only the aforementioned 12 individuals collected, divided between 3 species. This is not altogether surprising since the fungivorous species present in the archipelago belong to families composed mainly of specimens with small body-sizes and cryptic lifestyles. Compounding to this fact, the sampling was done on live tree specimens, whereas the adults and juveniles of these species live mainly on rotten wood, under tree bark or in the fruiting bodies of macrofungi (Watson & Dallwitz 2003; Amorim et al. 2012), thus reducing the chances of being collected using the present methodology.

COLONISATION STATUS

Looking at the colonisation status of the collected specimens, and keeping in mind that we focused in only one host tree species, our results are substantially different from those of previous studies that take into account both, ground and canopy arthropods or the totality of the Azorean habitats. Borges et al. (2010b, with additional updated data) gives 269 endemic arthropods for the Azores, out of a total of 2070 species and subspecies with a well defined colonisation status, which gives us a figure of approximately 13% of endemics. The same study reported that 47% of the arthropod species are introduced. Gaspar et al. (2008), sampling ground and canopy on native forest fragments and Borges et al. (2006) sampling the ground layer on Terceira forest fragments gives less grim figures, with approximately 25% of endemic species and 33% of introduced species. Florencio et al. (2013), working with epigeal arthropods across several habitats reports 13.5% of endemics and 55% of introduced species. These results contrast with ours, as we found that the overall percentage of endemic species on juniper canopies was around 31% (and reaching 50% in Flores Island), whereas the percentage of introduced species was of 30%, but being lower than 20% in Flores, Faial and São Jorge (Fig. 4).

Abundance of endemic and introduced species also differed from previous studies. Figures of almost 50% of endemics and 11% of introduced species are reported in Gaspar et al. (2008), while Florencio et al. (2013) states that 10 endemic and

10 introduced species accounted for 75% of all collected individuals. In our study, the percentage of introduced species on juniper canopies was extremely low, only less than 4% of individuals at archipelago level, but being as low as 1% on islands such as Flores and São Jorge (Fig. 7). This large difference in the relative proportions of abundance and diversity for introduced species in juniper canopies is particularly conspicuous when comparing figures 5 and 7.

As it was seen in previous studies across different habitats, with a higher or lower degree of anthropic disturbance, or even on the epigeal soil component of the extant native forests (Borges et al. 2006, Gaspar et al. 2008; Cardoso et al. 2009; Meijer et al. 2011; Florencio et al. 2013), there is a high abundance and richness of introduced species. Only the canopies, in our case, of *J. brevifolia* seem to remain resistant to the establishment and dominance by introduced species. The data seems to indicate that introduced species are able to disperse to the juniper canopies either from the ground strata or from nearby disturbed habitats (Borges et al. 2008), but that, for now, are unable to gain a foothold and colonise this habitat. This might be due to the high structural complexity of the juniper canopies and its high predator (spider) load (Ribeiro & Borges 2010) or to some sort of hitherto unknown chemical deterrent (see next section). However, since this pattern is also observed for the canopies of other native host tree species (Ribeiro & Borges 2010), it can also be due to the fact that the canopies, with their higher diversity and abundance of native and endemic species, could represent an habitat with less empty ecological niches or due to the fact that introduced generalist species are unable to properly access the nutritional resources present, to find shelter or the appropriate reproductive conditions. It can also be that this pattern is caused by the climatic harshness of the constant conditions of high humidity in the canopies of the Azorean high altitude forests remnants (see Grimbacher & Stork 2007).

Whatever the true cause might be, from these and previous results it is possible to assume that despite the high proportion of introduced species in the Azores archipelago, the remnants of the native forests, and more specifically their cano-

pies, still maintain a high proportion of its original fauna. This pattern is not exclusive of *J. brevifolia*, but a characteristic of the native Azorean canopies in general, as further articles dealing with the remaining structurally important native trees should confirm. As such, it can be said that the canopies in the extant patches of native forest act as a small window to what was the original pristine Azorean arthropod fauna, at least above the 500 m altitude.

BEETLES (COLEOPTERA)

The near absence of beetles (Coleoptera) in the canopies of juniper is quite remarkable. Coleoptera is the most diverse group of organisms, with approximately 360 000 described species worldwide (Bouchard et al. 2011). It is also a fact that of all the Macaronesia archipelagos, Azores has the lowest proportion of indigenous (native and endemic) beetle species (Triantis et al. 2010a). But this alone does not explain why only 153 individuals were collected, despite the fact that it was the third most diverse group.

Coleoptera diversity in the Azores, even if low compared with that of the Canaries or with other Macaronesian archipelagos (Triantis et al. 2010a) is not that dissimilar from the World's average (Borges et al. 2005c). According to this same study, 31% of arthropod species in the Azores are beetles, this rising to 35% if only endemics are considered. Gaspar et al. (2008) also reports high beetle diversity for native forests of Azores (approx. 30%) but low abundance, with beetles making up only 5% of the collected individuals. This pattern of relatively low diversity and low abundance of beetles for the native habitats of Azores is also alluded to by other authors (Gaspar et al. 2008; Amorim et al. 2012; Terzopoulou et al. 2015; Borges et al. in prep.) and is in sharp contrast with canopy studies in other parts of the world, where this group can comprise more than a quarter of all collected individuals (Stork 1991; Wagner 1997). The percentage of Coleoptera species in our study was low (13%) compared with these studies. Moreover, an important percentage of them are introduced and occurring at low number, thus they might just be habitat tourists. Also, it was previously demonstrated that a large portion of the beetle species present in the Azores are epigeal ground-dwellers (Gaspar et al.

2008) or fungivores with cryptic lifestyles (Amorim et al. 2012) and thus, would not appear in the canopy, or appear only as habitat tourists. Nevertheless, these facts alone do not explain the disproportionately small number of collected individuals. We propose two possible explanations for this disharmony: i) the Azores lost most of its forest area in the last 600 years (Triantis et al. 2010b) leaving only some small high altitude patches. Survivors of this habitat destruction would have been pushed upwards to the higher altitudes and many species could have been unable to cope with the new and harsher climatic conditions. In this scenario, ground-dwelling species would have been less susceptible to these changes, as this stratum is a somewhat more stable and sheltered habitat compared with the canopies, that are more exposed to the abiotic factors (Grimbacher & Stork 2007). Additionally, canopy beetle species have in general larger body-sizes than their ground-dwelling counterparts (Grimbacher & Stork 2007), making them inherently more extinction-prone (Terzopoulou et al. 2015). If this hypothesis was true we should expect to find more species of beetles in canopies at lower altitudes, which is not the case, at least for samples available from Pico Island (unpublished data); ii) alternatively there is an eco-evolutionary explanation: trees of the genus *Juniperus*, as well as many other Cupressaceae are known to produce several essential oils and other substances that are toxic or repellent to arthropods, beetles included (Carroll et al. 2010; Abad et al. 2013; Athanassiou et al. 2013). It can therefore be assumed that the probabilities of arrival to the archipelago of species capable of feeding and reproducing on *J. brevifolia* or its continental relative *J. navicularis*, at the right geologic moment, would be low. Also, it is possible that due to the fact that most of the archipelago's land area is younger than 1 Ma (Triantis et al. 2010a), most of the species that could potentially colonize juniper canopies would not have had enough time to speciate and adapt to that particular habitat. In spite of this, of all the arthropod groups evaluated in Triantis et al. (2010b), Coleoptera were considered to be at a higher extinction risk, and as such, it is possible that what we observe now in the canopies is a consequence of the aforementioned deforestation of the last 600 years or even a recur-

rent pattern with extinctions happening in the past due to some natural event.

SIMILARITIES IN ARTHROPOD ISLAND COMMUNITIES

The observed patterns of similarity between the islands were to be expected and are in accordance with previous works (e.g. Ribeiro et al. 2005). The islands from the Central group (Terceira, São Jorge, Pico and Faial) possess fairly similar communities, while Flores and, more conspicuously, São Miguel stand further apart. For native species the similarities between the islands are much stronger and the differences between São Miguel and Flores can likely be explained by geographical reasons, as both islands sit some 500 km apart on a WNW-ESE axis, and consequently will have different rates of species arrivals, either from continental landmasses or from other islands and archipelagos. The observed dissimilarity in species composition between São Miguel and the other islands is mainly due to the endemic species, and most likely derived by evolutionary processes. São Miguel is the oldest sampled island, meaning that there was more time for *in situ* speciation, increasing the number of endemic and single island endemic species (Borges & Brown 1999; Whittaker et al. 2008; Borges & Hortal 2009). São Miguel is also the closest island to Santa Maria, the oldest island (and from which it would also be interesting to have comparison data), and a probable source of further endemic species (Borges & Hortal 2009; Amorim et al. 2012). The physical distance between the Eastern and Central groups would also help cement this dissimilarity by hindering the dispersal of the species.

Regarding the introduced species, the lower R^2 value obtained suggests a grouping of these species driven by factors acting on different scales other than the island/geological scale (namely historical introduction and habitat change history). Several studies indicate that introduced species increase the similarity between locations (Case 1996; Dormann et al. 2007; Florencio et al. 2013; to name a few), but in this particular case it seems that introduced species have not played yet a big role on the homogenisation of the canopy species assemblages through the archipelago, most likely due to the low number of introduced

specimens present in the juniper canopies, which is in itself a probable consequence of the (for now) low capacity of habitat penetration and colonisation. Nevertheless, the introduced species assemblies are relatively similar throughout the juniper canopies in sampled Azorean islands.

We also recognise the need to study previously neglected but ecologically important arthropod orders such as Hymenoptera and Diptera (this knowledge gap is nevertheless starting to be addressed by currently ongoing studies in Terceira Island), as well as increasing the studies of other important taxonomic groups present in the native forests of the Azores, such as gastropods, fungi, epiphytes, birds and bats.

OTHER BIOTAS

The number of lichens and bryophytes listed as associated with the Azorean juniper is remarkable. Not only the number of endemic species is comparatively high, considering that neither of the groups has more than 10 Azorean endemic species (respectively 10 and seven; Borges et al., 2010a), but the number of conservation concern species for bryophytes is remarkable (30 out of 70; Gabriel et al. 2011). The complexity of the tree and the high diversity of micro-habitats created the conditions for epiphytic species to easily colonize all parts of the tree, from the bottom, trunk and branches. It is obvious that some islands are in need of further studies to complete list of the associated taxa, since there is a large difference among them in the number of species reported for *Juniperus brevifolia*.

FINAL REMARKS

Contrary to other habitats in the archipelago, the canopies of indigenous trees in natural forests, and in this particular case, *Juniper* canopies still maintain a large proportion of native and endemic species, with a low penetration of exotics, and could therefore be considered as windows (albeit incomplete ones) to the original faunal communities of the Azores. A comparison of the findings of this study with those regarding the other Azorean trees would allow a better look at the constancy in the community structure across host tree species and across the islands. It should also be stressed the necessity to do this kind of de-

scriptive analysis to the biota associated with the other structurally important trees from the Azorean indigenous forests. This holistic approach also emphasises the necessity for studies targeting less studied and neglected groups.

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APPENDIX I

Table 1. List of arthropod species associated with *Junipeus brevifolia* in the Azores. The classification system follows the general guidelines presented in Borges et al. (2010a), with the higher taxa listed in a phylogenetic sequence, from the less derived to more derived groups. The families, genera and species are listed by alphabetical order. Exceptions to this are the Arachnidae, who follow the classification of the “World Spider Catalogue” by Platnick (2014); Coleoptera, that follow Bouchard et al. (2011) and Lepidoptera, that follow Aguiar & Karsholt (2006). The genera and species are nevertheless also listed by alphabetical order. Species that were not identified to at least genus level were removed from this list. The colonisation status of each species is presented in the 5th column of the list as follows: E – endemic; N – native; I – introduced. The functional group is given the 6th column as follows: P – predator; H – herbivore; S – saprophyte; F – fungivore; Ex – External digestion and sucking; Ch – Chewing and cutting; Pi - Piercing and sucking; Si - Siphoning; No – Not feeding. Flo, Flores; Fai, Faial; Pic, Pico; SJo, São Jorge; Ter, Terceira, SMi, São Miguel.

Class	Order	Family	Species	Colonisation Status	Feeding Mode	Number of Individuals	Flo	Fai	Pic	SJo	Ter	SMi
Arachnida	Pseudoscorpiones	Neobisiidae	<i>Neobisium maroccanum</i> Beier	I	P-Ch	13		X	X			
	Opiliones	Phalangiidae	<i>Leiobunum blackwalli</i> Meade	N	P-Ch	14		X	X		X	X
Arachnida	Araneae	Mimetidae	<i>Ero furcata</i> (Villers)	I	P-Ex	24			X	X	X	
		Oecobiidae	<i>Oecobius navus</i> Blackwall	I	P-Ex	2					X	X
		Theridiidae	<i>Cryptachaea blattea</i> (Urquhart)	I	P-Ex	5						X
			<i>Lasaeola oceanica</i> Simon	E	P-Ex	99	X		X	X	X	X
			<i>Rhomphaea nasica</i> (Simon)	I	P-Ex	2						X
			<i>Rugathodes acorensis</i> Wunderlich	E	P-Ex	970	X	X	X	X	X	X
			<i>Steatoda grossa</i> (C.L. Koch)	I	P-Ex	11			X			X
			<i>Theridion musivivum</i> Schmidt	N	P-Ex	28			X			
		Linyphiidae	<i>Acorigone acorensis</i> (Wunderlich)	E	P-Ex	167	X	X	X	X	X	X
			<i>Canariphantes acorensis</i> (Wunderlich)	E	P-Ex	1			X			
			<i>Erigone atra</i> Blackwall	I	P-Ex	31		X	X	X	X	X
			<i>Erigone autumnalis</i> Emerton	I	P-Ex	1			X			
			<i>Mermessus bryantae</i> (Ivie & Barrows)	I	P-Ex	1				X		
			<i>Mermessus trilobatus</i> (Emerton)	I	P-Ex	1					X	
			<i>Microlinyphia johnsoni</i> (Blackwall)	N	P-Ex	5					X	
			<i>Minicia floresensis</i> Wunderlich	E	P-Ex	106	X		X	X	X	
			<i>Oedothorax fuscus</i> (Blackwall)	I	P-Ex	72	X	X	X	X	X	X
			<i>Palliduphantes schmitzi</i> (Kulczynski)	N	P-Ex	4					X	
			<i>Savigniorrhhipis acorensis</i> Wunderlich	E	P-Ex	5758	X	X	X	X	X	X
			<i>Tenuiphantes miguelensis</i> Wunderlich	N	P-Ex	8		X			X	
			<i>Tenuiphantes tenuis</i> (Blackwall)	I	P-Ex	66	X	X	X	X	X	
			<i>Walckenaeria grandis</i> (Wunderlich)	E	P-Ex	12					X	

Class	Order	Family	Species	Colonisation Status	Feeding Mode	Number of Individuals	Flo	Fai	Pic	Sjo	Ter	SMi
		Tetragnathidae	<i>Metellina merianae</i> (Scopoli)	I	P-Ex	5			X			
			<i>Sancus acoreensis</i> (Wunderlich)	E	P-Ex	451	X	X	X	X	X	X
		Araneidae	<i>Gibbaranea occidentalis</i> Wunderlich	E	P-Ex	706	X	X	X	X	X	X
			<i>Mangora acalypha</i> (Walckenaer)	I	P-Ex	2				X	X	
		Lycosidae	<i>Pardosa acorensis</i> Simon	E	P-Ex	14	X			X	X	X
		Pisauridae	<i>Pisaura acorensis</i> Wunderlich	E	P-Ex	34	X		X	X	X	X
		Dictynidae	<i>Emblyna acorensis</i> Wunderlich	E	P-Ex	30		X	X			
			<i>Lathys dentichelis</i> (Simon)	N	P-Ex	4089	X	X	X	X	X	X
			<i>Nigma puella</i> (Simon)	I	P-Ex	30						X
		Clubionidae	<i>Cheiracanthium erraticum</i> (Walckenaer)	I	P-Ex	14			X		X	
			<i>Cheiracanthium floresense</i> Wunderlich	E	P-Ex	3	X					
			<i>Cheiracanthium jorgeense</i> Wunderlich	E	P-Ex	1				X		
			<i>Clubiona decora</i> Blackwall	N	P-Ex	106		X	X	X	X	X
			<i>Clubiona terrestris</i> Westring	I	P-Ex	7						X
		Thomisidae	<i>Xysticus cor</i> Canestrini	N	P-Ex	634	X	X	X	X	X	X
		Salticidae	<i>Macaroeris cata</i> (Blackwall)	N	P-Ex	115	X	X	X	X	X	X
			<i>Neon acorensis</i> Wunderlich	E	P-Ex	3	X				X	
			<i>Pseudeuophrys vafra</i> (Blackwall)	I	P-Ex	1						X
Diplopoda	Julida	Julidae	<i>Ommatoiulus moreletii</i> (Lucas)	I	H-Ch	177	X	X	X	X	X	X
Chilopoda	Lithobiomorpha	Lithobiidae	<i>Lithobius pilicornis pilicornis</i> Newport	N	P-Ch	1						X
Insecta	Microcoryphia	Machilidae	<i>Dilta saxicola</i> (Womersley)	N	S-Ch	62			X	X	X	X
			<i>Trigoniophthalmus borgesii</i> Mendes et al.	E	S-Ch	60				X	X	
	Blattodea	Polyphagidae	<i>Zetha vestita</i> (Brullé)	N	S-Ch	1509	X	X	X	X	X	X
	Psocoptera	Caeciliusidae	<i>Valenzuela burmeisteri</i> (Brauer)	N	S-Ch	40	X			X		X
			<i>Valenzuela flavidus</i> (Stephens)	N	S-Ch	19	X	X	X	X	X	
		Ectopsocidae	<i>Ectopsocus briggsi</i> McLachlan	I	S-Ch	165	X	X	X	X	X	X
			<i>Ectopsocus strauschi</i> Enderlein	N	S-Ch	2		X				X
		Elipsocidae	<i>Elipsocus azoricus</i> Meinander	E	S-Ch	57	X	X	X	X	X	
			<i>Elipsocus brincki</i> Badonnel	E	S-Ch	778	X	X	X	X	X	
		Peripsocidae	<i>Peripsocus phaeopterus</i> (Stephens)	N	S-Ch	4			X			
			<i>Peripsocus subfasciatus</i> (Rambur)	N	S-Ch	1					X	
		Psocidae	<i>Atlantopsocus adustus</i> (Hagen)	N	S-Ch	3	X					X

Class	Order	Family	Species	Colonisation Status	Feeding Mode	Number of Individuals	Flo	Fai	Pic	Sjo	Ter	SMi	
		Trichopsocidae	<i>Trichopsocus clarus</i> (Banks)	N	S-Ch	82		X	X	X	X	X	
		Trogiidae	<i>Cerobasis cf sp.1</i>	E	S-Ch	557	X			X		X	
			<i>Cerobasis sp.3</i>	E	S-Ch	542	X						
	Hemiptera	Cicadellidae	<i>Aphrodes hamiltoni</i> Quartau & Borges	E	H-Pi	1	X						
			<i>Eupteryx azorica</i> Ribaut	E	H-Pi	1					X		
		Cixiidae	<i>Cixius azofloresi</i> Remane & Asche	E	H-Pi	752	X						
			<i>Cixius azopifajo azofa</i> Remane & Asche	E	H-Pi	164		X					
			<i>Cixius azopifajo azojo</i> Remane & Asche	E	H-Pi	239					X		
			<i>Cixius azopifajo azopifajo</i> Remane & Asche	E	H-Pi	523				X			
			<i>Cixius azoricus azoricus</i> Lindberg	E	H-Pi	3						X	X
			<i>Cixius azoterceirae</i> Remane & Asche	E	H-Pi	815						X	
			<i>Cixius insularis</i> Lindberg	E	H-Pi	1232							X
		Delphacidae	<i>Megamelodes quadrimaculatus</i> (Signoret)	N	H-Pi	2				X	X		
			<i>Muellerianella sp.1</i>	N	H-Pi	1		X					
			<i>Muellerianella sp.3</i>	N	H-Pi	1		X					
		Flatidae	<i>Cyphopterus adscendens</i> (Herr.-Schaff.)	N	H-Pi	804	X	X	X	X	X	X	X
		Anthocoridae	<i>Brachysteles parvicornis</i> (A. Costa)	N	P-Pi	5			X			X	X
		Lygaeidae	<i>Kleidocerys ericae</i> (Horváth)	N	H-Pi	33	X	X	X	X	X	X	X
		Microphysidae	<i>Loricula coleoptrata</i> (Fallén)	N	P-Pi	2							X
		Miridae	<i>Heterotoma planicornis</i> (Pallas)	N	P-Pi	3				X			
			<i>Monalocoris filicis</i> (Linnaeus)	N	H-Pi	6		X		X		X	
			<i>Pinalitus oromii</i> J. Ribes	E	H-Pi	839		X	X	X	X	X	X
			<i>Polymerus cognatus</i> (Fieber)	N	H-Pi	1			X				
			<i>Nabis pseudoferus ibericus</i> Remane	N	P-Pi	1						X	
		Reduviidae	<i>Empicoris rubromaculatus</i> (Blackburn)	I	P-Pi	1							X
		Psyllidae	<i>Strophingia harteni</i> Hodkinson	E	H-Pi	64			X	X	X	X	X
	Triozidae	<i>Triozia (Lauritriozia) laurisilvae</i> Hodkinson	N	H-Pi	210	X	X	X	X	X	X	X	
		<i>Amphorophora rubi</i> (Kaltenbach) sensu latiore	N	H-Pi	1		X						
	Aphididae	<i>Aphis craccivora</i> Koch	N	H-Pi	1						X		
		<i>Aphis sp.1</i>	N	H-Pi	1							X	
		<i>Rhopalosiphum rufiabdominalis</i> (Sasaki)	I	H-Pi	1						X		
		<i>Toxoptera aurantii</i> (Boyer de Fonscolombe)	I	H-Pi	4				X				

Class	Order	Family	Species	Colonisation Status	Feeding Mode	Number of Individuals	Flo	Fai	Pic	Sjo	Ter	SMi
		Drepanosiphidae	<i>Theriaphis trifolii</i> (Monell)	N	H-Pi	1					X	
		Lachnidae	<i>Cinara juniperi</i> (De Geer)	N	H-Pi	3085	X	X	X	X	X	X
	Thysanoptera	Phlaeothripidae	<i>Apterygothrips n.sp. ?</i>	E	H-Pi	1	X					
			<i>Eurythrips tristis</i> Hood	I	H-Pi	1					X	
			<i>Hoplothrips corticis</i> (De Geer)	N	F-Pi	3					X	X
			<i>Hoplothrips ulmi</i> (Fabricius)	I	F-Pi	4					X	
		Thripidae	<i>Aptinothrips rufus</i> Haliday	I	H-Pi	2			X		X	
			<i>Ceratothrips ericae</i> (Haliday)	N	H-Pi	1					X	
			<i>Heliothrips haemorrhoidalis</i> (Bouché)	I	H-Pi	5			X			X
			<i>Hercinothrips bicinctus</i> (Bagnall)	I	H-Pi	1		X				
			<i>Thrips flavus</i> Schrank	N	H-Pi	4		X		X		
	Neuroptera	Hemerobiidae	<i>Hemerobius azoricus</i> Tjeder	E	P-Pi	149	X	X	X	X	X	X
	Coleoptera	Carabidae	<i>Ocys harpaloides</i> (Audinet-Serville)	N	P-Ch	3	X		X	X		
		Hydrophilidae	<i>Cercyon haemorrhoidalis</i> (Fabricius)	I	S-Ch	1					X	
		Staphylinidae	<i>Aleochara bipustulata</i> (Linnaeus)	I	P-Ch	2				X	X	
			<i>Aloconota sulcifrons</i> (Stephens)	N	P-Ch	1	X					
			<i>Amischa analis</i> (Gravenhorst)	I	P-Ch	4					X	
			<i>Atheta dryochares</i> Israelson	E	P-Ch	21			X		X	X
			<i>Atheta fungi</i> (Gravenhorst)	I	F-Ch	5					X	
			<i>Gabrius nigrutilus</i> (Gravenhorst)	I	P-Ch	1					X	
			<i>Phloeostiba azorica</i> (Fauvel)	E	P-Ch	1			X			
			<i>Proteinus atomarius</i> Erichson	N	P-Ch	1						X
			<i>Sunius propinquus</i> (Brisout)	N	P-Ch	1					X	
		Cryptophagidae	<i>Cryptophagus sp.1</i>	I	S-Ch	2						X
			<i>Cryptophagus sp.6</i>	I	S-Ch	1					X	
			<i>Cryptamorpha desjardinsii</i> (Guérin-Méneville)	I	P-Ch	7					X	
		Phalacridae	<i>Stilbus testaceus</i> (Panzer)	N	S-Ch	1						X
		Nitidulidae	<i>Meligethes aeneus</i> (Fabricius)	I	H-Ch	2			X		X	
			<i>Meligethes sp.2</i>	I	H-Ch	2					X	X
		Latridiidae	<i>Cartodere nodifer</i> (Westwood)	I	S-Ch	1					X	
		Scaptiidae	<i>Anaspis proteus</i> (Wollaston)	N	H-Ch	47	X	X	X		X	
		Chrysomelidae	<i>Chaetocnema hortensis</i> (Fourcroy)	I	H-Ch	1					X	

Class	Order	Family	Species	Colonisation Status	Feeding Mode	Number of Individuals	Flo	Fai	Pic	Sjo	Ter	SMi
		Curculionidae	<i>Calacalles subcarinatus</i> (Israelson)	E	H-Ch	18	X	X	X	X	X	X
			<i>Phloeosinus gillerforsi</i> Bright	E	H-Ch	6			X	X	X	X
			<i>Pseudophloeophagus tenax</i> (Wollaston)	N	H-Ch	23	X	X	X	X	X	X
	Trichoptera	Limnephilidae	<i>Limnephilus atlanticus</i> Nybom ?	E	P-Ch	51	X	X	X	X	X	X
	Lepidoptera	Tineidae	<i>Oinophila v-flava</i> (Haworth)	I	H-No	3			X		X	X
		Yponomeutidae	<i>Argyresthia atlanticella</i> Rebel	E	H-Ch/Si	8483	X	X	X	X	X	X
		Blastobasidae	<i>Blastobasis sp.1</i>	N	H-Si	1				X		
			<i>Blastobasis sp.3</i>	N	H-Si	4					X	
			<i>Neomariania sp.1</i>	I	H-Si	2					X	
		Tortricidae	<i>Rhopobota naevana</i> (Hübner)	I	H-Ch/Si	92	X	X	X	X	X	X
		Crambidae	<i>Eudonia luteusalis</i> (Hampson) ?	E	H-Si	13				X	X	
			<i>Scoparia coecimaculalis</i> Warren ?	E	H-Si	21	X	X	X	X	X	
			<i>Scoparia semiamplalis</i> Warren ?	E	H-Si	2					X	
		Geometridae	<i>Ascotis fortunata azorica</i> Pinker	E	H-Ch	26		X	X		X	X
			<i>Cyclophora azorensis</i> (Prout)	E	H-Ch/Si	239	X	X	X	X	X	
			<i>Nycterosea obstipata</i> (Fabricius)	N	H-Ch	31		X	X	X	X	
			<i>Xanthorhoe inaequata</i> (Warren)	E	H-Ch	117	X	X	X	X	X	
		Noctuidae	<i>Mesapamea storai</i> (Rebel)	E	H-Si	2				X	X	
	Hymenoptera	Formicidae	<i>Lasius grandis</i> Forel	N	P/H-Ch	388	X	X	X		X	X

APPENDIX II List of other species associated with *Junipeus brevifolia* (Seub.) Antoine.

Cautionary note: The following lists do not generally reflect the complete distribution of the species in the different Azorean islands since they were assembled bearing in mind the connection with *Juniperus brevifolia*; therefore, they may be present in other islands, in different substrates (check Borges *et al.* 2010a for complete check-lists). The present lists also expose the different collection effort made among different taxonomical groups and among islands; Flo, Flores; Fai, Faial; Pic, Pico; SJo, São Jorge; Ter, Terceira, SMi, São Miguel.

II.1 VASCULAR PLANTS

(All Pteridophyta species are epiphytes. *Arceuthobium azoricum* is the hemiparasite of *J. brevifolia*)

Table 1. List of vascular plants associated with *Juniperus brevifolia*. Colonisation status for each species (Colon.) distinguishes among: END, Azorean endemic and NAT, native species.

Division	Class	Order	Family	Species	Colonisation							
					Status	Cor	Flo	Fai	Pic	SJo	Ter	SMi
Pteridophyta												
Polypodiopsida	Hymenophyllales		Hymenophyllaceae	<i>Hymenophyllum tunbrigense</i> (L.) Sm.	NAT	x	x	x	x	x	x	x
				<i>Hymenophyllum wilsonii</i> Hook. (L.) Sm.	NAT	x	x	x	x	x	x	
	Polypodiales		Dryopteridaceae	<i>Elaphoglossum semicylindricum</i> (Bowdich) Benl	NAT		x	x	x	x	x	x
				Polypodiaceae	<i>Ceradenia jungermannioides</i> (Klotzsch) L.E. Bishop	NAT		x				x
					<i>Grammitis azorica</i> (Sw.) H. Schaef.	END		x				x
Magnoliophyta												
Magnoliopsida	Santalales		Santalaceae	<i>Arceuthobium azoricum</i> Wiens & Hawksworth	END			x	x	x	x	x

II.2.1 BRYOPHYTES - DIVISION MARCHANTIOPHYTA

Table 2.1. List of liverworts associated with *Juniperus brevifolia*. Records coming from literature (L; check Appendix III) and/or Herbarium (H). Colonisation status for each species (Colon.) distinguishes among: END, Azorean endemic; Mac, Macaronesian endemic; IB-MAC, Iberian-Macaronesian endemic and EUR, European endemic; all other species are considered native; IUCN, mentions conservation concern species (Dierssen, 2001) and distinguishes among: V, vulnerable; R, rare; RT, regionally threatened; and T, taxonomic problems.

Class/Order	Family	Taxa	Colon.	IUCN	Cor	Flo	Fai	Pic	SJo	Ter	SMi
Jungermanniopsida Jungermanniales	Acrobolbaceae	<i>Acrobolbus wilsonii</i> Nees		V				H		H	L
		<i>Tylimanthus laxus</i> (Lehm. & Lindenb.) Spruce		V				H		L/H	
	Adelanthaceae	<i>Adelanthus decipiens</i> (Hook.) Mitt.						L/H		L/H	L
	Calypogeiaceae	<i>Calypogeia azorica</i> Bischl.	MAC	R							L
		<i>Calypogeia fissa</i> (L.) Raddi							H		L/H
		<i>Calypogeia muelleriana</i> (Schiffn.) Müll. Frib.					L	L/H	L	L/H	

Class/Order	Family	Taxa	Colon.	IUCN	Cor	Flo	Fai	Pic	SJo	Ter	SMi
		<i>Calypogeia neesiana</i> (C. Massal. et Carestia) Müll. Frib.								H	
		<i>Mnioloma fuscum</i> (Lehm.) R. M. Schust.		R			L	H	L	L/H	
	Cephaloziaceae	<i>Cephalozia bicuspidata</i> (L.) Dumort.								H	
		<i>Cephalozia crassifolia</i> (Lindenb. et Gottsche) Fulford		V				L/H	L	H	
		<i>Cephalozia lunulifolia</i> (Dumort.) Dumort.						L		H	
		<i>Nowellia curvifolia</i> (Dicks.) Mitt.						L/H	L	L/H	L
		<i>Odontoschisma denudatum</i> (Mart.) Dumort.						H			L
		<i>Odontoschisma prostratum</i> (Sw.) Trevis.				L		H	L	L/H	
	Cephaloziellaceae	<i>Cephaloziella divaricata</i> (Sm.) Schiffn.								H	
	Geocalyceaceae	<i>Geocalyx graveolens</i> (Schrad.) Nees						H		L/H	
		<i>Saccogyna viticulosa</i> (L.) Dumort.	EUR				L	L/H	L	H	
	Herbertaceae	<i>Herbertus sendtneri</i> (Nees) Lindb.		R		L		L/H		L/H	
	Lepidoziaceae	<i>Bazzania azorica</i> H. Buch et H. Perss.	END	R				L/H	L	L/H	
		<i>Lepidozia cupressina</i> (Sw.) Lindenb. subsp. pinnata (Hook.) Pócs						L/H	L	L/H	
		<i>Lepidozia reptans</i> (L.) Dumort.					L	H	L	H	
		<i>Lepidozia stuhlmannii</i> Steph.						H			
		<i>Telaranea azorica</i> (H. Buch et H. Perss.) Pócs ex Schumacker et Váña	MAC	V			L	L/H	L	L/H	L
		<i>Telaranea europaea</i> Engel et Merr.		R				L/H		L/H	
	Lophocoleaceae	<i>Chiloscyphus fragrans</i> (Moris et De Not.) J. J. Engel et R. M. Schust.						L/H		H	
		<i>Leptoscyphus azoricus</i> (H. Buch et H. Perss.) Grolle	EUR	V				H		L/H	L
		<i>Leptoscyphus cuneifolius</i> (Hook.) Mitt.								H	
	Plagiochilaceae	<i>Plagiochila bifaria</i> (Sw.) Lindenb.					L	L/H	L	L/H	
		<i>Plagiochila exigua</i> (Taylor) Taylor				L		H	L	H	L
		<i>Plagiochila longispina</i> Lindenb. et Gottsche								H	
		<i>Plagiochila punctata</i> (Taylor) Taylor								H	
	Pseudolepicoleaceae	<i>Blepharostoma trichophyllum</i> (L.) Dumort.					L	L/H		L/H	
	Scapaniaceae	<i>Barbilophozia attenuata</i> (Mart.) Loeske					L			H	
		<i>Diplophyllum albicans</i> (L.) Dumort.						H	L	H	
		<i>Lophozia ventricosa</i> (Dicks.) Dumort. aggr.						L		H	
		<i>Scapania curta</i> (Mart.) Dumort.						L			
		<i>Scapania gracilis</i> Lindb.				L	L	L/H	L	L/H	
		<i>Scapania nemorea</i> (L.) Grolle						H			
		<i>Scapania undulata</i> (L.) Dumort.					L			H	
Metzgeriales	Aneuraceae	<i>Riccardia chamedryfolia</i> (With.) Grolle						H		H	
		<i>Riccardia palmata</i> (Hedw.) Carruth.						H			
	Metzgeriaceae	<i>Metzgeria furcata</i> (L.) Dumort.			L		L	L		H	
		<i>Metzgeria leptoneura</i> Spruce						L/H		L/H	

Class/Order	Family	Taxa	Colon.	IUCN	Cor	Flo	Fai	Pic	SJo	Ter	SMi	
Pallaviciniales	Pallaviciniaceae	<i>Pallavicinia lyellii</i> (Hook.) Carruth.		V						L/H		
Porellales	Frullaniaceae	<i>Frullania azorica</i> Sim-Sim et al.	IB-MAC							H		
		<i>Frullania microphylla</i> (Gottsche) Pearson	EUR		L			H				
		<i>Frullania tamarisci</i> (L.) Dumort.			L	L/H	L/H	L/H	L		L/H	
		<i>Frullania teneriffae</i> (F. Weber) Nees			L	L	L	L/H			H	
	Lejeuneaceae	<i>Aphanolejeunea azorica</i> (V. Allorge et Ast) Pócs et Bernecker		V		L					L/H	
		<i>Aphanolejeunea microscopica</i> (Taylor) A. Evans							L/H		H	
		<i>Aphanolejeunea sintenisii</i> Steph.		V		L			H		H	
		<i>Cheilolejeunea cedercreutzii</i> (H. Buch et H. Perss.) Grolle	MAC	V					H		L/H	
		<i>Cololejeunea minutissima</i> (Sm.) Schiffn.				L						
		<i>Colura calyptrifolia</i> (Hook.) Dumort.		RT					H		H	
		<i>Drepanolejeunea hamatifolia</i> (Hook.) Schiffn.					L	L	L/H	H	L/H	
		<i>Harpalejeunea molleri</i> (Steph.) Grolle				L	L		L/H		H	
		<i>Lejeunea flava</i> (Sw.) Nees subsp. <i>moorei</i> (Lindb.) R. M. Schust.				L					L/H	
		<i>Lejeunea lamacerina</i> (Steph.) Schiffn.				L	H		H		L/H	
		<i>Lejeunea patens</i> Lindb.							H		L/H	
		<i>Marchesinia mackaii</i> (Hook.) Gray									H	
		Porellaceae	<i>Porella canariensis</i> (F. Weber) Bryhn	EUR	T					L		
Radulaceae	<i>Radula aquilegia</i> (Hook. f. et Taylor) Gottsche et al.					L	L	L/H		L/H		
	<i>Radula carringtonii</i> J. B. Jack			R				H		H		
	<i>Radula holtii</i> Spruce	EUR	R					L				
Marchantiopsida Marchantiales	Dumortieraceae	<i>Dumortiera hirsuta</i> (Sw.) Nees subsp. <i>hirsuta</i>		R					L			

II.2.2 BRYOPHYTES - DIVISION BRYOPHYTA

Table 2.2. List of mosses associated with *Juniperus brevifolia* in the various Azorean islands (Flo, Flores; Fai, Faial; Pic, Pico; SJo, São Jorge; Ter, Terceira, SMi, São Miguel). Records coming from literature (L; check Appendix III) and/or Herbarium (H). Colonisation status for each species (Colon.) distinguishes among: END, Azorean endemic; Mac, Macaronesian endemic; IB-MAC, Iberian-Macaronesian endemic and EUR, European endemic; all other species are considered native; IUCN, mentions conservation concern species (Dierssen, 2001) and distinguishes among: V, vulnerable; R, rare; RT, regionally threatened; and T, taxonomic problems.

Class/Order	Family	Taxa	Colon	IUCN	Cor	Flo	Fai	Pic	SJo	Ter	SMi	
Bryopsida Dicranales	Dicranaceae	<i>Dicranum canariense</i> Hampe ex Müll. Hal.									L	
		<i>Dicranum flagellare</i> Hedw.									H	
		<i>Dicranum scoparium</i> Hedw.						L	L			L
		<i>Dicranum scottianum</i> Turn.					L	L	L/H	L		L/H
	Leucobryaceae	<i>Campylopus cygneus</i> (Hedw.) Brid.			K							H
		<i>Campylopus flexuosus</i> (Hedw.) Brid.							L	L		H
		<i>Campylopus pyriformis</i> (Schultz) Brid.										H
		<i>Campylopus shawii</i> Wilson			R				L			
		<i>Leucobryum albidum</i> (P. Beauv.) Lindb.								L		
		<i>Leucobryum juniperoideum</i> (Brid.) Müll. Hal.					H					H
Diphysciales Hookeriales	Diphysciaceae	<i>Diphyscium foliosum</i> (Hedw.) D. Mohr										
	Daltoniaceae	<i>Daltonia stenophylla</i> Mitt.		V							L	
	Leucomiaceae	<i>Tetrastichium fontanum</i> (Mitt.) Cardot	IB-MAC	R				L	L			
Hypnales	Pilotrichaceae	<i>Tetrastichium virens</i> (Cardot) S. P. Churchill	IB-MAC	R							H	
		<i>Cyclodictyon laetevirens</i> (Hook. et Taylor) Mitt.		R				L			L/H	
	Amblystegiaceae	<i>Hygroamblystegium humile</i> (P. Beauv.) Vanderp., Goffinet & Hedenäs									H	
	Brachytheciaceae	<i>Brachythecium rutabulum</i> (Hedw.) Schimp.										H
		<i>Kindbergia praelonga</i> (Hedw.) Ochyra							L			
	Hylocomiaceae	<i>Hylocomium splendens</i> (Hedw.) Schimp.										L
		<i>Hyocomium armoricum</i> (Brid.) Wijk et Marg.								L		
		<i>Pleurozium schreberi</i> (Brid.) Mitt.							H			
	Hypnaceae	<i>Andoa berthelotiana</i> (Mont.) Ochyra	MAC	R					L/H			L/H
		<i>Hypnum andoi</i> Smith										H
<i>Hypnum cupressiforme</i> Hedw.					L	L		L			H	
<i>Hypnum jutlandicum</i> Holmen et E. Warncke								H				
<i>Hypnum uncinulatum</i> Jur.		EUR	RT	L	L	L	L/H	L	L		L/H	
<i>Pseudotaxiphyllum elegans</i> (Brid.) Z. Iwats.							L		L		L	
<i>Pseudotaxiphyllum laetevirens</i> (Koppe et Düll) Hedenäs		EUR	R					H			L/H	
Lembophyllaceae	<i>Isothecium prolixum</i> (Mitt.) Stech, Sim-Sim, Tangney et D.Quandt	MAC	R				L	L/H	L		L/H	

Class/Order	Family	Taxa	Colon	IUCN	Cor	Flo	Fai	Pic	SJo	Ter	SMi
	Myuriaceae	<i>Myurium hochstetteri</i> (Schimp.) Kindb.				L		H	L	H	
	Neckeraceae	<i>Neckera intermedia</i> Brid.	IB-MAC	RT		L					
		<i>Thamnobryum alopecurum</i> (Hedw.) Nieuwl.						L			
	Plagiotheciaceae	<i>Plagiothecium nemorale</i> (Mitt.) A. Jaeger						L		H	
	Sematophyllaceae	<i>Sematophyllum substrumulosum</i> (Hampe) Britton						L		H	
	Thuidiaceae	<i>Thuidium tamariscinum</i> (Hedw.) Schimp.						L/H	L	H	
Orthotrichales	Orthotrichaceae	<i>Zygodon conoideus</i> (Dicks.) Hook. et Taylor									L
Polytrichopsida	Polytrichaceae	<i>Polytrichastrum formosum</i> (Hedw.) G.L.Sm.						H		H	
Polytrichales		<i>Polytrichum commune</i> Hedw.								H	
Sphagnopsida	Sphagnaceae	<i>Sphagnum palustre</i> L.						H		H	
Sphagnales		<i>Sphagnum subnitens</i> Russow et Warnst.						H			

II.3.1 LICHENS - DIVISION ASCOMYCOTA

Table 3.1. List of lichens (Ascomycota) associated with *Juniperus brevifolia* in the various Azorean islands (Flo, Flores; Fai, Faial; Pic, Pico; SJo, São Jorge; Ter, Terceira, SMi, São Miguel). Records coming from literature (L; check Appendix III) and/or Herbarium (H). Colonisation status for each species (Colon.) distinguishes among Azorean endemics (END) and Macaronesian endemics (MAC); all other species are considered native.

Class / Order	Family	Taxa	Colon	Flo	Fai	Pic	SJo	Ter	SMi
Arthoniomycetes									
Arthoniales	Chrysothricaceae	<i>Chrysothrix candelaris</i> (L.) J. R. Laundon, 1981							L
		<i>Chrysothrix chrysophthalma</i> (P. James) P. James & J. R. Laundon, 1981							L
Eurotiomycetes									
Incertae sedis	Strigulaceae	<i>Strigula nitidula</i> Mont., 1842							L
Pyrenulales	Pyrenulaceae	<i>Pyrenula acutispora</i> Kalb & Hafellner, 1992							H
Verrucariales	Verrucariaceae	<i>Normandina pulchella</i> (Borrer) Nyl., 1861							L
Lecanoromycetes									
Agyriales	Agyriaceae	<i>Placynthiella dasaea</i> (Stirt.) Tønsberg, 1992							L
		<i>Trapelia corticola</i> Coppins & P. James, 1984		L					L
		<i>Trapeliopsis flexuosa</i> (Fr.) Coppins & P. James, 1984		L					L
		<i>Trapeliopsis pseudogranulosa</i> Coppins & P. James, 1984							H/L
Gyalectales	Gyalectaceae	<i>Coenogonium pineti</i> (Schrad.) Lücking & Lumbsch, 2004		L					L
Lecanorales	Candelariaceae	<i>Candelaria concolor</i> (Dicks.) Stein, 1879							L
	Cladoniaceae	<i>Cladonia borbonica</i> Nyl., 1868		L					

Class / Order	Family	Taxa	Colon	Flo	Fai	Pic	SJo	Ter	SMi
		<i>Cladonia chlorophaea</i> (Flörke ex Sommerf.) Spreng., 1827						L	
		<i>Cladonia coniocraea</i> (Flörke) Spreng., 1827		H				H/L	L
		<i>Cladonia diversa</i> Asperges, 1983						L	
		<i>Cladonia fimbriata</i> (L.) Fr., 1831						L	
		<i>Cladonia macilenta</i> Hoffm., 1796					L		
		<i>Cladonia ochrochlora</i> Flörke, 1828						H	
		<i>Cladonia polydactyla</i> (Flörke) Spreng., 1827						L	
		<i>Cladonia pyxidata</i> (L.) Hoffm., 1796		L					
		<i>Cladonia squamosa</i> Hoffm., 1796						H/L	L
		<i>Cladonia stereoclada</i> Abbayes, 1946		L		L		H/L	
		<i>Cladonia vulcanica</i> Zöll. & Moritz, 1847						L	
	Dactylosporaceae	<i>Dactylospora parasitica</i> (Flörke ex Spreng.) Zopf, 1896					L		
	Ectolechiaceae	<i>Tapellaria epiphylla</i> (Müll. Arg.) R. Sant., 1952						L	
	Lecanoraceae	<i>Lecanora jamesii</i> J. R. Laundon, 1963						H	
		<i>Lecanora symmicta</i> (Ach.) Ach., 1814						L	
		<i>Pyrrhospora lusitanica</i> (Räsänen) Hafellner, 1992						L	
		<i>Scoliciosporum umbrinum</i> (Ach.) Arnold, 1871						L	
	Loxosporaceae	<i>Loxospora elatina</i> (Ach.) A. Massal., 1852		L				L	
	Megalariaceae	<i>Megalaria albocincta</i> (Degel.) Tønsberg, 1996						H	
		<i>Megalaria pulverea</i> (Borrer) Hafellner & E. Schreiner, 1992		L				L	
	Megalosporaceae	<i>Megalospora tuberculosa</i> (Fée) Sipman, 1983		L				L	
	Mycoblastaceae	<i>Mycoblastus caesius</i> (Coppins & P. James) Tønsberg, 1992		L	L	L		H/L	L
	Pannariaceae	<i>Erioderma leylandii</i> (Taylor) Müll. Arg., 1888		L		L		L	
		<i>Fuscopannaria leucosticta</i> (Tuck.) P. M. Jørg., 1994				L			
		<i>Pannaria conoplea</i> (Pers.) Bory, 1828		L				L	
		<i>Pannaria rubiginosa</i> (Thunb.) Delise, 1828		L				H/L	
		<i>Parmeliella parvula</i> P. M. Jørg., 1977						L	
		<i>Protopannaria pezizoides</i> (Weber ex F. H. Wigg.) P. M. Jørg. & S. Ekman, 2000		L				L	
	Parmeliaceae	<i>Flavoparmelia caperata</i> (L.) Hale, 1986						L	
		<i>Hypotrachyna costaricensis</i> (Nyl.) Hale, 1975				L		L	
		<i>Hypotrachyna endochlora</i> (Leight.) Hale, 1975		L		L	L	H/L	
		<i>Hypotrachyna imbricatula</i> (Zahlbr.) Hale, 1975				L			
		<i>Hypotrachyna microblasta</i> (Vain.) Hale, 1975		L	L	L		L	
		<i>Hypotrachyna pulvinata</i> (Fée) Hale, 1975						H/L	
		<i>Hypotrachyna rockii</i> (Zahlbr.) Hale, 1975						H/L	
		<i>Hypotrachyna taylorensis</i> (M. E. Mitch.) Hale, 1975				L			
		<i>Parmelia saxatilis</i> (L.) Ach., 1803				L			
		<i>Parmelinopsis horrescens</i> (Taylor) Elix & Hale, 1987		L	L	L		L	
		<i>Parmotrema arnoldii</i> (Du Rietz) Hale, 1974				L			

Class / Order	Family	Taxa	Colon	Flo	Fai	Pic	SJo	Ter	SMi
		<i>Parmotrema perlatum</i> (Huds.) M. Choisy, 1952						L	
		<i>Parmotrema reticulatum</i> (Taylor) M. Choisy, 1952						L	
		<i>Parmotrema robustum</i> (Degel.) Hale, 1974			L			H/L	
		<i>Parmotrema subsidiosum</i> (Müll. Arg.) Hale, 1974				L		L	
		<i>Platismatia glauca</i> (L.) W. L. Culb. & C. F. Culb., 1968				L		L	
		<i>Usnea cornuta</i> Körb., 1859		L	L	L		L	L
		<i>Usnea flammea</i> Stirt., 1881				L			
		<i>Usnea geissleriana</i> P. Clerc, 2006	MAC			L			
		<i>Usnea hirta</i> (L.) Weber ex F. H. Wigg., 1780							L
		<i>Usnea krogiana</i> P. Clerc, 2006				L		H/L	
		<i>Usnea macaronesica</i> P. Clerc, 2006	MAC			L			
		<i>Usnea rubicunda</i> Stirt., 1881						L	
		<i>Usnea subflammea</i> P. Clerc, 2006	MAC			L		L	
		<i>Usnea subscabrosa</i> Nyl. ex Motyka, 1937						L	
	Physciaceae	<i>Buellia erubescens</i> Arnold, 1873						L	
		<i>Heterodermia japonica</i> (M. Satô) Swinscow & Krog, 1976		L				L	
		<i>Heterodermia leucomela</i> (Fée) Swinscow & Krog, 1976		L				L	
		<i>Heterodermia lutescens</i> (Kurok.) Follmann, 1974						L	
		<i>Pyxine sorediata</i> (Ach.) Mont., 1842						L	
	Pilocarpaceae	<i>Byssoloma leucoblepharum</i> (Nyl.) Vain., 1926						L	
		<i>Byssoloma subdiscordans</i> (Nyl.) P. James, 1971						L	L
		<i>Micarea lignaria</i> (Ach.) Hedl., 1892		L				H/L	L
		<i>Micarea prasina</i> Fr., 1825		L	L			L	
	Ramalinaceae	<i>Bacidina apiahica</i> (Müll. Arg.) Vezda, 1991						L	
		<i>Ramalina peruviana</i> Ach., 1810						L	
	Stereocaulaceae	<i>Lepraria incana</i> (L.) Ach., 1803						L	
		<i>Lepraria lobificans</i> Nyl., 1873						H/L	
		<i>Lepraria umbricola</i> Tønsberg, 1992						L	
Ostropales	Gomphillaceae	<i>Gomphillus calycioides</i> (Delise ex Duby) Nyl., 1855		L				L	
		<i>Gyalideopsis muscicola</i> P. James & Vezda, 1972		L				L	
	Graphidaceae	<i>Fissurina triticea</i> (Nyl.) Staiger, 2002		L	L	L		H/L	L
	Thelotremataceae	<i>Ramonia azorica</i> P. James & Purvis, 1993		L		L		L	
		<i>Thelotrema antoninii</i> Purvis & P. James, 1995	END	L		L		H/L	
		<i>Thelotrema isidioides</i> (Borrer) R. Sant., 1980		L	L	L			
		<i>Thelotrema lepadinum</i> (Ach.) Ach., 1803		L				H/L	L
Peltigerales	Coccocarpiaceae	<i>Coccocarpia palmicola</i> (Spreng.) Arv. & D. J. Galloway, 1979				L			
	Collemataceae	<i>Leptogium cyanescens</i> (Ach.) Körb., 1877		L				L	
	Lobariaceae	<i>Lobaria pulmonaria</i> (L.) Hoffm., 1796						L	

APPENDIX III

List of references mentioning different taxa associated with *Juniperus brevifolia*

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APPENDIX IV

Results of chi-square tests for all pairs of populations, with resulting p-values adjusted with Bonferroni method (for inflation due to multiple comparisons); FAI - Faial Island, FLO – Flores Island, PIC – Pico Island, SJG – São Jorge Island, SMG – São Miguel Island, TER- Terceira Island.

Table 1. Results of *post-hoc* Chi-square tests (with Bonferroni adjustment) for the proportion of abundance per colonisation status for endemic, native and introduced species.

Colonisation status	
comparison	Adjusted p-value
FLO vs FAI	0.00000
FLO vs PIC	0.03033
FLO vs SJG	NS
FLO vs TER	0.00000
FLO vs SMG	0.00107
FAI vs PIC	NS
FAI vs SJG	0.00278
FAI vs TER	NS
FAI vs SMG	NS
PIC vs SJG	NS
PIC vs TER	NS
PIC vs SMG	NS
SJG vs TER	0.00272
SJG vs SMG	NS
TER vs SMG	NS

Table 2. Results of *post-hoc* Chi-square tests (with Bonferroni adjustment) for the proportion of abundance per order at island level, for all species, endemics, natives and introduced species.

Total		Endemic	
comparison	Adjusted p-value	comparison	Adjusted p-value
TER vs FAI	0.00062	TER vs FAI	0.00000
TER vs FLO	0.00017	TER vs FLO	0.00102
TER vs PIC	NS	TER vs PIC	NS
TER vs SJG	0.00002	TER vs SJG	0.00000
TER vs SMG	0.00123	TER vs SMG	0.00000
FAI vs FLO	NS	FAI vs FLO	NS
FAI vs PIC	NS	FAI vs PIC	NS
FAI vs SJG	0.00030	FAI vs SJG	NS
FAI vs SMG	0.00002	FAI vs SMG	0.00000
FLO vs PIC	0.00002	FLO vs PIC	NS
FLO vs SJG	NS	FLO vs SJG	NS
FLO vs SMG	0.00000	FLO vs SMG	0.00000
PIC vs SJG	NS	PIC vs SJG	NS
PIC vs SMG	0.00000	PIC vs SMG	0.00000
SJG vs SMG	0.00000	SJG vs SMG	0.00000

Native		Introduced	
comparison	Adjusted p-value	comparison	Adjusted p-value
TER vs FAI	0.00127	TER vs FAI	0.00000
TER vs FLO	NS	TER vs FLO	0.00000
TER vs PIC	NS	TER vs PIC	0.00000
TER vs SJG	NS	TER vs SJG	0.00000
TER vs SMG	NS	TER vs SMG	0.00030
FAI vs FLO	0.00284	FAI vs FLO	-
FAI vs PIC	NS	FAI vs PIC	NS
FAI vs SJG	0.00000	FAI vs SJG	NS
FAI vs SMG	0.00000	FAI vs SMG	0.00000
FLO vs PIC	NS	FLO vs PIC	0.00487
FLO vs SJG	0.00003	FLO vs SJG	-
FLO vs SMG	0.00104	FLO vs SMG	0.00000
PIC vs SJG	0.00102	PIC vs SJG	0.00031
PIC vs SMG	0.00558	PIC vs SMG	0.00001
SJG vs SMG	NS	SJG vs SMG	0.00000

Table 3. Results of *post-hoc* Chi-square tests (with Bonferroni adjustment) for the proportion of abundance per different functional groups at island level.

Functional group comparison	Adjusted p-value
TER vs FAI	0.00053
TER vs FLO	0.03419
TER vs PIC	NS
TER vs SJG	NS
TER vs SMG	NS
FAI vs FLO	NS
FAI vs PIC	NS
FAI vs SJG	NS
FAI vs SMG	0.00608
FLO vs PIC	NS
FLO vs SJG	NS
FLO vs SMG	NS
PIC vs SJG	NS
PIC vs SMG	NS
SJG vs SMG	0.02355

Table 4. Results of *post-hoc* Chi-square tests (with Bonferroni adjustment) for the proportion of abundance per different feeding modes at island level.

Feeding mode comparison	Adjusted p-value
TER vs FAI	0.01233
TER vs FLO	0.00064
TER vs PIC	NS
TER vs SJG	0.00002
TER vs SMG	0.03018
FAI vs FLO	NS
FAI vs PIC	NS
FAI vs SJG	0.00045
FAI vs SMG	0.00006
FLO vs PIC	NS
FLO vs SJG	NS
FLO vs SMG	0.00000
PIC vs SJG	NS
PIC vs SMG	0.00001
SJG vs SMG	0.00000