

Invasive alien species in Macaronesia

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Characterization of the archipelagos

Although invasive alien species (IAS) are important in all the Macaronesian archipelagos, knowledge and legislation about IAS differs between regions and according to the taxonomic groups. In fact, there are considerable differences between the three archipelagos in terms of their geographical traits. The Canary Islands have a total land surface of 7447 km² (with seven islands), much larger than that for the Azores (2332 km², with nine islands) or for Madeira (801 km², including Madeira, Porto Santo, Desertas and Selvagens). The regions also differ in the number of inhabitants, which reached 1968280 in the Canaries (2005), but was 244098 inhabitants for Madeira (2007) and 241763 in the Azores (2007). Regarding human population density, it is highest in Madeira (305.9 inha./km²), intermediate in the Canaries (264.3 inha./km²) and lowest in the Azores (104 inha./km²). The earliest human settlement in the Canaries was very ancient (Preberber), occurring prior to European presence, whereas settlement began around 1425 in Madeira and in 1439 in the Azores. The Canaries are only 95 km from Africa while Madeira is in a somewhat central position, being 660 km from Africa, 980 km from Lisbon, 400 km from Gran Canaria and 880 km from Santa Maria island (Azores). The Azores on the other hand, are located at 1500 km from Europe, 1450 km from Africa and 3900 km from North America.

Regarding climate, temperature at sea level in the Canaries ranges between 17 and 25°C and rainfall ranges between 100 mm near the coast up to 300 or 700 mm per year at high altitude. At Funchal (Madeira) annual temperature is about 20°C at sea level and rainfall ranges from 500 mm to above 2000 mm. The Selvagens islands have an arid climate with rainfall below 200 mm. In the Azores, mean annual temperature at sea level

is 17°C, decreasing 0.6 °C per 100 m, while rainfall increases with altitude and from east to west, reaching 3000 mm per year. In general, although there is a variation of climatic conditions from one extreme of the archipelago to the other, and a significant spatial variation within each island, the Azorean climate might be classified as wet mesothermic with oceanic traits (Azevedo 2001).

Madeira is a mountainous island with several high peaks: Pico Ruivo (1862 m), Pico das Torres (1851 m), and Pico do Areeiro (1818 m). In the Azores Archipelago, the maximum altitude is found on Pico island (2351 m). Several islands have altitudes above or slightly below 1000 m. The most elevated point in Macaronesia is located in the Canaries, namely, El Teide, which is 3717 m above sea level in the island of Tenerife.

As a consequence of all the geographic conditions and of historical events, the Canaries show the richest biodiversity. As an example, regarding endemic taxa, the Canaries have 524 vascular plants and 2768 arthropods (Martín Esquivel *et al.* 2005) while the Azores have 72 and 267, respectively (Borges *et al.* 2005) and the archipelagos of Madeira and Selvagens altogether have 154 and 979 (Borges *et al.* 2008a) respectively. It is well known that there are several plant genera in the Canaries with high numbers of species (*Aeonium*, *Echium*, *Argyranthemum*, *Sonchus*, etc.), which probably resulted from adaptive radiation, while in the Azores endemic plant species are found at a rate of one, and more rarely two or three species per genus. An intermediate situation is found in Madeira where genera *Argyranthemum* (Asteraceae) and *Sinapidendron* (Brassicaceae) show six endemic taxa (Jardim & Sequeira 2008). There are also other significant differences among the archipelagos. For instance, regarding vertebrate taxa, in the Azores there are no native species of reptiles and there are only two native mammal species, two bats, one of which endemic (*Nyctalus azoreum*), while there are several species in those groups both in the Canaries and in Madeira, namely the small lizard from Madeira (*Teira dugesii*, with four subspecies) or the giant lizards from La Gomera (*Gallotia bravoana*), El Hierro (*G. simonyi*), Tenerife (*G. intermedia*) and Gran Canaria (*G. stehlini*), among others.

Thus, although there are similarities among the different regions, important geographic differences dictated that the native flora and fauna would show striking differences among the archipelagos. This is of considerable importance in order to understand what happened in each region, regarding the introduction of alien species. For instance, it is usually accepted that several species of Mediterranean distribution are considered as native in Madeira or in the Canaries, while the same species are considered as alien in the Azores.

Importance of IAS in Macaronesia

As stated above, more than 60% of the vascular plant flora in the Azores is considered as alien (frequently escaped or naturalized), all the mammals (except the Azorean bat),

amphibians and reptiles are introduced. For instance, Schafer (2002) suggested that there was a steady increase in the number of new plant records since the 18th century.

An analysis of the proportions of the colonisation categories for some arthropod taxa, for which adequate data is available, shows that the major portion of the arthropod fauna in Madeira and Selvagens corresponds to indigenous taxa (68%), while only 28% are considered as exotic (Borges *et al.* 2008b). This is in agreement with the pattern observed in the Canary Islands (see Izquierdo *et al.* 2001), but contrasts with the results for the Azores archipelago, where exotic taxa dominate (58%; see Borges *et al.* 2005). Furthermore, several exotic arthropods are considered as pests in the Azores, namely the Japanese beetle (*Popillia japonica*) which attacks pastureland and other crops, which is now expanding in several islands (Terceira, Faial and São Miguel); the armyworm (*Pseudaletia unipuncta*) in pastureland areas in several islands where it causes heavy annual damage in agriculture; the termites in urban areas, in particular *Cryptotermes brevis*, considered as the most dangerous dry wood termite in the world and that is presently considered as an urban pest in the cities of Angra do Heroísmo, Ponta Delgada and Horta (Borges & Myles 2007).

In the native Azorean forests the proportion of exotic species may reach about 65% in epigeal soil arthropod communities at disturbed locations (Cardoso *et al.* 2007), however at the canopy of endemic trees (e.g. *Juniperus brevifolia*, *Erica azorica*, *Laurus azorica*) native and endemic arthropods dominate (Borges *et al.* in press). It should be noted that invasion of natural habitats in the Azores by exotic arthropods is a dynamic process in which the smaller, more fragmented native vegetation plots are at greater risk, and where the surrounding habitat mosaic is of considerable importance, since the existence of a semi-natural pastureland matrix favours the maintenance of endemic and native species (Borges *et al.* in press). The continuous expansion of some invasive plants like *Hedychium gardnerianum*, *Pittosporum undulatum* and *Hydrangea macrophylla*, is threatening several fragments of native vegetation, leading to the prediction that several communities of lichens, vascular plants, molluscs, and arthropods native and endemic to the Azores might be endangered. This phenomenon seems to be more serious in the islands of São Miguel, Santa Maria and Flores. Recent studies (Borges *et al.* unpublished data) suggest that for several endemic species of arthropods with a wide distribution in the Azores the smallest population densities are found in fragments disturbed by exotic plants. Also of concern is the present situation of *Hedychium gardnerianum* in Terceira island, since it is now present in small gaps in the middle of large fragments of otherwise pristine native forest.

In the archipelagos of Madeira and Selvagens there are 430 species and subspecies of plants considered as naturalized, representing 35.7% of the vascular flora (Jardim & Sequeira 2008). Madeira island shows the highest number of exotic taxa (419) and Selvagens the lowest, only 17. The exotic flora has a tendency to increase, since there are several cultivated species with a considerable potential to become naturalized. Vieira (2002) pointed out that 20 species previously mentioned as cultivated (forestry, ornamental or food crops) have become naturalized in the last few years. It should also be pointed out that at the beginning of the 20th century, Menezes (1914) had only cited 160 plants as naturalized in the Madeira archipelago.

Figure 2 shows the importance of exotic vascular plant species in Macaronesia. In the Azores the number of exotic species per square km is one or two times the number of indigenous species (endemic and native). A situation only approximated by the Cape Verde Islands.

In Madeira, and regarding vertebrates, all the terrestrial mammals were introduced, with the exception of five species of indigenous bats (Oliveira 2008). The large majority of these species are included in the list of the worst 100 invasive species in the world, namely those which raise more concern due to their impact, three rodent species (*Rattus rattus*, *R. norvegicus* and *Mus musculus*), two species of herbivores (*Oryctolagus cuniculus* and *Capra hircus*) and one felid (*Felis silvestris catus*) (Oliveira 2008). The amphibians and reptiles are modestly represented, the indigenous taxa with a higher number of species than the introduced. The only species deserving attention are the frog (*Rana perezi*), due to its abundance and wide distribution and the geko (*Tarentola mauritanica*), the distribution area of which is in continuous expansion (Jesus 2008).

In Madeira island there is consistent work devoted to recover priority habitats and species, including actions for control or eradication of some of the above mentioned species at sites with high conservation value. This program involves large human and financial resources that have been partly secured through European Union programs, namely LIFE-Natura.

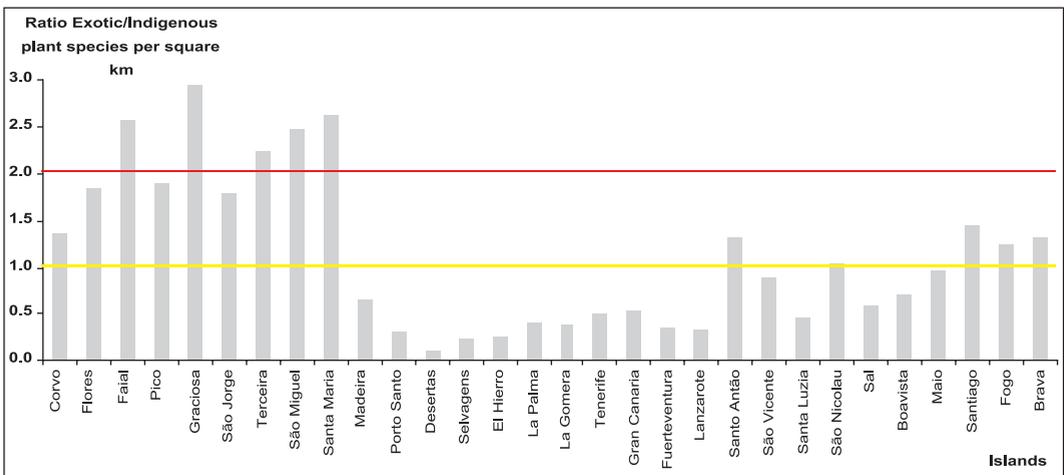


Figura 2. Ratio of the number of exotic and indigenous vascular plants per square km in the Macaronesian islands.

Included in this program, several initiatives assume relevance, namely the project for the recovery of the nestling habitat of Zino's Petrel (*Pterodroma madeira*) (Menezes & Oliveira 2002, 2003, Oliveira *et al.* 2007), the project for the recovery of the terrestrial habitats of Deserta Grande (Bell 2001), the project for the recovery of the habitat of Fea's Petrel (*Pterodroma feae*, www.sosfreiradobugio.com), the project for the recovery of the terrestrial habitats of Selvagem Grande (Zino *et al.* 2008, Oliveira *et al.* in press) and the project "Recovery of Laurel Forest at Funduras".

There is also a program devoted to the control of invasive plant species in Madeira protected areas, namely in Selvagens (*Nicotiana glauca*), in São Lourenço (*Carpobrotus edulis*) and in the Madeiran laurel forest (*Hedychium gardnerianum*, *Solanum mauritianum*, *Passiflora tripartita* var. *mollissima*, among others). We should also emphasise the invasive plant eradication action directed to *Carpobrotus edulis*, *Ageratina adenophora*, *Ulex europaeus* and *Cytisus scoparius*, with the participation of students from preparatory and high school.

For the Canaries, according to Martín Esquivel *et al.* (2005), the terrestrial biota includes 13328 species of which, one fourth is endemic. At least 1434 species are introduced (about 11 % of the total). The large majority of the alien species was introduced beginning in the 1960's, 43% of which have been recorded during the last three decades.

According to those authors, the alien species of Canaries, invasive or not, are represented by 47% of invertebrates, about 46% of vascular plants, 4% of fungi and about 3% of vertebrates. The middle-oriental islands include the largest proportion of alien species, particularly Gran Canaria, where they represent 15.5% of the island biota. However the largest number of introduced species is found in Tenerife (Table 8). Among those species, at least 151 are considered as invasive, of which 79 are phanerogmes, 1 is a fern, 45 are arthropods, and there are also 3 amphibians, one reptile, 10 birds and 12 mammals.

Table 8. Number of alien species per island in the Canaries (Martín Esquivel *et al.* 2005).

	El Hierro	La Palma	La Gomera	Tenerife	Gran Canaria	Fuerteventura	Lanzarote
Number of alien species	314	576	492	1064	886	364	336

Recent studies show the importance of the negative impact on biodiversity originated by IAS in the Canary Islands. According to Arechavaleta & Martín (2008), the most important threats, at least regarding the number of affected species, for the 100 endangered and priority species for conservation management, are those that derive from the presence of alien species.

Thus, IAS negatively affect 73% of those endangered species, the second most important threat being habitat loss or degradation (51 % of the cases). The main effect of IAS derives from the grazing pressure exerted by alien herbivores on plants. According to Nogales *et al.* (2006), among the IAS in the Canaries the negative effect originated by mammals should be emphasised, particularly that associated to the feral cat (*Felis silvestris catus*) and to alien herbivores like the mouflon (*Ovis aries*), Barbary sheep (*Ammotragus lervia*) and the rabbit (*Oryctolagus cuniculus*). The feral cat figures among the main factors threatening the survival of the giant lizards from El Hierro (*Gallotia simonyi*), La Gomera (*G. bravoana*) and Tenerife (*G. intermedia*). The above mentioned alien herbivores in conjunction with the effect of uncontrolled domestic sheep and goats threaten 27 plant species considered as critically endangered (Bañares *et al.* 2003).

National and regional legislation

In Portugal, there is a decree regulating the importation of IAS including a list of species that are considered as invasive and those that are known to pose an ecological risk. This decree is presently under revision. In the Azores there is a Program for Control or Eradication of Invasive Plants in Sensitive Areas (PRECEFIAS). There is also a regional decree regulating the introduction of animal species, and a new legal document is presently being prepared to regulate the importation and the detention of exotic species in the Azores archipelago.

In Madeira the only legislation with a specific and regional character regards the regulation of the transport and detention of non-indigenous animal species (Decreto Legislativo Regional # 27/99/M).

In Madeira the management plans of protected areas, presently being implemented, and the management plans of Natura 2000 network sites, presently being revised and restructured, make clear references to the problems associated with IAS, suggesting the need or proposing the maintenance or the creation of control or eradication programs.

In Spanish legislation, as well as in the Canaries Autonomous Community legislation, there are several regulations that have been used for the prevention and control of IAS. Besides legislation regarding animal health and plant protection, conservation of wildlife in zoos and protection of pets, the recovery plans and the management plans for protected areas, have also been used to regulate alien species. Recently, new legislation was approved, the Law 42/2007, from 13 December, regarding Natural Heritage and Biodiversity, that dedicates a specific chapter to the prevention and control of invasive species, from which some points are highlighted:

- In general the introduction of alien species, subspecies or races is prohibited.
- The Spanish Catalogue of IAS is created. The inclusion of a taxon implies the generic prohibition of its possession, transportation, traffic, and trade of live or dead specimens, its remains or propagules, including external trade.

- The Autonomous Communities should monitor the exotic species with invasive potential. Besides, in their territorial domain, they may define IAS catalogues and determine supplemental prohibitions and measures which are considered as necessary for IAS eradication.
- Any citizen or organization may demand the inclusion or exclusion of one taxon from the above mentioned catalogues, supporting the proposal with scientific evidence.

In the three regions, general regulations and planning regarding protected areas also include references, more or less specific, towards the problem of IAS. However, regarding European protected areas, only the Natura 2000 sectorial plan for the Azores includes explicit references to the problem of IAS, not only acknowledging the problem but also proposing what measures should be taken to reverse the situation.