California Fish and Game 100(1):79-85; 2014

Seed banking California's rare plants

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In addition to the protection and management of native habitats, preservation of biodiversity in *ex situ* storage facilities is an important component of plant conservation. In this article we provide an overview of the field of *ex situ* seed storage. We describe the basic guidelines of seed storage and how seed banks operate and manage genetic diversity. Focusing on the rare, wild plants of California, we examine the progress that has been made in long-term genetic conservation. We report data showing the numbers of rare taxa currently in seed bank storage, and show which institutions currently house seeds of Californian rare plant taxa. Using accession data from these institutions, we show that rare taxa with legal protection status under federal or state law have been relatively well covered in *ex situ* storage facilities (59% of taxa), while rare plants not afforded state or federal listing status have lower coverage (17% of taxa).

Key words: California, *ex situ*, rare plants, seed banks, conservation

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California is an important region for plant conservation; it is home to more than 6,500 native taxa — more than any other U.S. state (Jepson Interchange 2013). Further, the California Floristic Province (the region of California experiencing a Mediterranean climate) is considered one of 25 global biodiversity hotspots based on high rates of endemism and levels of threat to native taxa (Myers et al. 2000, Pavlik 1995). More than one third of the plant species native to California are endemic (Baldwin et al. 2012). Many plants endemic to California are naturally rare with narrow geographic ranges or habitat parameters (Pavlik 1995); however, their rarity is further compounded by the threats that they face. This is reflected in the more than 2,300 taxa or 35% of the total flora that are included by the California Native Plant Society (CNPS) in the Inventory of Rare and Endangered Plants of California (CNPS 2013). Plants in the CNPS Inventory are assigned ranks (known as California Rare Plant Ranks [CRPR]) in an effort to categorize their degree of rarity and concerns for threats or endangerment (CNPS 2013). These rare taxa continue to be a special focus for conservation efforts because they are thought to have an increased risk of extinction compared to taxa that are more common or wide-ranging (Pimm and Raven 2000). With

ever increasing threats such as development, the spread of non-native species, and climate change, time is of the essence to advance conservation strategies to protect native species (Pavlik 1995).

Conservation of plant species can be achieved by protection of habitats and populations in nature (*in situ*), or by the preservation of genetic diversity outside of an organism's natural habitat (*ex situ*), often in gene banks, botanic gardens, zoos, or translocation sites (Cohen et al. 1991). *Ex situ* conservation provides a back up for biological diversity that might otherwise be lost in nature due to human induced environmental change or natural extinction. Seed banks that specialize in maintaining samples from wild populations are increasingly seen as a central component of *ex situ* plant conservation (Maunder et al. 2004). In comparison with living plant collections, seed banks can house much larger quantities of genetically distinct individuals using much less space. Further, seeds of many taxa can be kept alive for decades or longer with relatively inexpensive equipment (Walters et al. 2005; Rancho Santa Ana Botanic Garden [RSABG], unpublished data).

Seed banking efforts for rare plant taxa have been of regional and international focus for nearly 30 years (Center for Plant Conservation [CPC] 2013). Networks such as the CPC and Botanic Gardens Conservation International (BGCI) promote seed banking as an effective conservation tool to enhance recovery and restoration of rare plant species (CPC 2013, BGCI 2013). This on-the-ground strategy has global significance and is featured as a target in the Global Strategy for Plant Conservation, which sets the goal of securing *ex situ* conservation collections of at least 75% of the world's threatened plant species by the year 2020 (Convention on Biological Diversity [CBD] 2013). Here we examine *ex situ* conservation efforts in California, focusing on the progress of seed banking as a mechanism to conserve rare plants.

Seed Banking of Wild Native Plants in California

Seed banks house viable seed samples (accessions) of diverse plant taxa (Figure 1). These facilities serve two major purposes: to acquire and maintain living seeds, and to distribute seeds to approved parties for various uses. Methods that are employed to maintain high viability in stored seed collections include drying seeds to a low moisture content and storing them in airtight packaging in freezers maintained at ≤–18° C (Linington 2003). Seeds that are long-lived and survive this drying and freezing process are classified as 'orthodox,' and generally maintain high viability for decades or more under these storage conditions (Walters et al. 2005; RSABG, unpublished data). Notable and diverse genera in California with orthodox seeds include *Clarkia*, *Ceanothus*, and *Arctostaphylos* (RSABG, unpublished data). Certain taxa, especially those with large, high lipid content seeds or those that are adapted to hydric environments do not survive the drying and freezing process and are classified as 'recalcitrant'; these cannot be stored using traditional methods (Roberts 1973). Well known examples of recalcitrant genera with taxa in California include *Quercus* and *Aesculus* (Bonner 1990). Emerging technologies such as cryopreservation may be employed for long-term storage of recalcitrant seeds (Walters et al. 2013).

California's diverse and unique flora includes many species that are adapted to seasonal aridity or cold temperatures. In addition, many taxa are known to maintain persistent soil seed banks (Keeley 1991). Assessments of storage behavior of wild collected seeds indicate that a wide range of taxa native to California can be considered orthodox located

Figure 1.—Seeds of *Xylorhiza cognata*; California Rare Plant Rank 1B.2 (rare, threatened or endangered in California and elsewhere), with no legal listing status. Photo credit: John Macdonald.

and long-lived under traditional storage regimes (RSABG, unpublished data). A number of institutions maintain seed banks that contain wild collected seeds of California native plants (Table 1). The most significant repository for seeds of taxa native to California is

Table 1.—Seed bank holdings of California Rare Plant Rank (CRPR) taxa at various institutions*.

Institution	Taxa Banked	Number of Accessions
Rancho Santa Ana Botanic Garden	404	1,143
Santa Barbara Botanic Garden	50	223
United States Department of Agriculture (various sites)	35	343
Kew Millennium Seed Bank	24	24
Rae Selling Berry Seed Bank	21	53
University of California Botanical Garden at Berkeley	20	36
Total (some taxa banked by multiple institutions)	514	1,822

* Additional seed collections may exist which are not accounted for in this analysis.

at RSABG in Claremont, California, where wild, field collected seeds comprise 3,994 accessions, representing more than 1,700 total taxa (RSABG, unpublished data). An ongoing focus of the RSABG seed bank is to secure rare plant seed collections for conservation purposes (Tables 1 and 2). Many taxa native to California are currently not maintained in seed banks (RSABG, unpublished data), and therefore are not secured for future research or conservation use.

Table 2.—Collections per California Rare Plant Rank (CRPR) and Federal Endangered Species Act (FESA) or California State Endangered Species Act (CESA) listing status. Analysis excludes extinct and extirpated taxa (CRPR 1A and 2A).

Rarity or Legal Status	Taxa Banked	Total Number of Taxa	Percentage Banked
All California Rare Plant Rank (CRPR) Taxa (excluding 1A and 2A)	514	2283	23%
CRPR 1B Taxa	345	1143	30%
CRPR 2B Taxa	41	495	8%
CRPR 3 Taxa	5	67	7%
CRPR 4 Taxa	123	578	21%
FESA and/or CESA Listed Taxa	167	284	59%
CESA Listed Taxa	124	218	57%
FESA Listed Taxa	138	195	71%

An analysis of current seed accession holdings of rare taxa native to California shows significant progress in meeting global goals for *ex situ* conservation (CBD 2013); however, there is still much work to be done. To date 167 (59% of the total) taxa with legal protection under the Federal Endangered Species Act (FESA) or the California Endangered Species Act (CESA) have been deposited at regional or national seed banks (Table 2). In comparison, seeds of only 17% of taxa that are considered rare, but do not have formal legal status, have been banked. Emphasis on collection of CESA- and FESA-listed taxa is likely due to funding that becomes available to secure seed collections through mitigation measures or strategic conservation efforts.

Utilization and Storage of Seed Collections

It is important to consider the intended use of a seed collection before it is made (Guerrant et al. 2004). For *ex situ* conservation collections, capturing high levels of representative genetic diversity in each accession is important for maximizing potential use. Various studies (Richards et al. 2007, Namoff et al. 2010) have focused on quantifying the amount of genetic diversity captured in *ex situ* plant populations. In both studies, allelic diversity of the collection was higher with increased sampling of individuals. Dolan et al. (2008) observed levels of allelic diversity in remnant wild populations, nurseries, and restoration sites to vary considerably depending on the taxon that was being sampled.

Guerrant et al. (2004) recommend collecting from ≥50 individual plants if possible in order to establish a minimum baseline of genetic diversity. For rare plants, the separate collection and storage of seeds from individual plants (known as maternal line collections) is recommended. While processing and curation costs are considerably greater for maternal line collections (versus bulked collections), this practice allows for the maximum control and management of genetic diversity. A target quantity of 2,500 to 10,000 seeds per accession is thought to provide sufficient material needed to meet the diverse uses of seed collections, including long-term genetic preservation and active use of the collection that may include germination testing, research, and restoration (Wall 2009).

Seed banks are, in essence, an ongoing seed longevity experiment. Many seed banks test seeds prior to being placed in storage and then test periodically throughout their storage life. Information on viability and germination is recorded and allows for easy longitudinal comparison of data throughout the storage history of each accession. These data not only provide information on seed storage behavior, but also provide dormancy and germination information for a large group of rarely cultivated plants. The data also guide germplasm management practices and advance horticultural and life history knowledge of these plants. The long-term storage and conservation of representative genetic samples, especially of threatened taxa, is another important facet of seed banks. Many seed banks maintain collections that are intended to stay in storage indefinitely to serve as propagules that can be utilized for reintroduction in the case of extinction or extirpation of populations in the wild.

Discussion

A large proportion of rare plant taxa native to California in seed banks have FESA or CESA status (Table 2). Funding opportunities and mitigation requirements for these taxa have created mechanisms to secure these valuable collections; however, this has also created a bias toward the collection of taxa that have formal legal status over other taxa of conservation concern. The listing of endangered species by the state and federal governments is an important aspect of plant conservation, but is subject to political pressures and a legislative process, which does not always reflect the most current knowledge of plant rarity and threats. Other ranking systems of rarity and threats, such as NatureServe Explorer and the CNPS Inventory of Rare and Endangered Plants are useful in assessing the conservation status of the entire flora (NatureServe 2013, CNPS 2013). These indices, as well as online diversity databases such as the California Natural Diversity Database (CNDDB) and the Consortium of California Herbaria (CCH) provide valuable assessment tools for seed collection prioritization (CNDDB 2014, CCH 2014).

Unique funding mechanisms need to be employed to target rare or threatened taxa that do not have FESA or CESA status, and to broaden *ex situ* conservation efforts in California. Rancho Santa Ana Botanic Garden seeks to collaborate with a wide variety of partners to advance this important endeavor, and staff currently are working on a conservation strategy and needs assessment for seed banking that will identify targets for collection based on presence or absence in seeds banks, storage behavior, rarity, threat levels, and other factors. We hope that this analysis will advance ongoing efforts to obtain high quality *ex situ* germplasm collections of the rare plants of California and to secure them for long-term preservation.

Acknowledgments

We thank H. Forbes of the University of California Botanical Garden at Berkeley, E. Guerrant of the Rae Selling Berry Seed Bank, D. Knapp of Santa Barbara Botanic Garden, and K. Wells of United States Department of Agriculture for supplying data. We also thank L. McDade for review of an early version of the manuscript, and H. Forbes and D. Wilken for formal review. We thank M. Wall, who built the seed conservation program at RSABG before retiring in May 2012. Wall made significant contributions to our knowledge of seeds of California plants.

Literature Cited

Baldwin, B. G., D. H. Goldman, D. J. Keil, R. Patterson, T. J. Rosatti, and D. H. Wilken (editors). 2012. The Jepson manual: vascular plants of California, second edition. University of California Press, Berkeley, California, USA.

Bonner, F. T. 1990. Storage of seeds: potential and limitations for germplasm conservation. Forest Ecology and Management 35:35-43.

Botanic Gardens Conservation International (BGCI). 2013. Seed Banks – Botanic Gardens Conservation International [Internet]. [cited 2013 Dec 22]. Available from: http://www.bgci.org/resources/seedbanks/

California Native Plant Society (CNPS). 2013. Inventory of rare and endangered plants of California [Internet]. [cited 2013 Dec 22]. Available from: http://www.rareplants.cnps.org

California Natural Diversity Database (CNDDB). 2014. California Natural Diversity Database Home [Internet]. [cited 2014 Mar 21]. Available from: https://www.dfg.ca.gov/biogeodata/cnddb/

Center for Plant Conservation (CPC). 2013. Center for plant conservation home page [Internet]. [cited 2013 Dec 22]. Available from: http://www.centerforplantconservation.org/

Cohen, J. I., J. T. Williams, D. L. Plucknett, and H. Shands. 1991. *Ex Situ* conservation of plant genetic resources: global development and environmental concerns. Science 253:886-872.

Consortium of California Herbaria (CCH). 2014. Consortium of California herbaria: search page [Internet]. [cited 21 March 2014]. Available from: http://ucjeps.berkeley.edu/consortium/

Convention on Biological Diversity (CBD). 2013. Global strategy for plant conservation: targets 2011–2020 [Internet]. [cited 22 Dec 2013]. Available from: http://www.cbd.int/gspc/targets.shtml

Dolan, R. W., D. L. Marr, and A. Schnabel. 2008. Capturing genetic variation during ecological restorations: an example from Kankakee Sands in Indiana. Restoration Ecology 16:386-396.

Guerrant, E. O., P. L. Fiedler, K. Havens, and M. Maunder. 2004. Appendix 1. Pages 419-438 *in* E. O. Guerrant, K. Havens, and M. Maunder, editors. *Ex Situ* plant conservation: supporting species survival in the wild. Island Press, Washington, D.C., USA.

Jepson Interchange. 2013. The Jepson online interchange California floristics. [Internet]. [cited 22 Dec 2013]. Available from: http://ucjeps.berkeley.edu/interchange.html

Keeley, J. E. 1991. Seed-germination and life history syndromes in the California chaparral. Botanical Review 57:81-116.

Linington, S. H. 2003. The design of seed banks. Pages 593-635 *in* R. D. Smith, J. B. Dickie, S. H. Linginton, H. W. Pritchard, and R. J. Probert, editors. Seed conservation: turning science into practice. Royal Botanic Gardens, Kew, United Kingdom.

Maunder, M., K. Havens, E. O. Guerrant, and D. A. Falk. 2004. *Ex situ* methods: a vital but underused set of conservation resources. Pages 3-20 *in* E. O. Guerrant, K. Havens, and M. Maunder, editors. *Ex situ* plant conservation: supporting species survival in the wild. Island Press, Washington, D.C., USA.

Menges, E. S., E. O. Guerrant, and S. Hamze. 2004. Effects of seed collection on the extinction risk of perennial plants. Pages 305-324 *in* E. O. Guerrant, K. Havens and M. Maunder, editors. *Ex situ* plant conservation: supporting species survival in the wild. Island Press, Washington, D.C., USA.

Myers, N., R. A. Mittermeier, C. G. Mittermeier, G. da Fonseca, and J. Kent. 2000. Biodiversity hotspots for conservation priorities. Nature 403:853-858.

Namoff, S., C. E. Husby, J. Francisco-Ortega, L. R. Noblick, C. E. Lewis, and M. P. Griffith. 2010. How well does a botanical garden collection of a rare palm capture the genetic variation in a wild population? Biological Conservation 143:1110-1117.

NatureServe. 2013. NatureServe explorer: an online encyclopedia of life. [Internet]. [cited 22 Dec 2013]. Available from: http://explorer.natureserve.org/

Pavlik, B. M. 1995. Inventory first step to conserving plant diversity. California Agriculture 49(6):18-22

Pimm, S. L., and P. Raven. 2000. Biodiversity: extinction by numbers. Nature 403:843-845. doi:10.1038/35002708

Richards, C. M., M. F. Antolin, A. Reilly, J. Poole, and C. Walters. 2007. Capturing genetic diversity of wild populations for *ex situ* conservation: Texas wild rice (*Zizania texana*) as a model. Genetic Resources and Crop Evolution 54:837-848.

Roberts, E. H. 1973. Predicting the storage life of seeds. Seed Science and Technology 1:499-514.

Wall, M. 2009. Seed collection guidelines for California native plant species [Internet]. Rancho Santa Ana Botanic Garden Webpage; [cited 1 Jan 2014]. Available from: http://www.rsabg.org/documents/horticulture/Seed%20Collecting%20and%20Storage%20Guidelines.pdf

Walters, C., P. Berjak, N. Pammenter, K. Kennedy, and P. Raven. 2013. Preservation of recalcitrant seeds. Science 399:915-916.

Walters, C., L. M. Wheeler, and J. M. Grotenhuis. 2005. Longevity of seeds stored in a genebank: species characteristics. Seed Science Research 15:1-20.

Received 28 January 2014
Accepted 26 February 2014
Corresponding Editor was C. Burton