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Regional responsibility for plant conservation: The 2010 GSPC Target 8 in Sardinia

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Abstract
The collections stored at the Sardinian Germplasm Bank (BG-SAR) were analysed to verify if setting conservation priorities on the exclusive endemic flora of Sardinia (Italy) would make it possible to reach the 2010 GSPC Target 8. By 2010, 39.9% of the exclusive-endemics of Sardinia, 43.1% of the BGCI European threatened species and 65.0% of the taxa listed in Annex II of DIR 92/43/EEC present on the island had been stored in BG-SAR. Of the stored plants, 40% of those listed in the DIR 92/43/EEC, and only 25.69% of the BGCI threatened plants are represented by an adequate number of populations. For a few of the stored threatened plants (ca. 36%), and for 60% of the DIR 92/43/EEC ones, at least one seedlot with more than 5000 seeds is available. These data indicate that focusing on exclusive endemics gave a substantial, although not decisive, contribution towards the achievement of the 2010 GSPC Target 8 in Sardinia, and that more efforts are needed to guarantee the effective long-term conservation of these threatened taxa with the aim of reaching the 2020 GSPC target.

Keywords: *Endemics,* ex situ *conservation, IUCN, Mediterranean hotspot, seed banking*

Introduction

Current plant diversity extinction is estimated to be as much as 100- to 1000-fold higher than during the recent geological past (Pimm et al. 1995). In an attempt to halt this biodiversity loss, within the framework of the UN Convention on Biological Diversity (CBD), the Global Strategy for Plant Conservation (GSPC) was adopted in 2002 by the Parties of the CBD and all signatory governments committed to deliver the 16 targets by 2010 (CBD 2002). In 2010, the Conference of the Parties signed the Updated GSPC 2011–2020, including 16 outcome-oriented global target sets for 2020 (www. cbd.int/gspc).

In Europe, the ''Council Directive 92/43/EEC of 21 May 1992 on the conservation of natural habitats and of wild fauna and flora'' (hereafter, DIR. 92/43/EEC) and the Natura 2000 network are by far the most important conservation efforts implemented to date (Maiorano et al. 2007). They have been proposed as the main strategy to meet the target of halting (or at least significantly reducing) biodiversity loss by 2010 (Balmford et al. 2005). Annex II of this Directive lists the ''animal and plant species of community interest whose conservation requires the designation of special areas of conservation'' and although it is not a conservation target list itself, it represents a European list of species for which *in situ* conservation actions should be activated.

In situ conservation measures, such as the protection and restoration of natural habitats, are the best methods of preserving plant diversity (CBD 2002; Burrascano et al. 2009). However, *ex situ* conservation often becomes an alternative way to prevent immediate extinction. One of the most effective ways to conserve plant diversity *ex situ* is storage in seed banks, which allows preserving large amounts of genetic material in a small space and with minimum risk of genetic damage (Iriondo & Pérez 1999); alternative methods are used for preserving fungal biodiversity (Varese et al. 2011). Although these conservation approaches should be viewed as complementary rather than alternative, there are economics drivers working against *in situ* conservation, with the costs for *ex situ* conservation being estimated as little as 1% of those needed for conserving the

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species *in situ,* although *ex situ* conservation must address some technical challenges (Li & Pritchard 2009). The 2010 GSPC Target 8 recommended that 60% of threatened plant species be placed ''in accessible *ex situ* collections, preferably in the country of origin, and 10% of them included in recovery and restoration programmes'' by 2010 (CBD 2002), while the Updated GSPC raised the targets to 75% and 20%, respectively (www.cbd.int/gspc). The achievement of these results is supported both at European (EU Biodiversity Strategy; European Commission 2011) and national levels (for Italy ''La Strategia Nazionale per la Biodiversità''; MATTM 2010).

Botanical Gardens Conservation International (BGCI) has developed a consolidated list of over 11,000 taxa of European threatened species (Sharrock & Jones 2009) as a step towards a formal Red List (Sharrock & Jones 2011). Based on this list, Godefroid et al. (2011b) reported that although ca. 70% of the European flora is currently stored in seed banks, only 27% of the threatened taxa, and 44% of the taxa listed in e Annex II of DIR 92/43/EEC are stored in European seed banks: at least two-thirds of the stored threatened species likely suffer from excessively low genetic diversity in the collections.

The Mediterranean region hosts a flora of around 25–30,000 flowering plants and ferns and has been identified as one of the world's 34 biodiversity hotspots (Mittermeier et al. 2004). When working in such species-rich areas, ''priority lists'' should be created in order to identify the target species for conservation measures, as the conservation of biodiversity occurs via the implementation of policy with only limited resources (Balmford et al. 2005). Gauthier et al. (2010), comparing three rarity-associated criteria in order to establish regional-level priorities, identified the ''regional responsibility'' (i.e. highest scores associated to species whose distribution is endemic to the study area) as the first order priority at the local level. However, it should be taken into account that a population of a narrow endemic species is not intrinsically more vulnerable than populations of widely distributed species (Iriondo et al. 2008).

Sardinia is the second-largest island in the Mediterranean Sea (after Sicily) situated in the west Mediterranean basin, where geographical isolation and high geological diversity have created a wide range of habitats with high levels of endemism (Médail & Quézel 1997). The Sardinian Germplasm Bank (BG-SAR), belonging to the Università degli Studi di Cagliari, has undertaken the *ex situ* long-term conservation of the plant diversity of Sardinia, with a major focus on its exclusive endemic flora (Mattana et al. 2005). This seed bank participates in international seed conservation consortia, such as the European Native Seed Conservation Network (ENSCONET) and the Network of Mediterranean plant conservation centres (GENMEDA), while at a national level, BG-SAR is the regional member of the Italian Network of Germplasm Banks for the *Ex Situ* Conservation of Native Flora (RIBES).

The aim of this study was to analyse the collections stored at the BG-SAR in order to (1) verify if setting conservation priorities on the exclusive endemic flora will make it possible to reach the 2010 GPCS Target 8, and (2) evaluate, according to Godefroid et al. (2011b), the conservation value of these collections from a quantitative point of view.

Material and methods

Several collecting trips covering the whole island were carried out yearly during the period 2004–2010. For species listed in the annexes of the Habitat Directive, as required by the European and national laws (articles 9 and 10 of DPR 357/97 modified by DPR 120/03), seeds were collected after obtaining permits from the Italian Ministry of the Environment (''Ministero dell'Ambiente e della Tutela del Territorio e del Mare''). Ferns were excluded due to the technical difficulties related to the long-term conservation of spores (Magrini 2011). Priority was given to the endemic flora, and in particular to the exclusive taxa of Sardinia. Seedlots have been stored at the BG-SAR, following the genebank standards elaborated by FAO/IPGRI (1994) for orthodox seeds, as described in Mattana et al. (2005).

The vascular flora of Sardinia (Table I) was assessed according to Conti et al. (2005b), while its exclusive component was assessed according to the checklist elaborated by Bacchetta et al. (2012). A reliable updated IUCN Red List at the Italian level is still in progress (Rossi & Gentili 2008). Therefore, in order to assess the degree of achievement of the 2010 GSPC Target 8, the species for which seed collections were present at BG-SAR by 2010 were compared with those of the BGCI European threatened plant list (Sharrock & Jones 2009), or those listed in Annex II of DIR 92/43/EEC (table I). According to Godefroid et al. (2011b), the thresholds of five populations per species and 5000 seeds per seedlot were used to evaluate the effectiveness of the conservation effort, as recommended by ENSCONET (2009), except for species present in Sardinia with less than five populations, that were considered effectively conserved only when all populations were sampled.

Results

By 2010, BG-SAR held 226 seedlots belonging to 67 exclusive endemics of Sardinia, 193 seedlots of 47 taxa listed in the BGCI European threatened plant

list and 69 seedlots of 13 taxa included in Annex II of DIR 92/43/EEC. Consequently, 39.88% of the endemics, 43.12% of the threatened taxa and 65.0% of the DIR 92/43/EEC taxa present in Sardinia are presently conserved (Figure 1). The majority of the banked taxa (i.e. 33 out of 47, corresponding to 30.27% of the total and 8 out of 13 taxa, corresponding to 40% of the total for the threatened plants and the DIR 92/43/EEC plants, respectively) are exclusive Sardinian endemics (Figure 1).

Of the threatened species, 25.69% were adequately represented in the seed bank, with 22.02% being species with up to five populations, all of which were sampled, and 3.67% with more than five populations for which at least five were sampled (Table II). This percentage rose to 40% for the species listed in Annex II of DIR 92/43/EEC (35% being species with up to five populations; Table II).The majority of the BGCI European threatened plants (63.83%) stored in BG-SAR were not represented by at least one seedlot with more than 5000 seeds, whereas 60% of the stored taxa of the Annex II DIR 92/43/EEC fulfilled this requirement.

The threatened taxa stored in BG-SAR by 2010 for which the two criteria of genetic representativeness were respected were 13 (12%). Among them, four are also included in Annex II of DIR. 92/43/EEC (*Astragalus maritimus* Moris, *A. verrucosus* Moris, *Lamyropsis microcephala* (Moris) Dittrich *et* Greuter, and *Linum muelleri* Moris), and four are classified as Critically Endangered (CR) according to the IUCN criteria (*Aquilegia barbaricina* Arrigoni *et* E. Nardi, *A. maritimus*, *A. verrucosus* and *L. microcephala*).

Table I. Number of plants belonging to the flora of Sardinia (Conti et al. 2005b) and to its exclusive component (Bacchetta et al. 2012), and listed in the BGCI European threatened plant list (Sharrock & Jones 2009) or in Annex II of DIR 92/43/EEC. For the two catalogues, the number of taxa present in Sardinia, and the exclusive endemics of the island are also reported.

	Total	Sardinia	Sardinian endemics
Sardinian vascular flora		2408	168
BGCI European threatened plant list	1917	109	62
Annex II DIR 92/43/EEC	431	20[a]	9

[a]*Marsilea quadrifolia* L. was not counted as its presence on the island was not confirmed (Conti et al. 2005a).

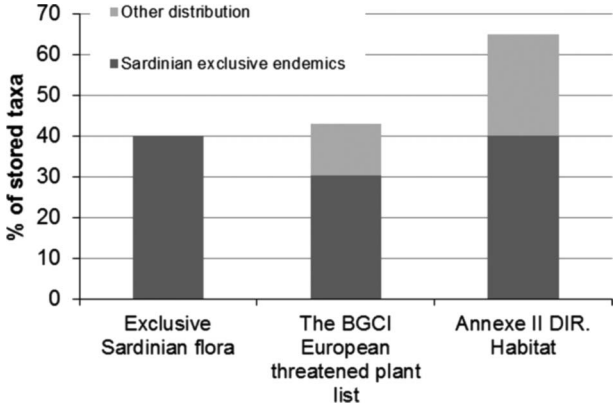

Figure 1. Percentages of exclusive Sardinian endemics, BGCI European threatened plants, and taxa listed in Annex II of DIR 92/43/EEC stored in BG-SAR by 2010. For the two catalogues, the percentage of stored endemics is also highlighted.

Discussion

The results presented here indicate that ca. 40% of the exclusive endemic species of Sardinia had been stored in BG-SAR by 2010 for their long-term conservation. The propensity of many rare species to grow in remote and/or inaccessible locations, and the lack of or low seed set of populations growing under sub-optimal conditions are two of the main obstacles inherent in harvesting seeds (Godefroid et al. 2011b). This is true for many Sardinian endemics, such as *Aquilegia nuragica* Arrigoni *et* E. Nardi, whose very small population is found on a nearly vertical limestone cliff (Camarda 2006), and *Ribes sardoum* Martelli for which the number of available seeds was always insufficient to allow effective seed collection (Fenu et al. 2012).

Sharrock and Jones (2009) reported that, as might be expected, the majority of the taxa included in the BGCI threatened plant list (90%) are single-country endemics. The data for Sardinia highlights the fact that ca. 58% of such plants, and 45% of the species included in Annex II of DIR. 92/43/EEC are exclusive of this island. Therefore, setting conservation priorities for exclusive Sardinian endemics, apart from responding to the criterion of ''local responsibility'' (*sensu* Gauthier et al. 2010), may give a substantial contribution to the achievement of the 2010 GSPC Target 8. However, the present study showed that while 65% of the taxa listed in Annex II of DIR. 92/43/EEC had been stored in BG-SAR by 2010, this percentage fell to ca. 40% for the BGCI threatened plants. This difference, considering that the percentages of exclusive endemics ranged from 30 to 40% on the two lists, is due to the different contribution of collected taxa with broader distributions than Sardinia, such as *Brassica insularis* Moris (Sardinia-Corsica-Pantelleria-North Africa), *Helianthemum caput-felis* Boiss. (W-Medit.) and *Rouya polygama* (Desf.) Coincy (SW-Medit.), listed in the Annex II DIR. 92/43/EEC, but not in the BGCI, list. Nonetheless, these percentages are above the average European ones (27% of BGCI threatened plants and

Table II. Percentage of species listed in the BGCI European threatened plant list or in Annex II of DIR 92/43/EEC and stored in BG-SAR by 2010 with seedlots belonging to all the known populations (when they are up to five) or to at least five seedlots (for species with five or more populations).

	Number of Sardinian populations	Adequate sampling (%)	Not adequate sampling (%)
BGCI European threatened plant list	Up to 5	22.02	6.42
	5 or more	3.67	11.01
	Total	25.69	17.43
Annex II DIR 92/43/EEC	Up to 5	35	5
	5 or more	5	20
	Total	40	25

44% of those listed in Annex II; Godefroid et al. 2011b).

From a quantitative point of view, the high number of threatened Sardinian plants for which an adequate sampling was not carried out (17–25%) is due to remote and/or inaccessible locations, where many rare species grow, preventing a more exhaustive seed sampling. When considering the parameter of seedlots with more than 5000 seeds, 30% of the stored BGCI threatened species have accessions of adequate size, while this percentage doubled for the species listed in Annex II of DIR. 92/43/EEC. Also in these cases, the differences between the two lists were due to the different contribution of non-exclusive endemics on the latter, and again the values are above the European average (Godefroid et al. 2011b).

Only 12% of the BGCI threatened species stored in BG-SAR 2010 had collections which fulfilled both quantitative criteria. Despite the low numbers, most of these taxa have high conservation values. In particular, four species, all of them Sardinian endemics, are classified as CR. Several seed dormancy and germination ecology studies have been carried out for these species (e.g. Mattana et al. 2009; Bacchetta et al. 2011; Mattana et al. 2011). This information, together with the availability of stored seedlots, genetically representative and of adequate size, will make it possible to activate effective recovery measures for these threatened species, in compliance with the second part of the 2010 GSPC Target 8 ''*... 10% of threatened plant species included in recovery and restoration programmes''*.

Seed longevity in seed bank conditions widely varies among species, and recent artificial seed ageing studies revealed the effects of seed structure and environmental conditions at the site of collection, with endospermic seeds from cool, wet environments (e.g. alpine species) being short-lived (Probert et al. 2009; Mondoni et al. 2011). Although species belonging to the dry Mediterranean climate should not suffer from low seed longevity, no data are available for species living in Mediterranean mountain ecosystems. Therefore, more studies are needed in order to evaluate the actual potential of the stored seed lots for long-term conservation. Considering this challenge and the apparent low success of many plant reintroduction programmes compared to the invested efforts (Godefroid et al. 2011a), complementary *in situ* conservation actions should be carried out, such as those already initiated for *L. microcephala* and *Ribes multiflorum* Kit. *ex* Roem. *et* Schult. ssp. *sandalioticum* Arrigoni (Fenu et al. 2011, 2012).

In conclusion, by implementing the criterion of ''regional responsibility'' *sensu* Gauthier et al. (2010), a substantial, though partial, contribution towards the achievement of the 2010 GSPC Target 8 in Sardinia has been given, especially if one considers the genetic representativeness of the collections, which is very difficult to achieve with other *ex situ* conservation methods, such as plant cultivation in botanical gardens. However, further efforts are needed to guarantee the long-term conservation of the genetic diversity for these threatened taxa, and to reach the new 2020 GSPC Target 8.

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