The status of plant conservation on the Macaronesian archipelagos

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Abstract

We assess the threats to the endemic plant diversity on the Macaronesian oceanic insular hotspot, consisting of five Atlantic archipelagos where heterogeneous bio-geographical, historical and political characteristics have determined contrasting conservation priorities. A recent review identified invasive alien plants and vertebrates, small population sizes and fragmentation, and demographic and economic growth as the main overall drivers of plant diversity loss in this area. Cogent with deficiencies detected on basic reproductive biology knowledge, taxonomy, and implementation of scientifically streamlined *in situ* conservation strategies (including management of invasives), priority actions to be undertaken by the botanic gardens in this region should include (i) to foster multi-disciplinary research collaboration aimed at filling those knowledge gaps, (ii) to monitor the possible effects of environmental shifts on plant diversity, and (iii) to increase interaction between policy makers and researchers through applying the resulting information. *Ex situ* conservation is a major priority for all the endemic floras; consequently, the already existing herbaria, seed banks and DNA banks should receive better institutional support. An international network of island plant conservationists would be a major milestone to share knowledge and expertise with other insular areas of the world facing similar challenges, and to better address urgent conservation needs.

Introduction

Macaronesia is an oceanic insular biodiversity hotspot in the Atlantic Ocean with a total land area of ca. 15,000 kilometres, and consisting of five archipelagos: from North to South, Azores, Madeira, Selvagens, Canaries, and Cape Verde. This region encompasses many minor islands and islets, and a total of 28 main islands, ranging from only one in both Madeira and the Selvagens to ten in Cape Verde. Politically, these archipelagos belong to three countries: the Azores, Madeira and Selvagens are Portuguese overseas territories, the Canaries are Spanish, and Cape Verde is an independent republic. Therefore, the laws, scientific priorities and practical policies to investigate and preserve biodiversity in different archipelagos vary considerably.

The Macaronesian archipelagos are situated between mainland Africa and Europe, which are also the main sources of the major colonizing stocks that gave rise to their current and variably lush floristic makeups. According to the reconstructions in published molecular phylogenies till last May (first author's personal database), about 35% of the current Canarian endemic plant species have Mediterranean ancestors, roughly 25% bear a closer relationship with North West African extant groups, 22% are

most related to taxa from distant geographical regions (especially East Africa, South Africa or the New World), and finally 18% of the flora derives from Macaronesian ancestors. Thus, founder events from mainly Mediterranean Europe and NW Africa plus a substantial contribution from Macaronesia, have shaped the rich and distinctive flora in the Canaries. With different proportions (but with less published molecular phylogenetic evidence), these geographic links may be generalized to the remaining Macaronesian archipelagos save for Cape Verde, where the principal mainland African founder stock is not associated with the same region.

Macaronesia is thus a geographically highly diverse oceanic insular region where (i) different island ages and biogeographic histories, (ii) variable distances among the archipelagos and with the mainland, and (iii) lack of substantial effects of glaciations on the floras, have created an extremely diverse landscape that has generated a high number of plant endemics (Figure 1). At present, the Macaronesian endemic flora is estimated to host 30 endemic genera that contain 68 species, and a total of about 850 endemic terrestrial plant species overall (Caujapé-Castells et al., 2010, and references therein). The archipelago with the highest species density is Madeira, and the small Canarian island of La Gomera features the greatest number of endemics per unit area in Europe and the northern quarter of Africa (Martín-Esquivel et al., 2005).

As the authorship of this contribution clearly demonstrates, the five botanic gardens of this multi-national oceanic insular hotspot do play a most distinctive and strategic role in the identification, research and conservation of the endemic terrestrial Macaronesian floras, and they are home to some of the most relevant researchers of the Macaronesian endemic plant diversity. These five institutions host four herbaria, five seed banks and three DNA banks that are both the causes and effects of most significant research on the conservation of plant biodiversity in this oceanic hotspot. There are also five universities in Macaronesia, though only three of them (in Tenerife, Azores and Madeira) feature thorough educational and research programmes on terrestrial floras. Furthermore, a comprehensive network of nature preserves and Natural Parks exists in all archipelagos, whose staff are extremely dedicated and knowledgeable about the plant diversity in their respective islands, and who offer strong support for investigation.

All these research and management assets are devoted to cope with the five threat factors that most affect the decline in plant biodiversity in Macaronesia according to a recently published review (Caujapé-Castells *et al*., 2010). Namely small population sizes and fragmentation, habitat alteration and destruction, invasive alien vertebrates and plants, and demographic and economic growth (Figure 2). Perhaps the Asteraceae *Atractylis preauxiana* is one of the cases that best illustrates the added effects of the threat factors highlighted (Figure 4). According to recent population genetic results (Caujapé-Castells *et al*., 2008), geographic isolation between Tenerife and Gran Canaria is an effective barrier to gene flow, and genetic heterogeneity within islands is also substantial, plausibly due to the negative impacts of fragmentation on genetic variation. Moreover, the population at Granadilla de Abona in Tenerife is threatened by the imminent construction of a port in that area (see Fig. 3). Low genetic variation and scarce gene flow within the islands, together with declining population sizes, poor seedling survival, and both recent and foreseeable population extinctions, compellingly indicate that *A. preauxiana* is undergoing an extinction ratchet, whereby every further local extinction will irreversibly add up to the probability of total species' extinction. Recent surveys of the populations in Gran Canaria revealed a very high number of dead individuals.

The survival plight that this plant is undergoing is probably not the general rule at present in the Macaronesian floras, although many endemics are indeed likely to

undergo similarly dramatic situations if we do not react immediately and adamantly to counter the threats posed by unsustainable development and, increasingly, climate change. Taking into account the impacts of thirteen drivers of biodiversity decline on the four Macaronesian archipelagos (Figure 2), it is evident that the threats to each archipelago´s biodiversity are not related to geographical proximity, except for the cases of Madeira and the Canaries, whose numerous floristic links partly explain the similar response of their plant biodiversity to these threats.

The rapidly growing human population and the high impact of tourism as the major source of income in all Macaronesian archipelagos (except for the Selvagens) makes it impossible to protect all habitats, and imposes at least two priorities. First, to complement habitat protection with *ex situ* conservation measures that use the information contained in hyper variable DNA regions to guide seed collections that represent natural genetic diversity in seed banks. Second, to foresee the impacts of climate change at least in the endemics that are most directly threatened, like those in mountain summits or coastal environments. Project BIOCLIMAC (Table 1) brings together three of the five Macaronesian botanic gardens to address specifically this important threat. To fulfill these needs, a stronger coordination among at least taxonomists in herbaria, seed banks, reproductive biologists and population geneticists is mandatory.

In the Azores, we find some other paradigmatic examples of plants endangered by the factors that affect the Macaronesian archipelagos. One of the most dramatic cases is the Scrophulariaceae *Veronica dabneyi*, considered extinct in the Azores in 1938, and rediscovered (only in Flores) in 2000. One of the major threats to this species (i.e., the action of road builders, who were unaware of its occurrence and cut it during maintenance works) was already eliminated by appropriate training actions. However, the impact of alien invasive flora and rabbit herbivory in Flores now make up the highest threats for this and other species. Project BASEMAC (Roca-Salinas *et al*., 2005; Table 1), is allowed to stock the seeds of this Scrophulariaceae and of 23 other Azorean rare plants (representing 1/3 of the archipelago's endemic flora) on Faial's Botanic Garden seed bank. Targets of new surveys have already been selected, like the Caldeira do Faial, where ca. 50 of the 75 Azorean endemic species concentrate in only 313 ha.

Moreover, the Azorean government is adopting a more focused approach to nature conservation; the current implementation of Nature Parks in all islands is aimed at protecting sensitive areas with a rich genetic heritage, and at the definition of strategic plans to (i) control and eradicate alien plant species, (ii) reduce cattle's impact on flora, and (iii) raise public awareness of the need to preserve the archipelagos' biodiversity.

Other necessary requirements in Macaronesia concentrate in four basic areas: first, consistent funding is needed to develop strategic research on biodiversity and to apply the emerging knowledge to its management and conservation. Second, sensible laws need to be passed, and other ones that already exist require proper enforcement. Third, field exploration and taxonomy have to be urgently promoted: many new species are still discovered on Macaronesia and others that were considered scarce or feared extinct reappear, yet young taxonomists are in short supply. And fourth, we need to increase scientific coordination both within and among archipelagos and with institutions from other areas that are interested in the Macaronesian plant diversity or may give complementary approaches to its investigation and conservation.

Our botanic gardens have been collaborating in a number of research projects that have significantly contributed to the cohesion of research on the floras of the Macaronesian oceanic hotspot and their conservation. Two of the agencies that funded

these initiatives (see Table 1) have spent from 2002 till mid June 2010 more than €22m in projects devoted to some aspect of the Macaronesian biodiversity (full details available at <www.interreg-mac.org>). Even a cursory analysis of the institutions involved in these initiatives highlights that coordination among the European archipelagos has been considerable (especially between the Canaries and the Azores [90 projects] and the Canaries and Madeira & Selvagens [93 projects], but only 32 projects between Azores and Madeira & Selvagens), whereas Cape Verde has participated in only a minority of initiatives, with six projects with only Canarian stakeholders.

Biodiversity does not take notice of political borders, and it is quite apparent that not enough effort and resources have been used at the pan-Macaronesian level to address the urgent problems that it faces. A lot more stimulus and strategic funding is thus needed so that Macaronesia may act coordinately as a single biogeographical unit (including some relevant enclaves in the mainland), based on the floristic links among the different insular and continental areas, but also on their different conservation needs and priorities. Furthermore, the geographic isolation that contributes so much to beget the distinctive Macaronesian plant biodiversity is also a strong deterrent to proper botanical exploration, and we do need to invest a lot of funds on taxonomy and field prospection to gain proper understanding on the composition and distribution of the floras.

The evolutionary singularity of the endemic insular floras and their extreme sensitivity to external changes, derived from prolonged isolation, should suffice to the integral protection of the Macaronesian biodiversity. In an ideal world, all insular biodiversity should be legally protected. However, as highlighted above, some of the most important activities for the survival and development of the growing Macaronesian populations need space and generate fragmentation that impinges on the survival and genetic cohesion of biodiversity. Hence, it is necessary to enforce the right laws that foster sustainable development policies to preserve biodiversity; furthermore, education and awareness about the value of biodiversity have to be promoted among the non-specialist population, and increasingly politicians.

Despite research efforts, the wrong laws are sometimes proposed, passed and enforced by persons alien to biodiversity conservation, and it is equally important that specialists react against these. One such wrong law was passed on May 18th 2010 by the Canary Islands Parliament that deprives most of this archipelago's biodiversity of legal protection in a clear and unconcealed move to allow many projects associated with unsustainable development. Certainly, this new law represents a huge problem for every solution that conservation scientists from this archipelago may suggest to preserve its lush biodiversity, and it contains a potentially more awful consequence: it may be contagious, thereby imperiling the endemic biodiversity in the remaining Macaronesian archipelagos, for a start.

The radical threats faced by the insular endemic floras are not local, but global, and only an effort of the same magnitude may provide the critical mass of knowledge needed to help take the right course of scientific and political action. The impacts of major threat factors on insular endemic plant biodiversity are unrelated to geographical proximity, thereby emphasizing the need for enhanced contact among island conservation scientists.

Botanic gardens are among the centres that conduct the most relevant research on plant conservation in all countries of the world. Notably, in many islands, botanic gardens are simply the only institutions that implement effective conservation measures for the endemic flora, based on the knowledge that they generate and glean.

Therefore, this 4th Global Botanic Gardens meeting in Dublin is a superb arena to set the stage of a global island plant conservation network, which is already operative at <http://www.bgci.org/ourwork/islands/>.

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Table 1. Projects co-funded by FEDER through the INTERREG-IIIB 2002-2006 or the PCT-MAC 2007-2013 initiatives (85% of the total amount) where botanic gardens or other institutions interested in/devoted to the research and conservation of the Macaronesian endemic floras have contributed (15% of the total amount). Participating institution abbreviations correspond to (in alphabetical order), CHA: Complexe Horticole d'Agadir, Institut Agronomique Vétérinaire Hassan II (Morocco); INIDA: Instituto Nacional de Investigaçoes e Desenvolvimento Agràrio (Cape Verde) JBCVC: Jardín Botánico Canario "Viera y Clavijo"-CSIC, Gran Canaria (Spain); JBF: Jardim Botânico do Faial, Azores (Portugal); JBM: Jardim Botânico da Madeira (Portugal); UA: Universidade dos Açores at Ponta Delgada (Portugal); ULPGC: Universidad de Las Palmas de Gran Canaria (Spain). In all these cases, the project leader was the JBCVC.

Acronym	Participating institutions	Total amount	Main objectives
BASEMAC	JBCVC, JBF, JBM	885,476.47 €	Improve seed banking facilities in three Macaronesian botanic gardens
BIOMABANC	JBCVC, UA, ULPGC	1,120,646.59 €	Generate new genetic diversity data (all) and create banks of DNA (JBCVC, UA), reproductive data (JBCVC), and ethnobotany (JBCVC)
CAVEGEN	INIDA, JBCVC	235,294.00 €	Create seed and DNA banks of the Cape Verdean endemic flora (JBCVC, as trust funds on behalf of the INIDA)
DEMIURGO	JBCVC, UA, ULPGC	814,377.87 €	Create public databases of genetic & biological information. Generate genetic diversity data on selected lineages
BIOCLIMAC	JBCVC, JBF, JBM	956,117.00 €	Design seed collection strategies based on genetic diversity data; study impact of climate change on selected taxa
ENCLAVE	CHA, JBCVC	519,315.00 €	Enhance multi-disciplinary knowledge and research collections on the floristic link Canaries-SW Morocco

FIGURE CAPTIONS

Figure 1. Examples of landscapes and Macaronesian endemic plants. Photo credits: João Melo, Nuno Rodrigues, Paulo Silva, Juli Caujapé-Castells, Águedo Marrero Rodríguez, Pepa Navarro, Felicia Oliva.

Figure 2. The five main drivers of endemic plant diversity decline on Macaronesia. The representation in the inset (below, left) is the relative position of the Macaronesian archipelagos relative to five other oceanic or para-oceanic archipelagos in the multivariate space defined by the 13 threat factors assessed in Caujapé-Castells et al. (2010). The five Macaronesian archipelagos are represented by different geometrical shapes that approximately correspond to their areas. G: Galápagos; H: Hawaii; J: Juan Fernández; M: Mascarenes; S: Seychelles.

Figure 3. Approximate present distribution of the extremely endangered endemic Canarian species *Atractylis preauxiana* (Asteraceae) in a few fragmented populations along the Eastern coasts of Tenerife and Gran Canaria. In Tenerife, eight populations have about 1600 censused individuals on the whole, but the size of many of these does not reach fifty specimens (the black circle pinpoints the population at Granadilla de Abona, see text). In Gran Canaria, only three populations are known, with roughly 4000 individuals overall. This species is in a critical situation because of the constant exposure of plants to intensive, uncontrolled anthropic action in the last few decades, that has generated demographic and habitat degradation.

Figure 1

Figure 2

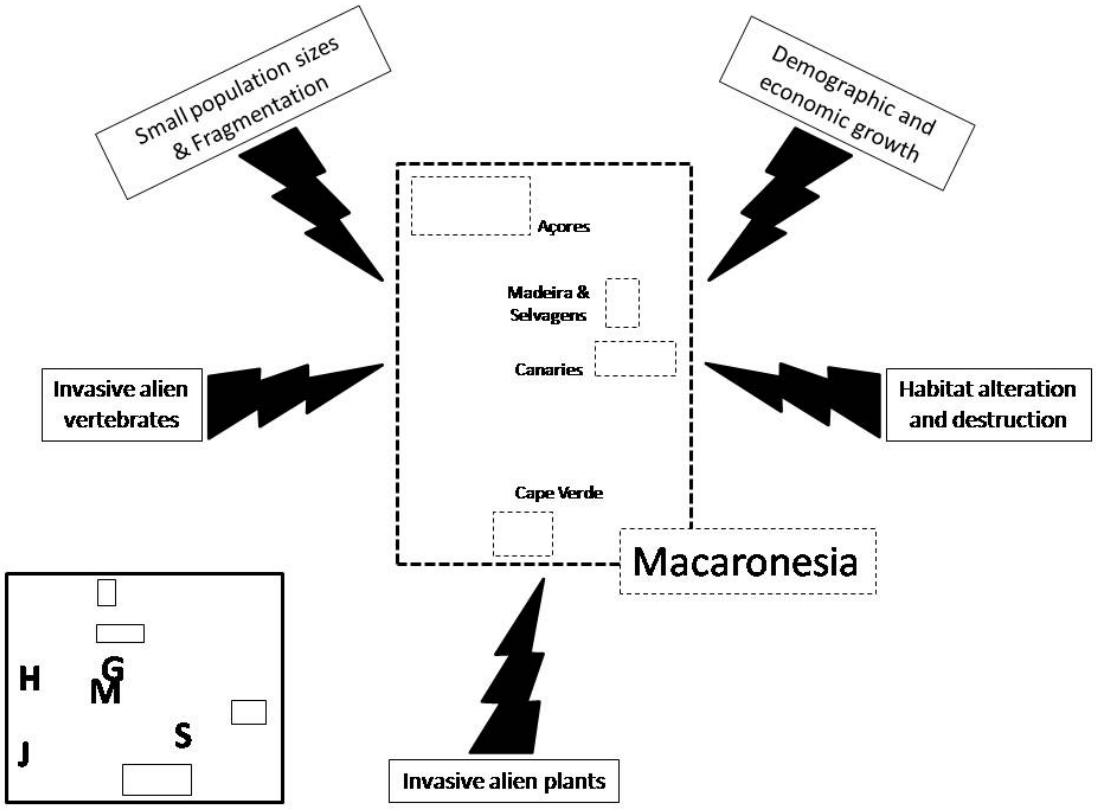
Small population sizes & Fragmentation
Demographic and economic growth
Açores
Madeira & Selvagens
Canaries
Cape Verde
Macaronesia
Invasive alien vertebrates
Habitat alteration and destruction
Invasive alien plants
H
G
M
S
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Figure 3