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ORIGINAL PAPER

How to meet the 2020 GSPC target 8 in Europe: priority-setting for seed banking of native threatened plants

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Abstract The contribution of the European Native Seed Conservation Network (ENSCONET, 2004-2009) and the ENSCONET Consortium (since 2010) towards meeting the 2020 Global Strategy for Plant Conservation (GSPC) target 8 was assessed in 2017. While the outcome was positive (62.7% of European threatened species already conserved ex situ in seed banks), the analysis showed that it was essential to provide guidance on which European native threatened species should be collected as a priority if the target was to be reached by 2020. In this paper we present a priority-setting method and its result, designed to guide collecting strategies across Europe to meet the 2020 GSPC target 8. The result of our study is a country-based checklist of European threatened taxa to be collected and stored ex situ across the seed banks of the ENSCONET Consortium by 2020. After discussing the results of the applied method, the ENSCONET Consortium Steering Committee has identified some key action points to support the implementation of such a collecting strategy across Europe in order to meet the 2020 GSPC target 8 for Europe.

Keywords Ex situ seed conservation · Seed banks · European threatened plant species · ENSCOBASE · ENSCONET Consortium

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Introduction

The 2010 Global Strategy for Plant Conservation (GSPC) target 8a (i.e., first part of the target) called for 60% of threatened plant species to be conserved in ex situ collections by 2010. In Europe, seed-bearing native threatened species were only partly conserved in seed banks as shown by Godefroid et al. (2011) and Sharrock and Jones (2011). An updated 2020 GSPC target 8a now aims to conserve 75% of threatened plant species in ex situ collections by 2020, preferably in the country of origin (Convention on Biological Diversity 2012).

Progress towards meeting the 2020 GSPC target 8a can be assessed by the extent of ex situ conservation in seed banks, which is an often applied and cost-effective way of preserving plants (Hay and Probert 2013; BGCI 2016). Some species cannot be preserved in traditional seed banks because they do not reproduce by seed, or because their seeds are not desiccation tolerant (Wyse and Dickie 2017), and for those species alternative ex situ storage techniques must be identified (Li and Pritchard 2009), including cryopreservation of embryonic tissue of recalcitrant seeds. In Europe, however, the vast majority of spermatophytes are desiccation tolerant and for them seed banking is possible and should be encouraged as a means of ex situ conservation (Rivière and Müller 2017). Such seed banking activities have been promoted by the ENSCONET Consortium since it was established in August 2010 with the aim of maintaining significant levels of ex situ seed conservation activity for European native plant species. The Consortium builds on the success of the ENSCONET project (European Native Seed Conservation Network), funded under the European Commission's Sixth Framework Programme for Research and Technological Development (FP6) between 2004 and 2009 (Eastwood and Müller 2012). A total of 31 institutes across Europe (29 equipped with a seed bank) currently constitute the ENSCONET Consortium, all of which have an explicit interest in seed conservation of European native plants. One of the successful outputs has been the establishment of ENSCOBASE, an online database that has been storing data on European native seed accessions since 2005 (ENSCOBASE 2017a). Contributors to ENSCOBASE are multiple: currently, 24 ENSCONET Consortium member seed banks have contributed data, and another 11 non-members seed banks have also shared their data (Table 1).

A recent analysis of seed bank holdings across Europe, as uploaded into ENSCOBASE, showed 62.7% of European threatened species were conserved ex situ in seed banks and concluded that the 2020 GSPC target 8a is not met (Rivière and Müller 2017). In addition this analysis stressed the need to increase the genetic diversity of the threatened species already banked as many species have only one to four accessions reported in ENSCOBASE, which may or may not come from the same population, and, therefore, may not represent sufficient levels of genetic diversity at the species level (Brown and Briggs 1991).

With the global aim of meeting the GSPC target 8a by 2020 and increasing the genetic representation of threatened species collected ex situ, this paper provides a strategy for achieving the target for Europe. It also includes a checklist of those species native to Europe that need to be collected and conserved in ex situ collections to fulfil, and if possible exceed, the requirement of the 2020 GSPC target 8a. Similar strategies for Europe have so far only been set up at the national level (e.g., Hölbling 2013) or regional level (e.g., Mattana et al. 2012). For our analysis we ran a priority-setting method to produce country-based collection plans of European threatened species by 2020. The chosen priority scores were based on the distribution range of threatened species across European countries, and the number of their ex situ accessions (if any) in ENSCOBASE at the time of the analysis.

Table 1 Ex situ conservation data contributors to ENSCOBASE and information about their link with the ENSCONET Consortium since 2010

Institution's acronym as shown in ENSCOBASE	Institution's country	Member of ENSCONET Consortium since 2010?	Total accessions in ENSCOBASE as of 31/10/2017[a]	Total accepted taxa in ENSCOBASE as of 31/10/2017[a]
ATHD	Greece	No	344	185
BBGK	Greece	No	909	623
BGBM	Germany	Yes	4466	1921
BGM	Belgium	Yes	980	535
BG-CBDC PAS	Poland	Yes	652	192
BOKU	Austria	Yes	709	364
Canario	Spain	Yes	4895	810
CCB	Italy	Yes	202	202
Cordoba	Spain	No	7054	2187
CYARI	Cyprus	Yes	399	249
Geneva	Switzerland	Yes	386	154
GIJON	Spain	Yes	1353	467
Kostrzyca	Poland	Yes	6259	95
LUOMUS	Finland	Yes	231	144
Luxembourg	Luxembourg	Yes	860	273
MAICh	Greece	Yes	773	307
MNHN	France	Yes	6202	2486
MUHNAC	Portugal	Yes	2670	912
NCU	Cyprus	Yes	29	12
NKUA	Greece	Yes	523	294
OEC	France	No	233	180
OSN	Germany	No	567	545
PAVIA	Italy	Yes	1443	524
Perugia	Italy	No	1285	77
PISA	Italy	Yes	968	658

Table 1 (continued)

Institution's acronym as shown in ENSCOBASE	Institution's country	Member of ENSCONET Consortium since 2010?	Total accessions in ENSCOBASE as of 31/10/2017[a]	Total accepted taxa in ENSCOBASE as of 31/10/2017[a]
RBGK	United Kingdom	Yes	11,839	5206
SARC-RIPP	Slovak Republic	Yes	66	18
Sóller	Spain	Yes	1025	395
SVGB	Romania	No	768	190
TCD	Ireland	No	165	59
UOBG	Norway	Yes	40	27
UNICT	Italy	No	200	179
UPM	Spain	Yes	5420	2234
UPOL	Czech Republic	No	88	82
UVEG	Spain	Yes	2902	960
Total institutions: 35	Total countries: 19	Total « Yes » : 24	Total accessions: 66,904	Total accepted taxa: 11,792

The number of accessions and accepted taxa per institution is also listed. A definition of acronyms is available in Supplementary Material S1

[a]The total of accessions is the sum of all institutions' accessions whereas the total of taxa is not as different institutions may store the same taxon. The following are not included

-History accessions which no longer exist (e.g. seed empty or dead)

-Taxa and accessions whose species epithet is only "sp."

-Taxa and accessions whose identification qualifier is "cf."

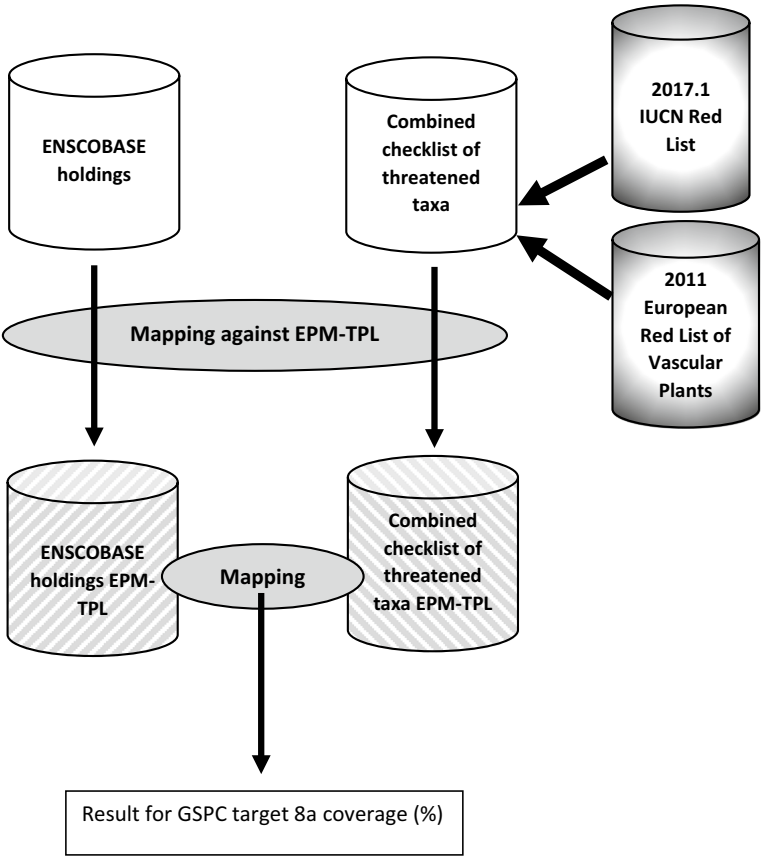

Fig. 1 Methodology used to map ENSCOBASE holdings (as of 31/10/2017) against the combined checklist of threatened taxa derived from the 2017.2 IUCN Red List and the 2011 European Red List of Vascular Plants (EPM = Euro+Med, TPL = The Plant List)

Methods

Updated checklist of the threatened flora of Europe

We produced an updated version of the checklist of European threatened species following the method described in Rivière and Müller (2017). In order to maintain taxonomic consistency, the 2011 European Red List of Vascular Plants checklist (Bilz et al. 2011) and the threatened species (IUCN global criteria CR, EN and VU[1]) of the IUCN Red List 2017.2 (IUCN 2017) were merged and mapped against a unique taxonomic referential made of Euro+Med (2006) and The Plant List (The Plant List 2010) (Fig. 1).

It should be noted that although the 2020 GSPC target 8a refers to the term "species", for this analysis we included infraspecific taxa. This was because mapping of the

[1] CR: Critically Endangered; EN: Endangered; VU: Vulnerable.

above-mentioned threatened checklists against the taxonomic referential revealed that some species were actually synonyms of infraspecific taxa (according to Euro+Med or The Plant List). We have, therefore, gone beyond the limits set by target 8a and included taxa of infraspecific ranks in our collection plan. Consequently the size of the threatened checklist increased slightly (from 622 species to 706 accepted taxa, see below). Hereafter, when referring to this checklist, we will use the term "the combined checklist of threatened taxa".

Mapping ENSCOBASE against the combined checklist of threatened taxa

Following Rivière and Müller (2017) who showed in their study that the 2020 GSPC target 8a was not met, the combined checklist of threatened taxa was mapped against ENSCOBASE holdings as of 31/10/2017 (Fig. 1). Since the threshold of 75% set by the target was still not reached (see below), we developed a method to identify and prioritise the threatened taxa to be collected in European countries[2] by 2020.

Prioritisation for ex situ seed conservation

After compiling the list of European-native taxa that are CR, EN and VU based on the combined checklist, all taxa were given the same "weight", regardless of their threat category, and no further prioritisation was made according to this criteria (i.e. CR taxa were not prioritised over VU taxa). The reason for this was two-fold: (a) in its definition, the 2020 GSPC target 8a does not differentiate between CR, EN and VU, but considers all "threatened" taxa which we interpret as those defined by these IUCN categories (IUCN 2001); and (b) by flagging CR taxa as higher-priority for collection, the ex situ conservation efforts of ENSCONET Consortium members would focus on such taxa until 2020—which could mean that "less threatened taxa" may not be collected at all or may have their collection delayed, despite their relevance for the 2020 GSPC target 8a, increasing the probability that this target will be missed again in 2020. Consequently, we adopted a priority-setting methodology which focuses first on making progress to meeting the 2020 GSPC target 8a and then on increasing the genetic diversity of the ex situ collections of threatened taxa. Given that having a threatened taxon stored ex situ at least once is more relevant for the 2020 GSPC target 8a than having it stored in multiple accessions, the main goal of our priority-setting method was to ensure that a threatened taxon was represented at least once in a European seed bank. However, mindful of the recommendation of Rivière and Müller (2017) to maximise the genetic diversity of the species conserved by ENSCONET Consortium members, a minimum of five accessions per species is desirable (following Brown and Briggs 1991). For this reason we distinguished two categories relating to the number of accessions: the highest priority being to collect those taxa with zero accessions currently held, and the next priority being to increase the number of accessions for each taxon to at least five. We did not break down the category of "1–4 accessions" into four individual categories (i.e., one, two, three and four accessions) as all taxa falling into this group will require additional collecting to maximise their genetic diversity, although not to meet the 2020 GSPC target 8a.

[2] For the purpose of this study, Europe is defined as countries west of the Ural and north of the African- and Near East-Mediterranean coast. We therefore included countries such as Azerbaijan, Armenia, Georgia and Turkey.

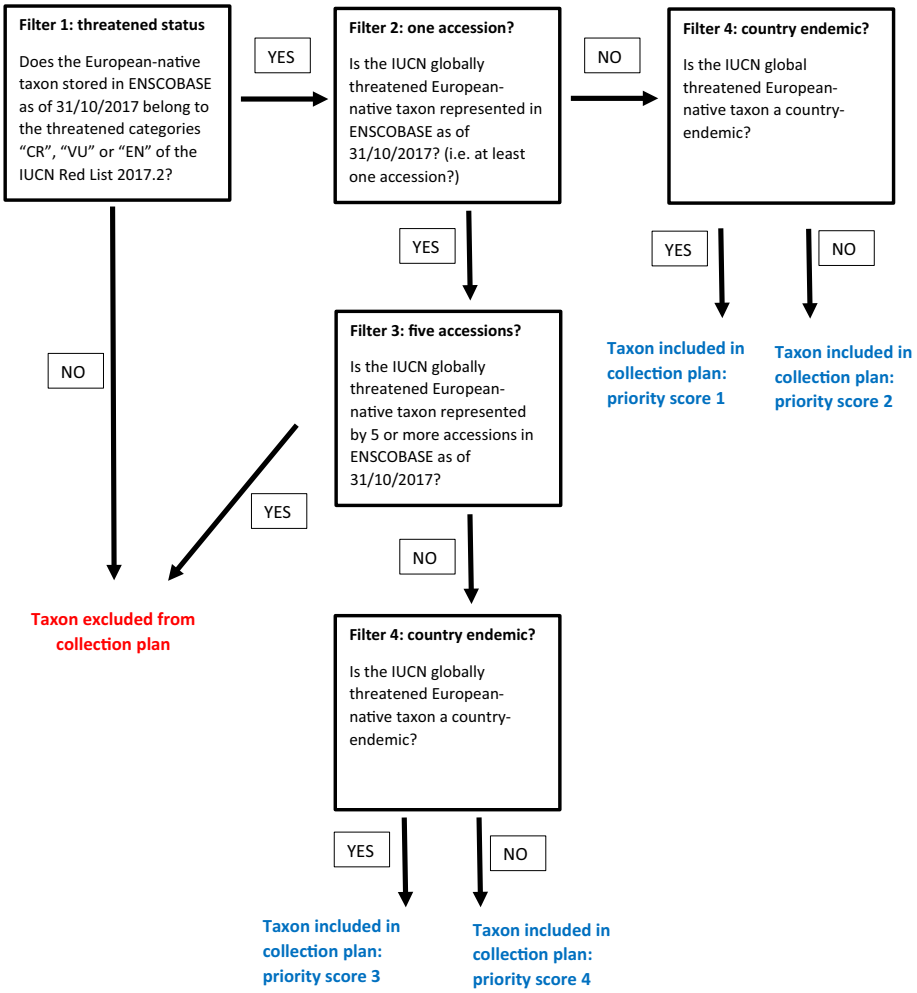

Fig. 2 Decision tree for the priority-setting methodology of the collection plan: retrieval of all threatened European-native taxa from the combined checklist of threatened taxa, filtered by "at least one accession", "equal to or higher than five accessions" and "country endemics"

The geographic distribution of a threatened taxon (i.e., the number of countries in which it naturally occurs) was selected as a second criterion for the priority-setting, whereby a taxon occurring in a single country (i.e., a country endemic) was prioritised over a taxon occurring in more than one country. It is important to note that a threatened taxon may occur in both a European country and in a non-European country (e.g., Spain and Morocco). For our analysis, which focused only on Europe, we considered only the European country in such cases, i.e. the number of countries of occurrence in the above example was equal to "1".

The resulting collection plan was based on four filters, summarised in a decision tree (Fig. 2): threatened status, "*at least one* ex situ *accession*", "*equal to or higher than five*

Table 2 Priority scores for the collecting activities of the ENSCONET Consortium until 2020

Priority scores (1: highest priority)	Number of accessions stored in ENSCOBASE as of 31/10/2017	Number of European country(ies) of occurrence for the threatened taxa
1	0	1 (Country endemic)
2	0	> 1
3	1–4	1 (Country endemic)
4	1–4	> 1

Top priority is given to taxa not represented in ENSCOBASE ("0 accessions") over the ones already represented ("1–4 accessions"). Next, taxa endemic to a country were prioritised over the ones occurring in more than one country

accessions" and "*country endemics*". Consequently, taxa with five and more accessions were beyond the scope of the collection plan, and were not considered further.

For the distribution range, we compiled a list of those European countries in which the threatened taxa of the combined checklist occur using native distribution information available in Euro+Med (2006) and the IUCN Red List version 2017.2 (IUCN 2017). In cases of conflict between the two sources of geographical information, we retained the source of information with the highest number of countries of occurrence. For example, we assigned two native countries of origin for *Phalaris maderensis*, which according to the IUCN Red List occurs only in Portugal, but occurs in Portugal and Spain according to Euro+Med.

Priority scores were assigned to the selected threatened taxa using the criteria listed above, in order of importance:

Number of accessions currently stored ex situ *according to ENSCOBASE* As our first aim was to collect taxa from the combined checklist of threatened taxa with "0 accessions" we prioritised them over those with "1-4 accessions". Having at least one ex situ accession of taxa which had not previously been collected was, therefore, considered a higher priority than increasing the genetic representation of threatened taxa which had already been collected.

Number of countries of occurrence of a threatened taxa A taxon occurring in a single country (i.e., a country endemic) was prioritised over a taxon occurring in more than one country.

By combining both criteria we produced a set of four scores (ranking from "1" to "4"). The details of the scores are shown in Table 2.

Results

Mapping ENSCOBASE against the combined checklist of threatened taxa

ENSCOBASE holdings (as of 31/10/2017) were mapped against the combined checklist of threatened taxa, which represented 706 accepted European threatened taxa. To achieve target 8a the ENSCONET Consortium needs to collect and store ex situ a total of 530 taxa (75% of the total). The updated analysis in this paper shows a reduced level of progress towards the 2020 GSPC target 8a compared to that presented in Rivière and Müller (2017)

because of new taxa included in the IUCN Red List 2017.2 used for this study and not stored in ENSCOBASE as of 31/10/2017. Currently 355 European threatened taxa are held (ENSCOBASE 2017b), representing 50.3% of the total, and below the threshold of 75% set by the 2020 GSPC target 8a. To reach this threshold an additional 175 taxa require collection. Of the 706 accepted European threatened taxa, 351 of them were not stored in ENSCOBASE (i.e. "0 accessions")—collecting 175 of these would consequently enable the ENSCONET Consortium to meet target 8a. Furthermore, 196 accepted European threatened taxa stored in ENSCOBASE are represented by only one to four accessions, and require additional collections to maximise the genetic diversity of the stored germplasm (Table 3).

To produce our collection plan we focused on both the "0 accessions" and "1–4 accessions" taxa which represented a total of 547 taxa (351 + 196). The 159 taxa represented by five accessions or more were beyond the scope of the study and were excluded from the collection plan (Table 3). They represent, however, the segment of accessions which is effectively conserved ex situ, i.e. 22.5% of the combined list of European threatened taxa (159/706).

Collection plan

Based on the above results we produced a collection plan of European threatened taxa by selecting the "0 accessions" and the "1–4 accessions" of accepted European threatened taxa and applying the priority-settings described in Table 2.

The full country-based collection plan with priority scores can be found in Supplementary Materials S2 for the 351 taxa with "0 accessions" and Supplementary Material S3 for the 196 taxa with "1–4 accessions".[3] For example, among the "0 accessions" threatened taxa, the country endemic *Campanula sabatia* is found only in Italy and is endemic to this country. It was given a priority score of 1, whereas *Anacyclus pyrethrum* can be found in five countries (France, Germany, Poland, Spain and Ukraine), and was, therefore, given a priority score of 2. With respect to "1–4 accessions" taxa, *Aethionema retsina* was given a priority score of 3 as it is endemic to Greece, whereas *Phalaris maderensis*, which occurs in both Spain and Portugal (according to Euro+Med, as explained above), was given a priority score of "4". A summary of the results is given in Table 4.

The 159 accepted taxa excluded from the collection plan (those with "equal to or higher than 5 accessions") can be found in Supplementary Material S4. Among the excluded threatened taxa, the Endangered Cretan endemic *Zelkova abelicea* was represented by seven accessions in ENSCOBASE, and the Critically Endangered Cretan endemic *Anthemis glaberrima* by 12, both above the threshold for inclusion.

Countries covered by the collection plan

The analysis revealed a total of 44 countries with "0 accessions" taxa to collect, and 36 countries with "1–4 accessions" taxa to collect (45 different countries for the two combined categories) (Supplementary Material S5). Greece, Italy, Portugal and Spain have the highest number of taxa to be collected for both priority scores 1–2 ("0 accessions") and priority scores 3–4 ("1–4 accessions") (Figs. 3, 4).

[3] Not all the listed taxa produce seeds and thus might require other methods of ex situ conservation (e.g. *Artemisia pancicii* which is currently tested for tissue culture in Austria).

Table 3 The three groups of threatened taxa identified after mapping ENSCOBASE holdings against the combined checklist of European threatened taxa, and their relevance to the collection plan

Groups of threatened taxa based on their representation in ENSCOBASE as of 31/10/2017	Total number of accepted taxa	Total number of accepted taxa required to achieve 2020 GSPC target 8a	Taxa considered for the ENSCONET Consortium collection plan to 2020
0 accessions	351	175	Yes
1–4 accessions	196	N/A	Yes
5 or more accessions	159	N/A	No
Total threatened taxa	706	175	547

Table 4 Summary of the total number of accepted taxa per category of priority score, the total number of countries of occurrence per priority score, the presence of ENSCONET Consortium seed banks in the countries of occurrence, and the percentage of countries with an ENSCONET Consortium seed bank

Priority score (see Table 2 for details)	Total number of accepted taxa listed by priority score class	Total number of countries in priority score class	Number of ENSCONET Consortium seed banks in these countries-	Number of accepted taxa occurring in a country where ENSCONET Consortium has seed banks	Percentage of countries with ENSCONET Consortium seed bank
1	257	21	9	199	9/21 (42.9%)
2	94	42	13	86	13/42 (31.0%)
3	148	11	8	146	8/11 (72.7%)
4	48	36	13	43	13/36 (36.1%)

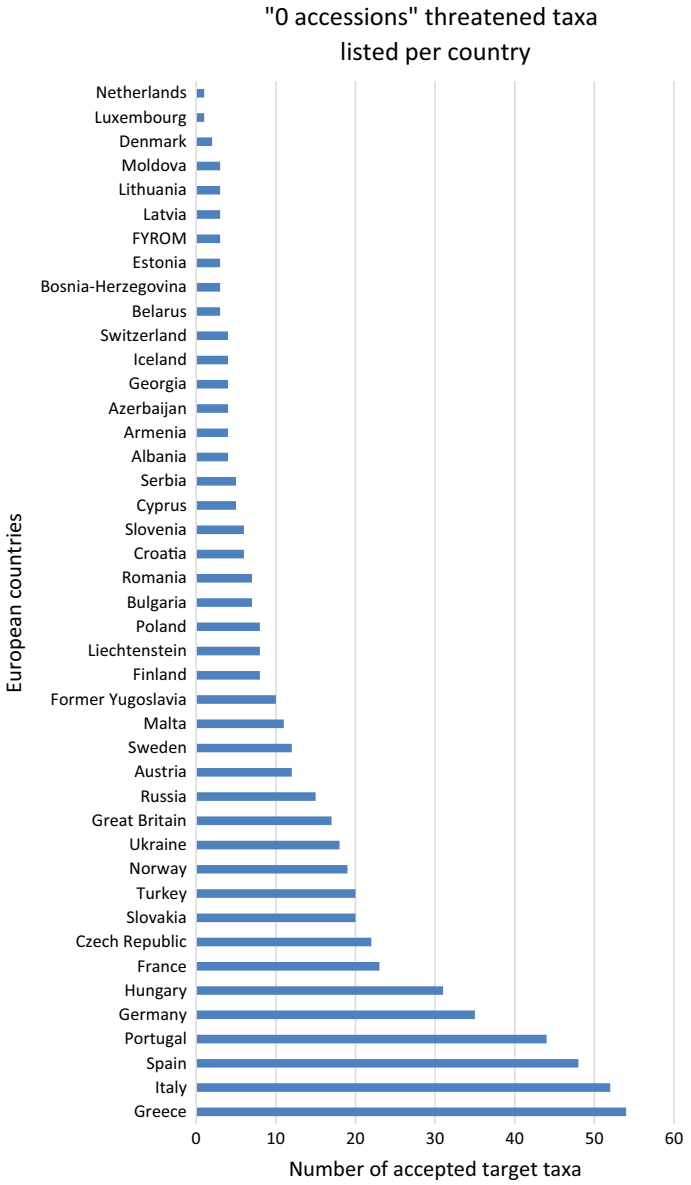

Fig. 3 Number of "0 accessions" (priority scores 1–2) threatened taxa by country of occurrence (note: the same taxa can occur in more than one country)

A summary of the total number of target taxa per priority score ("1", "2", "3" or "4") can be found in Table 4. The greatest number of taxa to be collected by 2020 corresponds to priority score 1 (257 accepted taxa), i.e. taxa which do not currently have a record in ENSCOBASE ("0 accessions") and which are distributed in one single country.

Fig. 4 Number of "1–4 accessions" (priority scores 3–4) threatened taxa by country of occurrence (note: the same taxa can occur in more than one country)

Total number of countries covered and overlap with ENSCONET Consortium seed banks

The complete list of countries per priority score ("1", "2", "3" or "4"), as well as the overlap of the geographical location of ENSCONET Consortium seed banks with these countries, can be found in Supplementary Materials S6-S9. A summary of the coverage of the relevant countries by ENSCONET Consortium seed banks is shown in Table 4.

Taxa of priority score 2 occur in the highest number of countries (42). The overlap between the location of ENSCONET Consortium seed banks and the countries where taxa

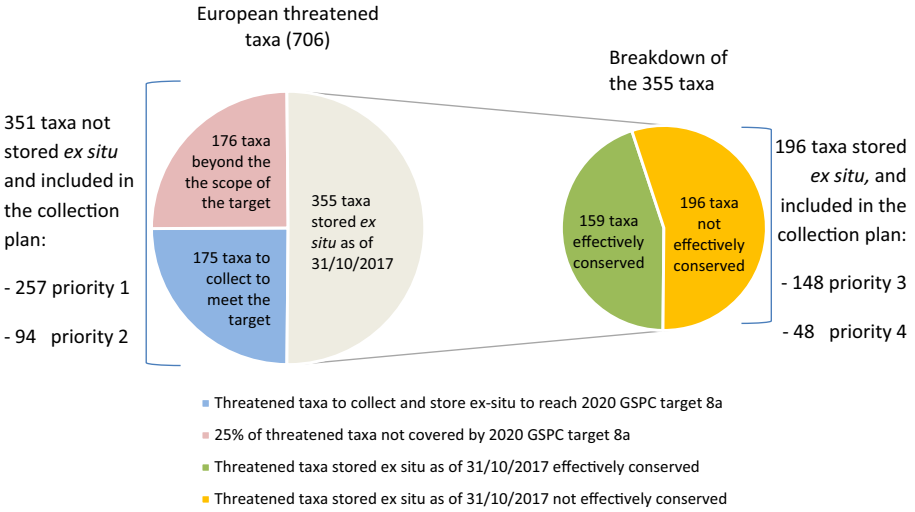

Fig. 5 Representation of the breakdown of the 706 European threatened taxa. A total of 351 taxa were not stored ex situ as of 31/10/2017 and have been included in the collection plan (257 priority 1 and 94 priority 2), as well as a further 196 which were underrepresented ex situ (148 priority 3 and 48 priority 4) at this date

require collection varies significantly according to the priority score, from 72.7% (priority score 3) to 31.0% (priority score 2).

In summary, 50.3% of the 706 European threatened taxa have been stored in European seed banks, with data relating to the accession uploaded to ENSCOBASE, as of 31/10/2017. To reach the GSPC target 8a of 75%, 175 additional threatened taxa need to be collected and stored ex situ within the seed banks of the ENSCONET Consortium. There are 355 European threatened taxa that are already conserved ex situ by the ENSCONET Consortium: 159 of these are effectively conserved ("equal to or higher than 5 accessions"), while 196 require wider coverage of their genetic diversity ("1–4 accessions") (Fig. 5).

Our collection plan was designed to specifically target the collection and ex situ storage of the 351 threatened taxa not currently represented in seed banks, of which the largest segment is represented by country-endemics (257 taxa, priority 1) versus non-endemics (94 taxa, priority 2). The highest proportion by country of these "priority 1" and "priority 2" threatened taxa that require collection are in Greece, Italy, Portugal and Spain (Fig. 4).

There are 196 accepted European threatened taxa stored in ENSCOBASE that are represented by one to four accessions, indicating that their genetic diversity may be underrepresented in ex situ collections. Since these taxa have already been collected at least once and data lodged with ENSCOBASE, they represented a lower priority for collection than taxa which have never been collected ("0 accessions"). Nevertheless, the collection plan aims to increase the genetic representation of such taxa and they are therefore listed under priority 3 (country-endemics) and priority 4 (non country-endemics). The highest number to be collected are country-endemics (148 taxa, priority 3). Here too, the same four countries (Greece, Italy, Portugal and Spain) have the greatest number of priority 3 and 4 threatened taxa to collect (Fig. 4). Finally, 159 taxa were effectively conserved ex situ (at least five accessions held), representing 22.5% of European threatened taxa (159/706).

Discussion

Our study showed that significant progress has been made towards the completion of the 2020 GSPC target 8a, with 50.3% currently conserved. In order to meet this target, the ENSCONET Consortium needs to collect an additional 175 taxa. To this end the Consortium has established this collection plan which will not only meet, but exceed, the target. At the same time the collection plan aims to increase the genetic diversity of ex situ collections of threatened taxa already conserved in seed banks by increasing the number of accessions per taxa to more than five. Our study is, therefore, vital to plant conservation at the European level, describing a concerted action plan to enable ENSCONET Consortium members to achieve the 2020 GSPC target 8a.

This study has highlighted four Mediterranean countries which hold the greatest proportion of the threatened taxa identified in this collection plan, namely Greece, Italy, Portugal and Spain. These four countries with the highest number of threatened taxa to collect under this action plan lie where the Mediterranean and Macaronesian biogeographical regions are predominant (EEA 2017). Considering the high plant diversity of these biogeographical regions (e.g., Thompson 2005) this result is not surprising. We recommend that seed conservation efforts should focus on these regional plant biodiversity hotspots (Myers et al. 2000).

Taxa of "priority score 1" represent the largest segment of taxa to be collected in this new collection plan (number to be collected 257, Table 4) and they are found in 21 countries. Since 42.9% of these countries have an ENSCONET Consortium seed bank in their territory, and 199 of these 257 priority taxa occur in countries where the ENSCONET Consortium has seed banks (Supplementary Material S10), these taxa could potentially be collected by the ENSCONET Consortium, and this should be a priority for the Consortium's members.

Taxa of "priority score 2" represent the third highest segment of taxa to be collected. A total of 86 of these 94 widely distributed taxa do occur in a country where there is an ENSCONET Consortium seed bank (Supplementary Material S11), which makes their collection possible. These taxa are however spread across the highest number of countries (42), and the presence of ENSCONET Consortium members in these countries is the lowest (31.0%). This reveals a gap in the coverage of European countries represented by the ENSCONET Consortium which may affect the collection of these "priority score 2" taxa across their European range once the top priority taxa have been collected. It is recommended that the ENSCONET Consortium looks to form links with institutes within these currently unrepresented countries.

Taxa of "priority score 3" represent the second highest segment of taxa to be collected. A total of 146 of these 148 priority taxa occur in countries where the ENSCONET Consortium has seed banks (Supplementary Material S12), these taxa could, therefore, potentially be collected by the ENSCONET Consortium. In addition, they are spread across the smallest number of countries (8), and the presence of ENSCONET Consortium seed banks in these countries is the highest (72.7%).These priority taxa should, therefore, be accessible for collection once taxa of priority scores 1 and 2 have been collected.

Taxa of "priority score 4" represent the smallest segment of taxa to be collected, and 43 of these 48 taxa occur in a country where there is an ENSCONET Consortium seed bank (Supplementary Material S13), which makes their collection possible. They are, however, spread across the second highest number of countries (36), and there is a low presence of

ENSCONET Consortium seed banks in these countries (36.1%). This may affect the collection of these lower priority taxa across their European range.

In summary, from the above figures, taxa of "priority score 3" seem the most accessible by national collectors currently involved in the ENSCONET Consortium, while many taxa of "priority scores 1, 2 and 4" occur in countries where there are no ENSCONET Consortium seed banks (e.g. Ukraine or Turkey). Taxa of "priority score 1" are likely to be collected due to the presence of either ENSCONET Consortium seed banks or members in the countries of occurrence (199 taxa, which is above the target of 175 to collect to meet the 2020 GSPC target 8a). Country-endemic taxa of "priority score 3" also occur almost entirely in countries where the ENSCONET Consortium has seed banks (146/148 i.e., all but two taxa, native to Bulgaria and Hungary). Taxa of "priority scores 2 and 4" are found in more than one country, so the likelihood for these taxa to be collected by existing ENSCONET Consortium members remains high, especially given the occurrence of these taxa where there is an ENSCONET Consortium seed bank (respectively 86/94 and 43/48). Overall, the ability of the ENSCONET Consortium to collect a further 175 taxa, and thus meet the 2020 GSPC target 8a, is high.

An analysis of the geographical distribution (at the country level) of collections held in ENSCOBASE showed that the majority of accessions had been collected in the country where the seed bank making the collection is located. It also highlighted that in some cases no ENSCONET Consortium seed bank is located in the country where a priority taxon occurs (e.g. Ukraine). Seed banks show a trend to collect and store European native taxa that occur in their own country—accessing and collecting taxa occurring in countries not covered by the ENSCONET Consortium poses a problem. In some areas, it will be possible for an ENSCONET Consortium member to go beyond the boundaries of its country to collect a priority taxa, but this will incur additional costs (Li and Pritchard 2009). Another problem lies in the fact that some taxa occur on islands, such as the Azores, and access to those taxa may prove to be more difficult for an ENSCONET Consortium member based in mainland Europe. For such collecting, the ENSCONET Consortium may have to rely on existing or future collaborations with island partners, and additional funding might be required in those instances.

Another possibility for the ENSCONET Consortium is to engage with seed banks in countries where priority taxa occur but where the ENSCONET Consortium is not currently present. Both of these options would help maximise the probability to collect and safely conserve priority taxa ex situ. In addition, for taxa distributed in more than one country, ENSCONET Consortium members from such countries will need to consult each other prior to collecting and share their individual collection plans up to 2020 to make sure that the coverage of these taxa is optimised in order for the overall collection plan to meet GSPC target 8a.

In parallel, as the ENSCONET Consortium is part of Kew's Millennium Seed Bank Partnership (MSBP), a complementary approach would be to work through the MSBP Data Warehouse (MSBP 2017) to access relevant collections data from countries where the ENSCONET Consortium is not present (e.g., countries in the Caucasus). This data is freely available to MSBP members and could, therefore, be analysed alongside ENSCOBASE data, to track progress towards the 2020 GSPC target 8a.

As far as we are aware, the presented collection plan is unique for the European native flora across the above-mentioned range of European countries. In a literature review of published collecting guidelines for other continents, we could only find a regional study in North America, (Hird and Kramer 2013) which highlighted that 35% of North America's 5000 threatened taxa were stored in ex situ collections. Other initiatives actively working

towards GSPC target 8a at a national level, and highlighting collection gaps, include Teixido et al. (2017) in Brazil, Hölbling (2013) in Austria and Krigas et al. (2016) in Greece. We advocate for the publication of targeted collection plans similar to this one in other world regions in order to harmonise collecting activities across the globe. We also advocate for data collection sites like ENSCOBASE to enable regional tracking of progress which is otherwise impossible when data is stored in individual institutions. Such initiatives will maximise the likelihood of achieving the 2020 GSPC target 8a at regional levels, and increase the genetic diversity of priority threatened taxa in ex situ conservation.

Conclusion

Our study describes a concerted action plan at the European level to enable the associated countries to undertake ex situ conservation in the form of seed banking to achieve the 2020 GSPC target 8a. It also demonstrates the need for collaboration between institutions involved in ex situ conservation to meet this target. Greece, Italy, Portugal and Spain are the four countries with the highest number of priority taxa that the ENSCONET Consortium needs to focus on if it wants to achieve the 2020 GSPC target 8a and increase the ex situ genetic diversity of priority taxa. In addition, the overlap between the European native taxa currently stored ex situ by the ENSCONET Consortium and the location of its seed banks show that a significant segment of priority taxa, especially those with the highest priority ("priority score 1"), could be collected and stored by existing ENSCONET Consortium members. Given that 175 additional taxa are required for this target to be met for Europe, it seems possible that the ENSCONET Consortium will succeed in this endeavour for the European region.

This collection plan is a snapshot of the situation in October 2017 and will evolve in the years leading to 2020 as additional collections are made and the IUCN Red List is revised. The collecting strategy will, therefore, need to be revised (e.g., every year after each collecting season) to incorporate new datasets. Additionally, some taxa currently listed for certain countries might have gone extinct in their territories. This may be reflected in national red lists, against which the collection plan needs to be checked. Revisions of this analysis will, therefore, also include any new versions of the IUCN Red List published before 2020. After each revision the collection plan will be adjusted. A final analysis after the last collecting season in 2020 will conclude whether or not the ENSCONET Consortium has met the 2020 GSPC target 8a in Europe. We are hopeful that, with such a collecting strategy of threatened taxa deployed across the ENSCONET Consortium, this will be the case.

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References

BGCI (Botanic Gardens Conservation International) (2016) Seed Banks https://www.bgci.org/resources/seedbanks/ (accessed 31 October 2017)

Bilz M, Kell SP, Maxted N, Lansdown RV (2011) European Red List of Vascular Plants. Publications Office of the European Union, Luxembourg. http://ec.europa.eu/environment/nature/conservation/species/redlist/downloads/European_vascular_plants.pdf (accessed 31 October 2017)

Brown AHD, Briggs JD (1991) Sampling strategies for genetic variation in ex situ collections of endangered plant species. In: Falk DA, Holsinger KE (eds) Genetics and Conservation of Rare Plants. Oxford University Press, New York, pp 99–122

Convention on Biological Diversity (2012) Global Strategy for Plant Conservation: 2011–2020. Botanic Gardens Conservation International, Richmond

Eastwood R, Müller JV (2012) Achievements of the European Native Seed Conservation Network—ENSCONET. In: Maxted N, Ehsan Dulloo M, Ford-Lloyd BV, Frese L, Iriondo J, Pinheiro de Carvalho MAA (eds) Agrobiodiversity conservation: securing the diversity of crop wild relatives and landraces. Wallingford (CABI), pp 286–291

EEA-European Environment Agency (2017) https://www.eea.europa.eu/data-and-maps/figures/biogeographical-regions-in-europe-2 (accessed 31 October 2017)

ENSCOBASE (2017a) http://enscobase.maich.gr/total_country.tml (accessed 31 October 2017)

ENSCOBASE (2017b) http://enscobase.maich.gr/gspc2020_target8a.tml (accessed 31 October 2017)

Euro+Med (2006) Euro+Med PlantBase—the information resource for Euro-Mediterranean plant diversity. http://ww2.bgbm.org/EuroPlusMed/ (accessed 31 October 2017)

Godefroid S, Rivière S, Waldren S, Boretos N, Eastwood R, Vanderborght T (2011) To what extent are European threatened plant species conserved in seed banks? Biol Conserv 144:1494–1498

Hay FR, Probert RJ (2013) Advances in seed conservation of wild plant species: a review of recent research. Conserv Physiol. https://doi.org/10.1093/conphys/cot030

Hird A, Kramer AT (2013) Achieving target 8 of the global strategy for plant conservation: lessons learned from the North American collections assessment. Ann Mol Bot Gard 99:161–166

Hölbling M (2013) Die Global Strategy for Plant Conservation" in Österreich. Masterarbeit, Universität Wien. http://othes.univie.ac.at/30444/1/2013-10-31_0405589.pdf (accessed 31 October 2017)

IUCN (2001) The IUCN 2001 Categories & Criteria (version 3.1) http://www.iucnredlist.org/static/categories_criteria_3_1 (accessed 31 October 2017)

IUCN (2017) The IUCN Red List of Threatened Species. Version 2017-1. http://www.iucnredlist.org (accessed 31 October 2017)

Krigas N, Menteli V, Vokou D (2016) Analysis of the ex situ conservation of the Greek endemic flora at national European and global scales and of its effectiveness in meeting GSPC Target 8. Plant Biosyst 150:573–582

Li D-Z, Pritchard H (2009) The science and economics of ex situ plant conservation. Trends Plant Sci 14:614–621. https://doi.org/10.1016/j.tplants.2009.09.005

Mattana E, Fenu G, Bacchetta G (2012) Regional responsibility for plant conservation: The 2010 GSPC Target 8 in Sardinia. Plant Biosyst 146:649–653

MSBP—Millennium Seed Bank Partnership Data Warehouse (2017) http://brahmsonline.kew.org/msbp [accessed 31 October 2017]

Myers N, Mittermeier RA, Mittermeier CG, da Fonseca GAB, Kent J (2000) Biodiversity hotspots for conservation priorities. Nature 403:853–858. https://doi.org/10.1038/35002501

Rivière S, Müller JV (2017) Contribution of seed banks across Europe towards the 2020 Global Strategy for Plant Conservation targets, assessed through the ENSCONET database. https://doi.org/10.1017/s0030605316001496

Sharrock S, Jones M (2011) Saving Europe's threatened flora: progress towards GSPC Target 8 in Europe. Biodivers Conserv 20:325. https://doi.org/10.1007/s10531-010-9912-z

Teixido AL, Toorop PE, Liu U, Ribeiro GVT, Fuzessy LF, Guerra TJ, Silveira FAO (2017) Gaps in seed banking are compromising the GSPC's Target 8 in a megadiverse country. Biodivers Conserv 26:703–716

The Plant List (2010) Version 1. http://www.theplantlist.org/ (accessed 31 October 2017)

Thompson JD (2005) Plant evolution in the Mediterranean. Oxford University Press, Oxford

Wyse SV, Dickie JB (2017) Predicting the global incidence of seed desiccation sensitivity. J Ecol 105:1082–1093