

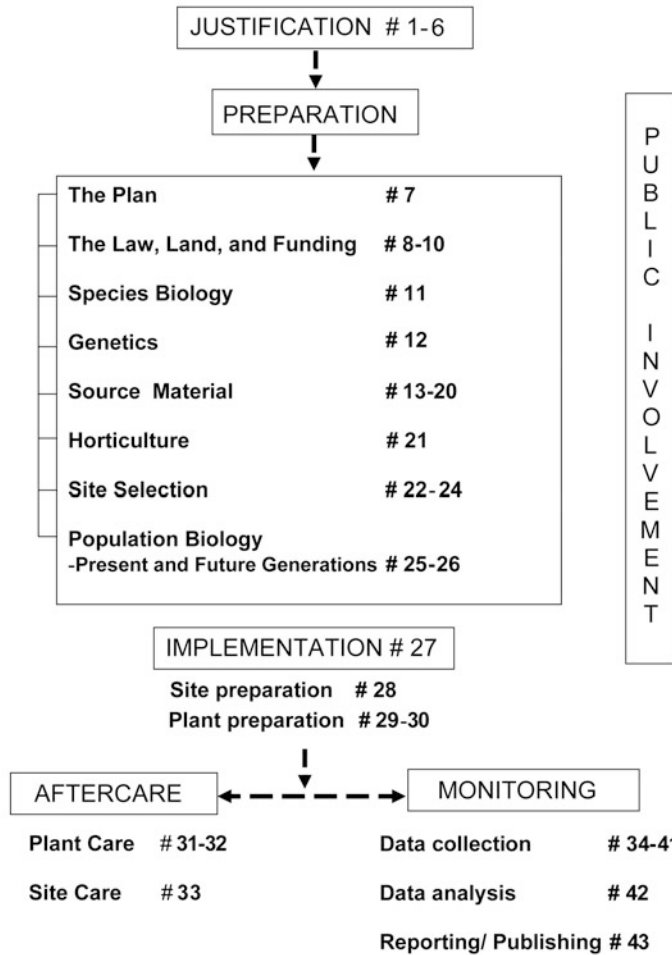
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## *Center for Plant Conservation Best Reintroduction Practice Guidelines*

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The ultimate goal of rare plant conservation is to ensure that unique taxa experience continued evolution in a natural context. Over the past 20 years conservation officers working with the Center for Plant Conservation (CPC) have conducted plant reintroductions of many species in many habitats. In this appendix we provide our *CPC Best Reintroduction Practice Guidelines*, which refine reintroduction planning based on a review of past protocols, the experience of CPC practitioners, findings presented in this volume, and comments from conference attendees. The science and practice of rare plant reintroduction are expanding, and these guidelines represent the state of the art.

Our goal is to provide a quick reference for practitioners to use when planning and executing rare plant reintroductions (fig. [Al.1](#)). The term *reintroduction* in this appendix implies any attempt to introduce propagules to an unoccupied patch, including augmentations, introductions, and translocations. Managed relocations would require following these same guidelines in addition to the points presented by Haskins and Keel (this volume) and the modeling, interdisciplinary, multiagency, and potentially international collaborations cautioned by Kennedy and colleagues (this volume). The sections are intended to help practitioners do the following: justify the decision to conduct a reintroduction; prepare the reintroduction design with legal, funding, species biology, horticulture, and recipient site considerations in mind; implement the reintroduction; conduct project aftercare; and design monitoring to document long-term establishment of the rare population. All phases of the reintroduction process should include opportunities for public involvement. In addition, we suggest a template to use for documenting all aspects of the reintroduction that can be found on the North Carolina Botanical Garden website (North Carolina Plant Conservation Program Scientific Committee 2005).



**FIGURE A1.1.** Flow diagram of reintroduction justification, preparation, implementation, aftercare, and monitoring.

In comparison to previous guidelines, these offer suggestions based on the meta-analyses described in this volume. Thorough examinations of existing populations are recommended to help determine the trajectory of population growth and guide selection of recipient sites. When possible we advise linking the ecology to the demography of the species. In addition, we provide suggestions for improving the possibility of creating a sustainable population in a changing climate.

To support our recommended best practices, we reference appropriate sections of the text of this volume. Additional literature can be found in the chapters. For more in-depth details about some of the sections, we refer readers to previous publications with reintroduction guidelines: *Restoring Diversity* (Falk et al. 1996), *IUCN Guidelines for Reintroductions* (IUCN 1998a), *The SER Primer on Eco-*

*logical Restoration* (Society for Ecological Restoration Science & Policy Working Group 2002), and *Guidelines for the Translocation of Threatened Plants in Australia* (Vallee et al. 2004).

It is our hope that these guidelines will improve recovery of endangered species and will leave a lasting impression on all those who are concerned with saving biodiversity. We welcome feedback on the guidelines and encourage practitioners to report any reintroductions to the *CPC International Reintroduction Registry*. CPC practitioners throughout the United States can be contacted through the CPC national office (<http://www.centerforplantconservation.org/> or [cpc@mobot.org](mailto:cpc@mobot.org)).

## I. Justifying and Deciding Whether to Conduct a Reintroduction

We do not support or promote reintroduction as an alternative to in situ ecosystem protection. All those working in plant conservation firmly agree that the priority is to conserve species in situ and to preserve their wild populations in natural habitats in as many locations as possible. Reintroduction is never the first action to take for a critically endangered species, even when crisis is imminent. First steps for species in dire straits must be ex situ collection, threat control, and habitat management (Guerrant et al. 2004a; Bruegmann et al. 2008).

Before any reintroduction is conducted, thorough status surveys and careful review of rarity status and threats should be undertaken. Reintroduction should be considered only if habitat protection is not possible or if the taxon is critically imperiled and appropriate sites and propagule source materials are available. We recognize that in the very near future introductions may need to be used as a tool to mitigate the impacts of climate change, because some in situ rare plant populations will be unsustainable in their current historical ranges.

To determine whether a species should be considered for reintroduction, it should meet the criteria described in the checklist box (box A1.1). If the species does not meet these criteria, a reintroduction should not be attempted at this time. If conditions change in the future, a second evaluation could be done. For some taxa, it may *never* be appropriate to conduct reintroductions. For others, changed conditions and improved horticultural, genetic, and ecological knowledge may make it feasible to conduct a reintroduction in the future.

### 1. DOCUMENT THE SPECIES' STATUS AND DISTRIBUTION.

- Conduct surveys, create maps, and obtain population distribution information.
- Assess habitat-specific population information (Knight, this volume). In each population, count the number or estimate the percentage of

**BOX A1.1. JUSTIFICATION FOR REINTRODUCTION**

A reintroduction may be justified if:

- Species is extinct in the wild OR
- The distribution of the species is known and there are few, small, and declining populations; AND
- Alternative management options have been considered and conducted yet have been judged to be inadequate for long-term conservation of the species; AND
- Threats have been identified; AND
- Threats from habitat destruction, invasive species, land conversion and/or climate change are imminent and are uncontrollable. Species has high risk of extinction if only managed in situ.

If the species meets any one of the following criteria, then do *not* proceed with reintroduction. Consider ex situ conservation practices (Guerrant et al. 2004b). If the unmet criterion is resolved in future, then reevaluate.

- Reintroduction will undermine the imperative to protect existing sites.
- Previous tests indicate that it has not been possible to propagate plants or germinate seeds.
- High-quality, diverse source material is not available.
- Existing threats have not been minimized or managed.
- The reintroduced species may potentially negatively affect species in the recipient site via competition, hybridization, or contamination.
- There is evidence that the reintroduced taxon would harm other threatened and endangered species or conflict with their management.
- The reintroduction is not supported legally, administratively, or socially.
- Suitable habitat is not available or not understood.

reproductive, juvenile, and seedling stages and, if possible, measure growth and reproduction.

- Note abiotic and biotic conditions in occupied patches. Whenever possible, quantify these factors (e.g., near adults and seedlings, record the canopy cover, associated species, plant density, soil moisture, light, and other factors).

2. ASCERTAIN THREATS AND, WHEN POSSIBLE, TAKE ACTION TO REMOVE, CONTROL, OR MANAGE THEM.

- Note specific abiotic and biotic factors that may be causing the population decline. Realize that threats may be direct or indirect and will be best observed over time (Dalrymple et al., this volume).
- If stochastic processes (e.g., wildfires, storms, or random events) have occurred and have decreased the number of individuals in the population, we advise augmenting the population.

3. ENGAGE LAND MANAGERS IN DISCUSSION ABOUT OPTIONS FOR THE SPECIES CONSERVATION.

- Attempt or consider all feasible alternative management options before considering reintroduction.
- Ensure that the population will have long-term protection and management (e.g., invasive species removal, controlled burns).

4. IF YOU CANNOT JUSTIFY A REINTRODUCTION, DO NOT PROCEED. USE OTHER CONSERVATION OPTIONS.

5. CONSIDER WHETHER YOUR REINTRODUCTION WILL DO ANY HARM TO THE RECIPIENT COMMUNITY OR TO EXISTING WILD POPULATIONS. IF SO, CONSIDER ALTERNATIVE CONSERVATION STRATEGIES.

- Determine whether the potential collateral impacts of the species in the recipient site are negligible. Is there a threat of hybridization, invasion, or contamination?
- The reintroduction should not undermine the imperative to protect existing populations and their habitats.

6. DETERMINE THAT THE REINTRODUCTION IS FEASIBLE LEGALLY, LOGISTICALLY, AND SOCIALLY.

- Laws governing rare species protection vary by location and jurisdiction; therefore, it is essential to discuss any plans for a reintroduction with authorities.
- Determine whether the species has a legal document such as a recovery plan or a conservation action plan, wherein reintroduction has been identified as an important step for preserving the species.

- Hold public meetings to review reasons for the reintroduction and solicit support or involvement.
- Document that the recipient site landowner (public or private) is committed to protecting the reintroduced population.

## II. Preparing the Reintroduction

Although it is impossible to say definitively, we believe that many failed reintroductions could have succeeded if appropriate preparation had been undertaken. Being prepared for a reintroduction requires a good plan coupled with large investments of time and resources. This demands commodities that are often in short supply in our rapidly changing world: patience and persistence. It may not be possible to know all of the factors we describe here, but the more that is known, the higher the likelihood of success, and practitioners should at least be aware of the gaps in their knowledge.

Reviewing your reintroduction plan by addressing the following questions will allow you to assess your degree of preparedness (box A1.2). Once knowledge gaps are identified, there is an opportunity to weigh whether there is adequate information to proceed. The risk of proceeding without the knowledge can be assessed along with the risk of taking no action and losing the species. We strongly recommend that reintroductions be conducted as experiments precisely designed to address these knowledge gaps. In this way, each reintroduction can not only help future reintroductions of the practitioner's target species but also help others doing plant reintroductions around the world.

Previous CPC publications have addressed detailed preparations for reintroductions with regard to demography, genetics, and horticultural practice (Falk and Holsinger 1991; Falk et al. 1996; Guerrant 1996a). Specific guidance for ex situ collection and management is essential preparation for reintroductions (see Guerrant et al. 2004a). Our aim here is to provide guidance for establishing sustainable populations in the wild where they may have opportunities for adaptation, evolution, and interactions within a natural ecosystem. Although it is necessary to describe the steps of the plan sequentially, often several steps are conducted simultaneously.

### *The Plan*

7. DEVELOP A REINTRODUCTION PLAN. WHENEVER POSSIBLE, DESIGN THE REINTRODUCTION AS AN EXPERIMENT AND SEEK PEER REVIEW.

- Identify the project leader and key collaborators, who will be responsible for planning, supporting, implementing, site management, monitoring, and reporting findings.

**Box A1.2. QUESTIONS TO CONSIDER WHEN PLANNING A REINTRODUCTION**  
(FALK ET AL. 1996; VALLEE ET AL. 2004)

- \_\_\_\_\_ Is this an augmentation (reinforcement), reintroduction, or introduction (see Glossary)?
- \_\_\_\_\_ Have you considered legal issues, logistics, and land management (McDonald 1996)?
- \_\_\_\_\_ Are the biology and ecology of the species understood (Menges 2008; Maschinski et al. [chap. 7], this volume)?
- \_\_\_\_\_ Are genetic studies needed (Neale, this volume)?
- \_\_\_\_\_ Have germination protocol and propagation methods been determined (Guerrant 1996a; Guerrant et al. 2004a; Haskins and Pence, this volume)?
- \_\_\_\_\_ Has a suitable recipient site been identified, and are land managers supportive (Fiedler and Laven 1996; Maschinski et al. [chap. 7], this volume)?
- \_\_\_\_\_ Are pollinators known and present?
- \_\_\_\_\_ Are plants susceptible to herbivory? Will they be protected?
- \_\_\_\_\_ Have threats been reduced or eliminated?
- \_\_\_\_\_ How many plants or seeds are available, and how many are needed (Guerrant 1996a; Albrecht and Maschinski, Knight, this volume)?
- \_\_\_\_\_ What question is being addressed, and does your experiment answer the question?
- \_\_\_\_\_ How will success be measured (Pavlik 1996; Monks et al., this volume)?
- \_\_\_\_\_ What kind of aftercare for plant and site management will be needed and how frequently?
- \_\_\_\_\_ What is the involvement of the land manager or owner?
- \_\_\_\_\_ What are the monitoring design and plan for reporting results?
- \_\_\_\_\_ In what ways will you involve the public in your project (Maschinski et al. [chap. 4], this volume)?

- Identify areas of expertise needed to execute the reintroduction. If they are not represented in the collaborative group, then seek outside experts to join the team. For example, enlist the help of a scientist with experience in experimental design and statistical analysis to ensure that you have adequate replication to answer your research question. Consider addressing theoretical questions (box A1.3).
- Plan the reintroduction based on the best scientific information available. Rely on peers to review your reintroduction plan and provide feedback and

**Box A1.3. QUESTIONS TO CONSIDER WHEN DESIGNING REINTRODUCTION EXPERIMENTS**

- \_\_\_\_\_ What additional knowledge is needed about the species' biology or other factors?
- \_\_\_\_\_ What is the question being asked? Does your experimental design answer the question?
- \_\_\_\_\_ How much replication is needed for adequate statistical power? How will the study be analyzed?
- \_\_\_\_\_ Who will conduct the data analyses?
- \_\_\_\_\_ Have you considered testing aspects of ecological theory, such as founder events, small population dynamics, establishment phase competition, dispersal and disturbance ecology, succession, metapopulation dynamics, patch dynamics on population persistence, resilience, and stability over time?
- \_\_\_\_\_ Using the reintroduced population as a cohort, will you examine natural variation in survival, mortality, and recruitment and tie these to environmental factors?
- \_\_\_\_\_ Will the reintroduction test key habitat gradients of light, moisture, elevation, or temperature?
- \_\_\_\_\_ Will the underlying environmental drivers of  $\lambda$  be measured (Knight, this volume)?
- \_\_\_\_\_ Will genetic factors be part of the experimental design? If so, how will they be analyzed?
- \_\_\_\_\_ Will the reintroduction further our knowledge of key principles related to rare species' ability to cope with climate change?
- \_\_\_\_\_ Are you testing factors within a single site or across multiple sites?
- \_\_\_\_\_ Has a monitoring plan been developed? How long will monitoring be conducted? Have you considered an adaptive monitoring plan? What will the duration of the experiment be?
- \_\_\_\_\_ Have you developed a clear unambiguous datasheet to track reintroduced plant growth, reproduction, and survival? If the monitoring persists for decades, will your successors be able to interpret the data you have collected?
- \_\_\_\_\_ Will the data be housed within your institution or elsewhere so that your successors will be able to use it?
- \_\_\_\_\_ How will the plants be mapped and marked or numbered?
- \_\_\_\_\_ If plants are susceptible to herbivory, will their response be included in the design, or should the plants be protected?

*Sources:* Falk et al. (1996); Vallee et al. (2004).



**BOX A1.4. POTENTIAL REVIEWERS FOR REINTRODUCTION PLANS**

In some regions, there are panels of plant conservation experts who review reintroduction plans as a part of an ongoing legislative process. For example, the scientific advisory committee of the North Carolina Plant Conservation Program requests and evaluates reintroduction plans as part of the process of granting legal permission to proceed with a plant reintroduction in the state of North Carolina (North Carolina Department of Agriculture and Consumer Services 2010).

Experts operating in different areas of the world are also available. *The CPC International Reintroduction Registry* (CPC 2009) provides a resource to learn about reintroductions that have been done and is a source for potential peer reviewers.

The IUCN Reintroduction Specialist Group (IUCN 1998b) has a *Reintroduction Practitioner's Directory 1998* intended to facilitate communication between individuals and institutions undertaking animal and plant reintroductions.

The Global Restoration Network (Society for Ecological Restoration 2009) provides a web-based information hub linking research, projects, and practitioners.

alternative points of view. Rely on the global conservation community to assist you (see suggested reviewers in box A1.4).

- Train and carefully manage all personnel and volunteers who are involved.
- Define goals of reintroduction related to the recovery of the species. Set objectives.
- Develop methods, select which plant and population attributes will be measured, and determine monitoring protocol, frequency, and duration.

### *The Law, the Land, and Funding*

#### 8. OBTAIN LEGAL PERMISSION TO CONDUCT THE REINTRODUCTION.

- In some locations you may be required to obtain one or many permits before conducting a reintroduction (e.g., from the land owner or manager and local, regional, and national authorities). A reintroduction plan is often required for permit acquisition.
- Note the expiration date of all permits involved. Also note the requirements of permits, such as periodic reports or updates to the permitting agency.

- If the reintroduction is done as mitigation, it is critical that all preliminary planning steps be taken within legal parameters. (See Falk et al. 1996 for extensive discussion of mitigation.)

9. ENSURE THAT LANDOWNERS AND MANAGERS ARE SUPPORTIVE OF THE PROJECT AND CAN ACCOUNT FOR POSSIBLE CHANGES IN THE FUTURE.

- Discuss the long-term support and management of the recipient habitat with land managers.
- Develop a written agreement outlining who will be responsible for what action and any special protocols that need to be followed by parties working on the site.
- Set a schedule to meet periodically with the recovery team to assess the species' condition and the status of the reintroduction.
- If future changes warrant intervention, determine a process for evaluating impacts on the reintroduced species. For some agencies, it may be necessary to develop a protocol or decision tree to trigger management action.
- Develop a mechanism for handling any conflicts that may arise (e.g., management for one species is detrimental to another species).

10. SECURE ADEQUATE FUNDING TO SUPPORT THE PROJECT.

- Ideally, funding should be garnered for implementation and management for several years, if not decades, after the installation. At the very least, parties proposing to reintroduce a species should be committed to seek long-term funding support for the project. Committed partners who are willing to provide in-kind services or volunteer citizens who are willing to monitor the reintroduction will help make this step feasible.
- Determining the outcome of a reintroduction takes much more time than we thought. Expect to devote more than 10 years to monitoring to determine whether a population is sustainable (Monks et al., this volume).

### *Species Biology*

The design of your reintroduction will benefit from knowing the biology and ecology of your taxon. We advise gathering information from the literature on your target taxon and closely related congeners. If there are gaps in your knowledge, use the reintroduction as an opportunity to learn more about the species and its ecology. See documentation section (p. 306).

## 11. KNOW THE SPECIES' BIOLOGY AND ECOLOGY.

- Knowing the mating system will determine whether source material should come from a single population or from mixed populations. For example, because remnant populations lacked compatible alleles for successful reproduction, reintroductions done with Florida ziziphus required carefully selecting compatible individuals from more than one location to achieve reproductive success (Weekley et al. 1999, 2002). In contrast, the facultatively autogamous *Schiedea obovata* requires keeping all outplantings separate (Kawelo et al., this volume).
- Because some taxa need symbionts to germinate or grow (Ogura-Tsujita and Yukawa 2008; Janes 2009; Haskins and Pence, this volume), knowing whether there are obligate mutualists will influence reintroduction success. Attempts to germinate or grow such species without their obligate mutualists will fail.
- If a species is dioecious, the spatial design of plantings should place male and female plants in close proximity (e.g., *Zanthoxylum coriaceum* in Maschinski et al. 2010).
- Species or conditions that may require special techniques for growing and implementing a reintroduction include edaphic endemics, species with specialist pollinators, and species that need symbionts for germination and growth.

### *Genetics*

Ideally, the genetic composition of the reintroduced material is a balance between representing the local gene pool and creating a new, genetically diverse population. Reviewing your current knowledge of wild population genetics will facilitate decisions about appropriate locations for collecting source material, confirming whether hybridization may be a potential problem, or confirming the species taxonomy (Falk and Holsinger 1991; Falk et al. 1996; Neale, this volume; see boxes A1.3 and A1.5). For example, you may want to pursue genetic studies before your reintroduction if you suspect there are hybridization problems, if the morphology of the species looks different in different locations, if one or more populations of the species has distinct ecology from the majority of populations, or if it is difficult to distinguish this species from a congener. Using genetically heterogeneous founders will improve the ability of propagules to cope with varying environmental conditions (Falk et al. 1996; Guerrant et al. 2004a; Neale, this volume). Theoretically, high levels of genetic diversity will equip the new population with the adaptive potential needed to withstand stochastic and deterministic

**BOX A1.5. QUESTIONS RELATED TO WILD POPULATIONS (MCKAY ET AL. 2005; NEALE, THIS VOLUME)**

- \_\_\_\_\_ What is the genetic structure of the wild populations?
- \_\_\_\_\_ What is the dispersal capability of the species?
- \_\_\_\_\_ If hybridization is a concern, what are the ploidy levels of the wild populations (McKay et al. 2005)?
- \_\_\_\_\_ Does the species show symptoms of inbreeding depression?
- \_\_\_\_\_ Is there evidence of outbreeding depression?
- \_\_\_\_\_ Based on special ecology, unique morphology, or spatial disconnection from other populations, do you suspect that a population has local adaptation?
- \_\_\_\_\_ Based on the presence of a congener in the wild population or variable morphology, do you suspect that the species is hybridizing with a congener?

events, including climate change, and can defend against potential genetic pitfalls of small populations such as founder effects and inbreeding depression.

Working with local geneticists at universities or government facilities to do the genetic studies may be necessary. Adequate funding must be garnered for proper genetic work. But also be aware that there are alternatives to genetic studies. These include hand pollination studies, common garden experiments, and reciprocal transplant studies. Each has advantages and disadvantages.

**12. ASCERTAIN WHETHER GENETIC STUDIES ARE NEEDED BEFORE CONDUCTING THE REINTRODUCTION AND, IF POSSIBLE, CONDUCT STUDIES TO MEASURE GENETIC STRUCTURE OF THE FOCAL SPECIES (NEALE, THIS VOLUME).**

- A genetic assessment of wild populations is advised before a reintroduction if the species meets any of the following criteria (S. Wagenius, personal communication).
  - The population has fewer than fifty individuals flowering and setting fruit.
  - The species has highly fragmented and isolated populations.
  - No pollinators are present.

No viable seed is being set.

There are high levels of herbivory, especially on flowers, seeds, and fruits.

The morphology of the species looks different in different locations.

One or more populations of the species have distinct ecology from the majority of populations.

It is difficult to distinguish this species from a congener.

There is recent disagreement about the taxonomy, and a reintroduction may create the undesired opportunity for hybridization.

- In the absence of genetic data, it is valuable to use information on species life history traits, such as habit and breeding system, to inform reintroduction decisions (Neale, this volume).

### *Source Material and Horticulture*

The source material used for any reintroduction may determine its fate. To give the new population a chance at success and a buffer against future stochastic or catastrophic events, it is important to use plants that are genetically diverse and vigorous.

#### 13. SELECT APPROPRIATE SOURCE MATERIAL.

- Collect source material from a location that has similar climatic and environmental conditions to the restoration site(s).
- Minimize artificial selection during seed increases or augmentation of natural populations by resisting the temptation to use abundantly available, vigorously growing maternal lines that may skew the diversity of the population, but rather attempt to maintain even family line representation for a reintroduction (Guerrant et al. 2004a; McKay et al. 2005).
- Traditionally it is recommended to use a single source unless adequate information is available about mating system, dispersal, and genetic structure to justify mixing source material. Justifications for mixing source material include a lack of concern about disrupting local adaptation and evidence of inbreeding depression (Dalrymple et al., Neale, this volume).
- Consider the genetics of the reintroduced population in the context of the wild populations (box A1.6). For example, if the species is an obligate out-croser and is locally adapted to a site, then breeding with natural populations may lead to outbreeding depression (Neale, this volume).

**BOX A1.6. QUESTIONS TO CONSIDER ABOUT THE GENETICS OF  
SOURCE MATERIAL**

- \_\_\_\_\_ From which wild population(s) should the material be collected for use in the reintroduction?
- \_\_\_\_\_ What is the basis for collecting source material from a particular location?
- \_\_\_\_\_ How will the source material be sampled?
- \_\_\_\_\_ What is the genetic composition of the reintroduced material?
- \_\_\_\_\_ Should material come from an ex situ source, only one wild source population, or mixed population sources?

14. USE EX SITU SOURCE MATERIAL BEFORE COLLECTING NEW MATERIAL FROM THE WILD UNLESS THE EX SITU PROPAGULES YOU HAVE AVAILABLE ARE NOT GENETICALLY DIVERSE OR THERE IS A MORE APPROPRIATE WILD SOURCE POPULATION THAT CAN WITHSTAND COLLECTION (GUERRANT ET AL. 2004A).

- Ex situ samples are not immortal, and they degrade over time. Consider using ex situ material first, and then replenish ex situ stock.
- As a precaution favoring wild population integrity, we recommend using ex situ propagules despite some evidence that wild-sourced propagules tended to achieve higher levels of recruitment than ex situ propagules (Dalrymple et al., this volume). The comparative advantage of wild-collected over ex situ propagules may be related to greater plant age or size of wild-collected propagules. For example, an introduction of wild source and ex situ propagules of *Amorpha herbacea* var. *crenulata* showed that the largest plants had greatest survival (Wendelberger et al. 2008). The propagule origin was a less critical factor influencing transplant survival than was plant size.
- Bulking up ex situ collections through vegetative reproduction is recommended if feasible.
- If ex situ material is not available, collect no more than 10% of seed produced in any year from wild populations to avoid harm to the wild populations with more than fifty plants. Collect from all individuals within the population if there are fifty or fewer plants. Capturing broad genetic diversity may require collecting in different years and across the range of the fruiting season. See Guerrant et al. (2004a) for specific guidance on ex situ collection and management.

15. FOR LONG-LIVED SPECIES, REINTRODUCE PLANTS OF VARYING SIZES AND LIFE STAGES TO ACCOUNT FOR VARIABLE SUCCESS OF STAGES IN DIFFERENT MICROSITES (ALBRECHT AND MASCHINSKI, THIS VOLUME).

- The key is to provide heterogeneity. For example, use juveniles and reproductive plants in your reintroduction. Sometimes the two will have different microsite needs. Using different-stage plants will result in a more diverse population structure in the present and future and will increase your probability of finding the optimal conditions for the whole population to grow.

16. USE LARGE, MATURE FOUNDERS TO INCREASE THE LIKELIHOOD OF ESTABLISHING A PERSISTENT POPULATION (GUERRANT ET AL. 2004A; ALBRECHT AND MASCHINSKI, THIS VOLUME); USE WHOLE PLANTS RATHER THAN SEEDS UNLESS THERE ARE COMPELLING CIRCUMSTANCES (E.G., ROCK OUTCROP HABITATS) WHERE SEEDS ARE NECESSARY.

- Grow plants as large as is feasible to manage for transport to the reintroduction site and planting.
- Develop a demographic model for the species to determine the optimum founder plant and population size (Knight, this volume).
- To maximize the number of plants that will be available for the reintroduction, particularly when few seeds are available, we recommend germinating seeds under controlled nursery conditions and transplanting whole plants to the reintroduction site (Albrecht and Maschinski, this volume). A sample of 100 seeds may yield 95 plants if germinated in a greenhouse, whereas only a single seedling may emerge in the field.
- When seeds are the only option (e.g., annuals) we recommend using an experimental protocol that involves irrigation in the field until seeds germinate and become established, a practice often used with long-lived perennials. Also consider protecting seeds from herbivory or providing conditions that will decrease the probability of desiccation (e.g., Bainbridge 2007).

17. CONFIRM THAT THE SPECIES CAN BE SUCCESSFULLY PROPAGATED AND THAT AN ADEQUATE AMOUNT OF HIGH-QUALITY, HEALTHY, GENETICALLY DIVERSE SOURCE MATERIAL IS AVAILABLE.

- A critical step to accomplish before reintroduction is mastering the art of propagating large numbers of the species, acclimatizing them, and growing them *ex situ*. A declining species that cannot be propagated *ex situ* is simply not a good candidate for reintroduction. Acknowledge that you are not ready to proceed if you have not mastered this step.

18. ALLOW ENOUGH TIME TO GENERATE AN ADEQUATE AMOUNT OF SOURCE MATERIAL BEFORE INITIATING THE REINTRODUCTION, KNOWING THIS COULD TAKE MONTHS OR YEARS.

19. KEEP DETAILED DOCUMENTATION ON ALL SOURCE MATERIAL USED TO RESTORE POPULATIONS. THIS DOCUMENTATION SHOULD BE LINKED TO PERMANENT PLANT LABELS OR ID TAGS ATTACHED TO THE REINTRODUCED PLANTS. STORE THESE DATA IN MULTIPLE LOCATIONS.

20. DO NOT USE ALL YOUR SOURCE MATERIAL FOR THE REINTRODUCTION.

- Genetically diverse source material should be safely backed up in an ex situ location so that regardless of whether the reintroduction succeeds or fails, there is still germplasm conserved.

21. USE GOOD HORTICULTURAL PRACTICE.

- Acclimate plants to novel conditions (Haskins and Pence, this volume). Transitions from culture medium to soil and from greenhouse to outdoors will require a period of adjustment to reduce the chance of shock. If using propagules that were derived from tissue culture, we recommend gradually decreasing humidity while subjecting cultures to ventilation or air exchanges before transfer to soil. Alternatively, methods could include increasing ambient CO<sub>2</sub>, decreasing sugar levels in the cultures, or treating with growth regulators to increase stress tolerance.
- Take phytosanitary precautions to ensure that diseases will not be transmitted.
- Using native soils from the recipient site is advised for nursery production to provide necessary microbial mutualists. Native soils may need augmentation with sterile perlite or vermiculite to achieve consistency necessary for container growth. The possibility of transferring pathogens with native soil should be considered, and good nursery hygiene practices must be followed. If the use of native soil is impractical, then microbial inoculum can be purchased or self-cultured (Brundrett et al. 1996; Dumroese et al. 2009). Note that microbial additions involve translocating multiple species, and therefore all the considerations discussed in these guidelines must be considered for the microbes as well.
- Remove weeds from pots containing reintroduction propagules.

### *Site Selection*

A recipient site should be chosen with great care and intention. Several conditions influence a species' ability to colonize a new site, including functional ecosystem



**BOX A1.7. QUESTIONS TO ASK ABOUT RECIPIENT SITE OR  
REINTRODUCTION LOCATION**

- \_\_\_\_\_ Have you researched the history of the recipient site?
- \_\_\_\_\_ Have you incorporated species-specific factors related to optimal population growth into the recipient site assessment?
- \_\_\_\_\_ Have you identified species-specific environmental and community factors in occupied and unoccupied patches?
- \_\_\_\_\_ Have you ranked several potential suitable recipient sites to determine the best place for the reintroduction to occur?
- \_\_\_\_\_ Is there still suitable habitat left within the species' range? (See Falk et al. 1996 for discussion of range.)
- \_\_\_\_\_ Are recipient sites of sufficient quality and with sufficient long-term protection to ensure the long-term security of the reintroduced population?
- \_\_\_\_\_ Are threats absent or adequately managed at the site?
- \_\_\_\_\_ What were the previous threats that may have caused the species to become extirpated from site?
- \_\_\_\_\_ What is the potential for future threats?
- \_\_\_\_\_ Is current and future land use of the recipient site and surrounding sites compatible with sustainability of the reintroduced population?
- \_\_\_\_\_ Are potentially hybridizing congeners present at recipient site? Which ones? Are they present at nearby sites? Are they present within the target species' range?
- \_\_\_\_\_ Is the recipient site within the species' climate envelope now? Do models suggest that the location will be safely within the climate envelope in the future?
- \_\_\_\_\_ What site preparation is needed before the plants can be installed (e.g., canopy thinning, invasive removal)? Will habitat manipulation continue after reintroduction?
- \_\_\_\_\_ Does the species need habitat conditions that no longer exist on site (e.g., fire, periodic inundation)? Can those conditions be mimicked?

processes, appropriate associated species, and ongoing management to remove threats and maintain ecosystem health. Review what is known about a proposed recipient site (box A1.7). Seek a recipient site with great similarity to the place where the rare species is thriving. Understanding the site history may help explain existing conditions. Although it is impossible to predict with certainty what a site will become in the future, as much as possible practitioners should try to imagine

the future conditions the reintroduced population will face. Ongoing management and threat abatement are essential for maintaining conditions conducive to population sustainability.

In addition, it is important to think about any recipient site in the context of the species' whole distribution. Because corridors may facilitate migration and dispersal between patches, especially with the onset of climate change (Noss 2001), a reintroduced population can serve an important function of connecting existing populations by forming a stepping stone between patches or expanding the size of existing patches. Connecting fifteen or more patches will improve chances for the entire metapopulation capacity (see Hanski and Ovaskainen 2000).

## 22. CHOOSE A SUITABLE RECIPIENT SITE.

- Evaluate potential reintroduction sites using the recipient site assessment or other quantitative assessment (Maschinski et al. [chap. 7], this volume). Base your evaluation on the natural habitat where a population has positive (or at least stable) growth rate (Dalrymple et al., Knight, this volume).
- To choose between several potential sites, rank reintroduction sites incorporating logistics or ease of implementation, quality of habitat, and management influencing the species' ability to persist at a site (table 7.1; Maschinski et al. [chap. 7], this volume).
- Consider landscape-level phenomena. Evaluating the landscape from the perspectives of topography, ecosystem dynamics, and patterns of possible restoration trajectories will help determine the locations with greatest likelihood of sustaining a reintroduced population (Maschinski et al. [chap. 7], this volume).
- To account for uncertainty, incorporate heterogeneity into the reintroduction plan. Use multiple sites and multiple microsites (even outside your expectations) to test heterogeneity of conditions needed for optimal growth for all life stages of a species (Dalrymple et al., Maschinski et al. [chap. 7], this volume).
- Because the fine-scale needs for individual plant growth and optimal population growth are often unknown, using microsite as an experimental factor is good practice. Measure abiotic conditions (e.g., soil, precipitation, temperature) and biotic conditions (e.g., predators, mutualists, invasive species) at the reintroduction site that are associated with plant performance and population growth (Knight, Maschinski et al. [chap. 7], this volume). Ensure that there are adequate areas for population expansion (e.g., microsites are available within the recipient site and adjacent suitable habitat is available outside of the recipient site).

- Realize that if environments conducive to positive population growth are rare or nonexistent, additional activities, beyond simply reintroducing propagules, will be necessary (Knight, Maschinski et al. [chap. 7], this volume).

23. NOTE THAT USING EXTANT POPULATIONS AND THEIR HABITAT CONDITIONS AS REFERENCE POINTS FOR REINTRODUCTIONS WILL NOT ALWAYS BE APPROPRIATE IF THE SPECIES DOES NOT HAVE POSITIVE GROWTH RATE AT THESE LOCATIONS (POSSLEY ET AL. 2009; DALRYMPLE ET AL., KNIGHT, MASCHINSKI ET AL. [CHAP. 7], THIS VOLUME).

- An experimental context is essential to determine factors necessary for positive population growth.
- Reference points may not be available within core habitat under climate change conditions (Dalrymple et al., this volume). Similarly, geographic distribution may not be a good reference for fundamental niche space. For this reason, known historic range may not necessarily be the only guide to assess optimal habitats for successful reintroduction (Maschinski et al. [chap. 7], this volume).

24. INCREASE THE PROBABILITY OF CREATING A SUSTAINABLE POPULATION BY CHOOSING RECIPIENT SITES THAT HAVE CONNECTIVITY AND INCREASE THE PROBABILITY OF DISPERSAL TO ADDITIONAL LOCATIONS (MASCHINSKI ET AL. [CHAP. 7], THIS VOLUME; BOX A1.8).

- Recipient sites in close proximity to wild or reintroduced populations may have a higher probability of gene exchange.
- Recipient sites with adequate suitable habitat have a higher probability of providing space for population expansion.

### *Population Biology: Present and Future Generations*

Guerrant (1996a, p. 194) suggested that the “founding population should be as large as possible, with the ceiling set primarily by practical and other strategic considerations.” With this in mind, it is important to introduce enough individuals (seeds or juveniles) to break through demographic and environmental stochasticity of low populations to achieve a viable population (Knight, this volume). A good reintroduction plan will address population biology questions (box A1.9).

**BOX A1.8. QUESTIONS RELATED TO HABITAT OR  
LANDSCAPE-LEVEL CONSIDERATIONS**

- \_\_\_\_\_ Does the recipient site contribute to natural patterns of heterogeneity in the species' distribution?
- \_\_\_\_\_ Have you considered habitat connectivity? Is healthy suitable habitat nearby that will allow the reintroduced population to expand in area and number of individuals? Is adjacent property suitable habitat? Is adjacent property protected?
- \_\_\_\_\_ Are there metapopulation possibilities? Have you accounted for between-site factors as well as within-site factors? Is the site located close to extant populations or other reintroduced populations?
- \_\_\_\_\_ What are the distances between the proposed reintroduction and nearby wild populations? What advantages or disadvantages do the nearby sites give the reintroduced population?

**BOX A1.9. QUESTIONS RELATED TO POPULATION BIOLOGY CONSIDERATIONS**

- \_\_\_\_\_ What founder population size will be used? (Albrecht and Maschinski, Knight, this volume)
- \_\_\_\_\_ What size and stage structure of plants will be used?
- \_\_\_\_\_ How will the founding population be spatially configured to favor demographic persistence and stability?
- \_\_\_\_\_ What is known about population growth, recruitment, and survivorship in wild habitats, and what environmental or community factors are correlated with population growth rates?
- \_\_\_\_\_ How will population growth, recruitment, and survivorship be monitored in the reintroduced population? And by whom?

**25. USE AT LEAST FIFTY PLANTS FOR A REINTRODUCTION (ALBRECHT AND MASCHINSKI, THIS VOLUME).**

- When working with perennial herbs and sites in highly competitive environments such as grasslands, founder population sizes will need to be larger than fifty.
- We recommend developing a demographic model for the species to determine the optimum founder size (see Knight, this volume).

26. SEEK OR DEVELOP GROWING CONDITIONS WITH THE INTENTION OF IMPROVING GERMINATION, ESTABLISHMENT, AND SURVIVAL OF NEXT-GENERATION SEEDLINGS (ALBRECHT AND MASCHINSKI, THIS VOLUME).

- Implementing techniques or manipulating site conditions, such as using nurse plants, drip irrigation, or sculpting microcatchments (Bainbridge 2007) to improve success of field germination and seedling establishment, is a critical part of creating a sustainable population. More attention should be paid to this step in the reintroduction process.

### III. Implementing the Reintroduction

To use our limited conservation resources to the fullest extent, all reintroductions should be viewed as opportunities to learn about the species, either through experimentation or through documented observation. Even when there is reasonably good information about the environmental attributes associated with the species and its occurrence, test plantings can show which microhabitat conditions are optimal for growth, survival, and long-term population growth (Maschinski et al. [chap. 7], this volume). Effective implementation entails considering logistics and design (box A1.10).

27. DETERMINE THE TIME, MATERIALS, PERSONNEL, AND LOGISTICS NEEDED TO IMPLEMENT THE REINTRODUCTION.

- Ensure that you have enough help to treat the site and install plants.
- This is a wonderful opportunity for student and citizen volunteers of all ages. Ensure that they are provided with adequate training, supervision, water, and snacks.

28. IF NECESSARY, REMOVE INVASIVE SPECIES OR THIN CANOPY TO IMPROVE SITE CONDITIONS FOR THE REINTRODUCED SPECIES.

- Site preparation will take time before and after the reintroduction.
- Multiple treatments (e.g., irrigation, soil amendment) may be needed to ensure ideal conditions for reintroduced plants.

29. PLACE PLANTS IN A SPATIAL PATTERN THAT WILL PROMOTE EFFECTIVE POLLINATION, SEED PRODUCTION, AND RECRUITMENT.

- Plant density strongly influences variation in outcrossing (or selfing) among plants, so plant in a spatial pattern that will encourage appropriate breeding for your species (Monks et al., this volume).

**BOX A1.10. QUESTIONS ABOUT IMPLEMENTATION LOGISTICS**  
(VALLEE ET AL. 2004)

- \_\_\_\_\_ What is the best season to transplant or sow seeds? Keep in mind that best season for rainfall may also be that hottest time of the year, and plants may need more attention.
- \_\_\_\_\_ Have you invited participation from enough staff, volunteers, community members, agency members, and landowners or land managers to execute the reintroduction?
- \_\_\_\_\_ Are permits acquired and up to date?
- \_\_\_\_\_ How will you ensure that plants will be able to be tracked for many years in the future? Are plants tagged and coordinates recorded?
- \_\_\_\_\_ How will you transport plants to the recipient site? Do you have necessary off-road equipment for transport away from roadways?
- \_\_\_\_\_ What is the planting layout design?
- \_\_\_\_\_ Have you notified the press or arranged for photos to be taken of the event? (Note that there may be circumstances in which the exact location of the reintroduction must not be publicized to prevent unauthorized collection of the taxon; however, good conservation news with general descriptions of the reintroduction can be used to engender public enthusiasm for plant conservation. If you are uncertain, talk to your regulatory agency before notifying the press.)

- Planting individuals in small clusters throughout the recipient area, instead of a few large clusters, may increase spread of the population (Reichard et al., this volume).
- Understanding a target species' tolerance for competition and disturbance, as well as habitat composition and structure, can help inform spatial and temporal placement of any reintroduction (Maschinski et al. [chap. 7], this volume). For example, if the target species is not a good competitor, planting into open spaces with few other species present is advised.

30. USE A SYSTEM SUCH AS COLOR CODING TO DISTINGUISH PLANTS IN DIFFERENT EXPERIMENTAL TREATMENTS EASILY. SELECT DURABLE, LONG-LASTING TAGS FOR LABELING PLANTS AND PLOTS.

- If you have a large number of plants and a large number of people helping with the installation of the reintroduction, it is important to be able to distinguish plants from different treatments. For example, if you are testing

plants that received mycorrhizal fungal inoculum and those that did not, clearly mark plants before getting to the field and clearly mark the location at the site where plants of each group should be planted.

#### IV. Conduct Aftercare of the Reintroduction

After the reintroduction is installed, it will need additional care. Success cannot be assumed just because plants or seeds are in the ground. The first few weeks are often most crucial in ensuring that the species survives in its new home. Practitioners should take care to consider these activities in time and cost estimates (box A1.11).

31. WATER PLANTS AND SEEDS UNTIL ESTABLISHED.

32. PERIODICALLY REMOVE WEEDS NEARBY UNTIL PLANTS ARE WELL ESTABLISHED.

33. ONGOING SITE MANAGEMENT IS IMPORTANT. COLLABORATORS SHOULD REVIEW THE STATUS OF THE SITE PERIODICALLY TO ASCERTAIN WHETHER FURTHER MANAGEMENT IS NEEDED.

- Control overabundant herbivores. Cage plants, if necessary.
- Restore historical disturbance regimes such as fire.
- It may be necessary to control competing native and exotic vegetation over the long term, especially if fire cannot be restored to the recipient site.
- Periodically survey the site to detect unforeseen problems (e.g., trampling, theft, herbivory, pest insects, vandalism, maintenance personnel abuse of plants). Take appropriate action to protect the reintroduced population.

##### BOX A1.11. POST-PLANTING QUESTIONS TO CONSIDER (VALLEE ET AL. 2004)

- \_\_\_\_\_ What aftercare will be needed, and how frequently will plants need attention?
- \_\_\_\_\_ What habitat management and threat abatement are needed? How frequently?
- \_\_\_\_\_ Has a monitoring plan been prepared and reviewed?
- \_\_\_\_\_ Are sufficient funds available for aftercare?
- \_\_\_\_\_ Do permits cover aftercare activities?

## V. Design Appropriate Monitoring Plans

A well-designed monitoring plan is an essential component of any reintroduction program. To ensure the long-term persistence of a species in the face of environmental change, a long-term monitoring plan is needed to evaluate how reintroduced populations respond to infrequent events (e.g., drought) and to detect changes in the population that might take years to express (e.g., inbreeding depression in long-lived perennials, replenishing of the soil seedbank). Our goal in this section is not to provide an exhaustive review of how to monitor plant populations but rather to provide standards for the minimum amount of information needed to evaluate the long-term fate of reintroduced populations. Although all monitoring plans must be tailored to individual projects in order to obtain relevant data, all reintroduction monitoring plans include basic components needed to provide information relevant to species' biology and techniques for managing rare plant populations (table A1.1). A long-term monitoring strategy will depend on a number of factors, including the trajectory of population growth, the life history of the focal species, monitoring resources, and the goals of the experimental components of the project. See Elzinga and colleagues (1998) for more details.

### 34. DEVELOP A MONITORING PLAN.

- A well-designed monitoring plan with clear objectives provides information on the species' biology and techniques for managing rare plant populations. It should be easily understood by your successors; record details as if you are writing for institutional memory.
- If any changes are made to the monitoring plan, then document changes in detail.

### 35. GATHER DEMOGRAPHIC DATA ON THE REINTRODUCED POPULATION UNLESS IT IS NOT APPROPRIATE FOR THE LIFE HISTORY OF THE TARGET SPECIES (MORRIS AND DOAK 2002; SEE #37).

- Determine the stages of your population and count them. Most commonly, this will be seedlings, juveniles, nonreproductive adults, and reproductive adults.
- We recommend measuring survival, growth, and reproduction on each plant, preferably over multiple generations (Monks et al., this volume).
- If you plan to develop and compare population viability analysis models for the reintroduced population and natural populations, then the frequency of monitoring will need to be at a rate that accurately charts movement of an individual from one life stage to another (table A1.1).



**TABLE A1.1**

*List of actions essential to monitoring plans for reintroduced plant populations.*

Action	Description
1. Develop clear monitoring objectives.	Take into account the life history of the focal species, propagule stages planted, and biological and project goals (Pavlik 1996).
2. Define sample units.	Use individuals or transplants for demographic monitoring or plot- or transect-based methods for monitoring demographic structure. All transplants and plots must be permanently marked and mapped, preferably with GPS.
3. Determine appropriate monitoring frequency.	Monitoring period should match key phenological phases (e.g., peak fruiting and flowering) and life history of the focal species.
4. Monitor vital rates.	Follow the fates (survival, growth, fecundity, and recruitment) of transplanted individuals and their progeny or quantitatively track abundance of stage classes (seedling, juvenile, nonreproductive adult, reproductive adult).
5. Evaluate fecundity.	Measure seed production by counting the number of fruits per plant and estimate the number of seeds per fruit through subsampling. Compare results to reference or natural populations.
6. Survey new habitat patches for dispersal and spread.	Search for seedlings at each census, both near and far from sample units. Add new recruits to demographic studies; subsample if recruitment densities are large. Conduct searches for the focal species in suitable habitat patches within and beyond the initial planting site. Establish new sample units to monitor the growth and development of new patches or populations.
7. Monitor wild reference populations.	Simultaneously monitor reintroduced and natural populations to gain insight into key factors that underlie restoration success. Natural populations should be monitored across several sites and during the same years to capture variation in vital rates for comparison to reintroduced populations.
8. Monitor threats.	Document evidence of changes in exotic species distribution and abundance, successional patterns, hydrology, disturbance regimes, land management, herbivores, predators, and disease.
9. Prepare backup plan to relocate lost sample units.	Document all sites and plots with GPS and supplement with precise directions that include compass directions and measured distance from permanent visible landmarks (Elzinga et al. 1998). Produce geographic information system layers and maps if possible.
10. Archive monitoring data and provide metadata.	Enter, store, and back up all monitoring data in digital files. A minimum of two copies of raw datasheets should be kept on paper file, preferably in separate locations. One copy should be accessible to take into the field during subsequent monitoring events. Metadata should be assembled during the project and continually updated.

GPS = Global Positioning System.

- Define the boundaries of your search area to determine dispersal of new recruits and survey these as needed. Realize that these boundaries may need to be expanded or changed over time.

36. WHEN POSSIBLE, MONITOR MULTIPLE WILD REFERENCE POPULATIONS TO COMPARE TO THE REINTRODUCED POPULATION (BELL ET AL. 2003; COLAS ET AL. 2008; MENGES 2008).

- Reference populations will give context for spatial and temporal variation in the reintroduced population's vital rates (table A1.1) and aid in identifying the vital rates that are driving population trends (Morris and Doak 2002).
- In augmentations, the fate of augmented individuals and naturally occurring ones should be distinguished in demographic or quantitative censuses whenever possible to determine whether transplants are performing differently from naturally occurring individuals in the population.

37. ADOPT A MONITORING STRATEGY THAT IS APPROPRIATE FOR THE LIFE HISTORY OF YOUR TARGET SPECIES AND THE FOUNDING PROPAGULE USED.

*a. For long-lived perennial plants, monitoring plans will need to accommodate changes in population structure over time.*

- Note when transplants transition into larger size classes and sexually reproduce.
- Tag new seedlings as they recruit into the population.
- Most perennial plants will need to be monitored each year to obtain annual vital rates, but some long-lived species (e.g., trees) with slow growth and low reproduction may need less frequent monitoring.
- Time monitoring visits with peak seasonal activity of fecundity and seed germination.
- Searches beyond the transplant plots or transects will need to be conducted to document dispersal, seedling recruitment, and metapopulation dynamics adequately.

*b. For short-lived plants, such as annuals, whose populations are often spatially and temporally variable, seed will most often be used to found reintroduced populations (Albrecht and Maschinski, Dalrymple et al., this volume). We recommend sowing seed into permanently marked and mapped plots or transects.*

- In annual species, dormancy and germination are often driven by climatic cues that vary from year to year, resulting in wide annual fluctuations in dis-

tribution and abundance. As subsequent generations disperse seed, restricting the census to the original sown plots would fail to capture local dispersal. It will be important to note which microsites are suitable for germination and survival.

- Regular counts of individuals within grids or belt transects that cover broad areas within the habitat may be needed to capture changes in the complete spatial distribution and abundance over the long term and to assess population trends effectively (Young et al. 2008).

*c. The method used to monitor seeds will depend on the sample unit.*

- When sample sizes are small, seeds can be tracked individually. In most cases, however, seeds are sown directly into plots and cohorts are followed.

*d. If demographic monitoring of individuals is not possible, monitor stages or size classes that are most important in maintaining population growth.*

- If the importance of the vital rates is known for your species, you can concentrate on the most important vital rate and note changes across years to understand population trends.
- If populations begin to decline, then monitoring individuals in all stage classes may be needed to understand mechanisms that are driving the decline and to determine what management actions are needed to reverse the decline.

*e. When the target species has characteristics or traits such as clonal reproduction, seed or plant dormancy, or cryptic life history stages (e.g., orchid germinants), all of which make demographic monitoring of marked individuals difficult or impractical, we recommend doing census counts of all or key life history stages to detect population trends (Menges and Gordon 1996).*

38. MONITOR FOR AT LEAST 3 YEARS AND IF POSSIBLE FOR 10 YEARS OR MORE (FALK ET AL. 1996; DALRYMPLE ET AL., THIS VOLUME).

- Long-term monitoring provides information necessary to evaluate how reintroduced populations respond to events (e.g., drought) that were infrequent or nonexistent during the early phase of population establishment. It can reveal genetic problems that might play out only after multiple generations (e.g., inbreeding). The importance of these data cannot be overemphasized.
- To develop population viability models and predict population trajectories, a minimum of 3 years of monitoring data is needed. To predict long-term trends (10–100 years) and determine whether a reintroduced population is

potentially self-sustaining under current environmental conditions, extended periods of monitoring are necessary.

- Enlist the help of volunteers to accomplish long-term monitoring (Maschinski et al. [chap. 4], this volume). When possible, include land managers in the monitoring process to foster a close connection between project members and the reintroduced population.

39. IT IS SAFE TO ASSUME THAT SOME OF THE SAMPLE UNITS WILL BE LOST OVER TIME. USE MULTIPLE PERMANENT MARKERS AND MAP PLANTS AND PLOTS WITH A GLOBAL POSITIONING SYSTEM DEVICE TO HELP PREVENT THE LOSS OF VALUABLE DATA.

- Realize that over time, natural or anthropogenic disturbances can impede access to sites or complicate relocating sample units. Plots and transect boundaries or demographic markers may be lost due to fire, flood, downfalls, burial, vandalism, animal impacts, and so on.
- Losses can be mitigated with a good insurance plan, which can be used to reestablish or relocate the boundaries of sample units or tagged individuals when necessary. Whether through plot-based methods or monitoring of individuals, there are several ways to ensure the accurate relocation of lost plot markers, transects, and tagged individuals. See pages 190–191 in Elzinga and colleagues (1998) for more details.

40. DETERMINE HOW SUCCESS WILL BE MEASURED AND HAVE REALISTIC GOALS.

- Identify and define short-, mid-, and long-term goals and determine how you will assess whether those goals have been met.
- Consider project success and biological success (Pavlik 1996).
- Consider population, genetic, and reproductive attributes as indicators of success (Monks et al., this volume).

41. AS SHORT-TERM GOALS ARE ACHIEVED IN A REINTRODUCTION PROGRAM, MONITORING INTENSITY MAY CHANGE FROM EXPERIMENTAL TO OBSERVATIONAL.

- For example, when reintroducing the perennial forb *Helenium virginicum* to sinkhole ponds in the Ozarks, Rimer and McCue (2005) initially set out to determine how planting position and maternal lines affected establishment rates of transplants over a 2-year period. Individuals of the species were

grown *ex situ* and transplanted in a replicated experimental design, and then the fates of transplants were followed demographically. After meeting the initial goals of the reintroduction, the populations grew rapidly due to vegetative reproduction and successful seedling recruitment, making it impractical to differentiate demographically between transplants and new recruits in subsequent censuses. Because the short-term goals of the experimental design were accomplished, the populations grew rapidly, and the species was capable of completing its life cycle in this location, the monitoring protocol switched to count estimates and surveys for new threats rather than full-scale demographic monitoring of individuals. Likewise, transitioning to observational monitoring may lead to less frequent data collection (e.g., annual rather than quarterly) than was needed during the more intense experimental stage.

42. ANALYZE DATA IN A TIMELY FASHION. DISCUSS YOUR ANALYSES WITH PEERS AND STATISTICIANS.

43. REPORT RESULTS BY PUBLISHING OR PUBLICIZING VIA THE POPULAR MEDIA, NEWSLETTERS, AND WEBSITES. ENTER DATA INTO RELEVANT DATABASES FOR GLOBAL ACCESS.

## Documentation

Because documentation is an essential component of reintroduction (box A1.12), we encourage careful documentation so that the reintroduction project is justified, good decisions are made about preparedness before the reintroduction event, appropriate monitoring is implemented, the data are analyzed, and the project is published and made available to others in one form or another. These steps are important to represent the reintroduction accurately from a legal and scientific perspective (see Dalrymple et al., this volume). A documentation form is available on the North Carolina Botanical Garden website (North Carolina Plant Conservation Program Scientific Committee 2005).

**Box A1.12. DOCUMENTATION NEEDED TO JUSTIFY AND DECIDE WHETHER TO CONDUCT A REINTRODUCTION**

- \_\_\_\_\_ Survey and status updates are complete. Status includes degree of protection, threats, and management options for the extant populations.
- \_\_\_\_\_ Specific information on the number of populations has been collated within the last 18 months.
- \_\_\_\_\_ Counts or estimates of the number of individuals in each population have been done.
- \_\_\_\_\_ The age structure of the populations is known.
- \_\_\_\_\_ The relationship of populations in a metapopulation context is compiled.
- \_\_\_\_\_ Surveys identifying suitable habitat are complete.
- \_\_\_\_\_ Suitable recipient sites have been assessed and ranked.
- \_\_\_\_\_ Long-term protection and management plans are documented for suitable recipient sites.
- \_\_\_\_\_ Sufficient money is secured to conduct the reintroduction.

## *Studies Used for Meta-Analyses*

EDWARD O. GUERRANT JR., MATTHEW A. ALBRECHT,  
AND SARAH E. DALRYMPLE

The reintroductions that were used in the meta-analyses reported by Albrecht and Maschinski, Dalrymple and colleagues, and Guerrant (this volume) are listed here. Included are the species epithet, family, country where the work was conducted, life history or life form, reintroduction type, year of first attempt, the authors who used this species in their meta-analysis, and the references. In some cases the reintroductions have been published in peer-reviewed literature, but many are reported either in gray literature or in the *CPC International Reintroduction Registry* (2009).

Species Name	Family	Country	Life History or Form	Reintroduction Type	First Year	Dataset Identifier	References
<i>Abronia umbellata</i> ssp. <i>brevisflora</i>	Nyctaginaceae	USA	Ann, SLMP	Int WHR	1995	A, D, G	(CPCIRR: Thorpe et al. 2008a; McLaughlin et al. 2002)
<i>Acacia aprica</i>	Mimosaceae	Australia	WP, LLPP	Int OHR, Int WHR	1998	A, D, G	(CPCIRR: L. Monks; Monks 2002)
<i>Acacia cochilocarpa</i> ssp. <i>cochilocarpa</i>	Mimosaceae	Australia	WP	Int WHR	1999	A, G	(CPCIRR: L. Monks)
<i>Acacia cretacea</i>	Mimosaceae	Australia	WP	Aug	1992	A, D, G	(CPCIRR: Jusaitis 1997, 2005; Jusaitis and Val 1997)
<i>Acacia whitbleyana</i>	Mimosaceae	Australia	WP	Int WHR, Aug	1996	A, D, G	(CPCIRR: Jusaitis 2005; Jusaitis and Sorensen 2007; Jusaitis and Polomka 2008)
<i>Acanthomintha duttonii</i>	Lamiaceae	USA	Ann.	Int WHR	1991	D	Pavlik and Espeland 1998
<i>Aciathera saundersiana</i>	Orchidaceae	Brazil	HP	Trans, Int WHR	2001	D	Jasper et al. 2005
<i>Aciathera sonderana</i>	Orchidaceae	Brazil	HP	Trans, Int WHR	2001	D	Jasper et al. 2005
<i>Acomastylis rossii</i>	Rosaceae	USA	HP, ULPP	Trans	1973	G	(CPCIRR: Mav et al. 1982)
<i>Aconitium noveboracense</i>	Ranunculaceae	USA	HP, ULPP	Aug	2009	G	(CPCIRR: V. Pence)
<i>Aechmea calyculata</i>	Bromeliaceae	Brazil	HP	Trans, Int WHR	2001	D	Jasper et al. 2005
<i>Aechmea recurvata</i>	Bromeliaceae	Brazil	HP	Trans, Int WHR	2001	D	Jasper et al. 2005
<i>Agave arizonica</i>	Agavaceae	USA	LLMP	Aug	1989	G	(CPCIRR: K. Rice; Ecker 1990; Gentry 1982)
<i>Agrimonia incisa</i>	Rosaceae	USA	HP	Trans, Int WHR	1998	D	Glitzenstein et al. 2001
<i>Aldrovanda vesiculosa</i>	Droseraceae	Czech Republic	HP	Int WHR	1995	A, D, G	(CPCIRR: Adamec and Lev 1999); Adamec 2005
<i>Amorpha herbacea</i> var. <i>crenulata</i>	Fabaceae	USA	WP	Reint, Int WHR, Int OHR	1995	A, D, G	(CPCIRR: Maschinski et al. 2006, 2007; Wendelberger et al. 2008)
<i>Amsinckia grandiflora</i>	Boraginaceae	USA	Ann.	Int WHR	1989	A, D, G	Pavlik 1991; (CPCIRR: Pavlik et al. 1993; Pavlik 1996)
<i>Antennaria flagellaris</i>	Asteraceae	USA	HP	Trans	1983	D	Fiedler and Laven 1996
<i>Apium repens</i>	Apiaceae	UK	HP	Int WHR	1996	D	McDonald and Lambrick 2006
<i>Aquilegia canadensis</i>	Ranunculaceae	USA	HP	Int WHR	1994	D	Drayton and Primack 2000



<i>Arabis koehleri</i> var. <i>koehleri</i>	Brassicaceae	USA	ULPP	Aug	2001	A, G	(CPCIRR: Guerrant 1996a; Yandell 1997; Guerrant and Kaye 2007)
<i>Aralia racemosa</i>	Araliaceae	USA	P	Int WHR	1994	D	Drayton and Primack 2000
<i>Arenaria cumbertlandensis</i>	Caryophyllaceae	USA	HP	Int WHR	2005	G	(CPCIRR: V. Pence)
<i>Arenaria grandiflora</i>	Caryophyllaceae	France	HP	Reint	1999	A, G	Adamec and Lev 1999; (CPCIRR: Bottin et al. 2007)
<i>Argusia argentea</i>	Boraginaceae	Australia	WP	Reint	1999	D	McDonald 2005
<i>Aristida beyrichiana</i>	Poaceae	USA	HP	Int WHR	1993	D	Glitzenstein et al. 2001
<i>Asclepias meadii</i>	Asclepiadaceae	USA	HP, LLPP	Int WHR	1994	A, G	(CPCIRR: Tecic et al. 1998; Bowles et al. 1998, 2001; Hayworth et al. 2001; Bell et al. 2003)
<i>Aster linosyris</i>	Asteraceae	UK	HP	NS	NS	D	BSBI Introductions Database
<i>Astragalus bibullatus</i>	Fabaceae	USA	HP	Int WHR	2001	A, G	(CPCIRR: Albrecht and McCue 2010)
<i>Astragalus crennophyllax</i> var. <i>crennophyllax</i>	Fabaceae	USA	HP	Aug	1990	A, G	(CPCIRR: Maschinski and Rutman 1993)
<i>Banksia anctona</i>	Proteaceae	Australia	WP	Int OHR	2007	A, G	CPCIRR: L. Monks
<i>Banksia brownii</i>	Proteaceae	Australia	WP	Int OHR	2007	A, G	CPCIRR: L. Monks
<i>Barbosella cogniauxiana</i>	Orchidaceae	Brazil	HP	Trans, Int WHR	2001	D	Jasper et al. 2005
<i>Billbergia nutans</i>	Bromeliaceae	Brazil	HP	Trans, Int WHR	2001	D	Jasper et al. 2005
<i>Bletia urbana</i>	Orchidaceae	Mexico	HP	Int WHR	1986	A, D	(CPCIRR: Rublno et al. 1989)
<i>Brachycome muelleri</i>	Asteraceae	Australia	Ann.	Aug, Int OHR	1996	A, D, G	(CPCIRR: Jusaitis et al. 2004)
<i>Caladenia arenicola</i>	Orchidaceae	Australia	HP	Int OHR	1996	D	Batty et al. 2006a
<i>Caltha palustris</i>	Ranunculaceae	USA	HP	Int WHR, Trans	1994	D	Drayton and Primack 2000
<i>Campylocentrum burchellii</i>	Orchidaceae	Brazil	HP	Trans, Int WHR	2001	D	Jasper et al. 2005
<i>Capanemia micromera</i>	Orchidaceae	Brazil	HP	Trans, Int WHR	2001	D	Jasper et al. 2005
<i>Capanemia superflua</i>	Orchidaceae	Brazil	HP	Trans, Int WHR	2001	D	Jasper et al. 2005
<i>Carex pyrenaica</i>	Cyperaceae	USA	HP, ULPP	Trans	1973	G	(CPCIRR: May et al. 1982)
<i>Carex rupestris</i>	Cyperaceae	USA	HP, ULPP	Trans	1973	G	(CPCIRR: May et al. 1982)
<i>Carex vulpina</i>	Cyperaceae	UK	HP	Aug	NS	D	Porley 2005

Species Name	Family	Country	Life History or Form	Reintroduction Type	First Year	Dataset Identifier	References
<i>Carpinus caroliniana</i>	Betulaceae	Mexico	WP	Reint	2000	G	(CPCIRR: Alvarez-Aquino et al. 2004)
<i>Centaurea corymbosa</i>	Asteraceae	France	HP	Int	1994	A	Kirchner et al. 2006
<i>Cerastium nigrescens</i>	Caryophyllaceae	UK	HP	Reint	1995	D	BSBI Introductions Database
<i>Chamaesyce skottsbergii</i> var. <i>skottsbergii</i>	Euphorbiaceae	USA	WP	Int WHR	1979	D	Mehrhoff 1996
<i>Chrysopsis floridana</i>	Asteraceae	USA	SLPP	Int WHR	2008	G	(CPCIRR: C.L. Peterson)
<i>Cimicifuga elata</i>	Ranunculaceae	USA	HP	Aug	2001	G	(CPCIRR: Kaye 2001)
<i>Cirsium pitcheri</i>	Asteraceae	USA	HP	Reint, Int WHR	1991	A, D, G	(CPCIRR: Bowles et al. 1993; McEachern et al. 1994; Bowles and McBride 1996; Bell et al. 2003)
<i>Cirsium tuberosum</i>	Asteraceae	UK	HP	Reint	1989	A, D	(CPCIRR: Pigott 1988)
<i>Cochlearia polonica</i>	Brassicaceae	Poland	HP	Trans	1970	A	Cieslak et al. 2007
<i>Conradina glabra</i>	Lamiaceae	USA	WP	Int	1991	A, D, G	(CPCIRR: Gordon 1996a, 1996b)
<i>Consolea corallicola</i>	Cactaceae	USA	LLPP	Aug, Int WHR	1996	A, D, G	(CPCIRR: Maschinski et al. 2004b; Stiling et al. 2000)
<i>Cordylanthus maritimus</i> ssp. <i>maritimus</i>	Scrophulariaceae	USA	Ann.	Int WHR	1995	A, G	(CPCIRR: Parsons and Zedler 1997)
<i>Ctenium aromaticum</i>	Poaceae	USA	HP	Int WHR	1993	D	Glitzenstein et al. 2001
<i>Cyanea superba</i> ssp. <i>superba</i>	Campanulaceae	USA	LLPP	Reint	1997	G	(CPCIRR: M. Kier; USFWS 2005)
<i>Damasonium alisma</i>	Alismataceae	UK	Ann.	Int WHR	NS	D	Plantlife data, Wheeler 2001
<i>Daviesia bursarioides</i>	Fabaceae	Australia	WP	Aug	1997	D	Cochrane et al. 2000
<i>Decalepis arayalpathra</i>	Periploaceae	India	HP	Reint	1998	D	Gangaprasad et al. 2005
<i>Delissea rhytidisperma</i>	Campanulaceae	USA	ULPP	Reint	NS	G	(CPCIRR: D. Bender)
<i>Deschampsia caespitosa</i>	Poaceae	USA	HP, ULPP	Trans	1973	G	(CPCIRR: May et al. 1982)
<i>Diuris fragrantissima</i>	Orchidaceae	Australia	HP	Int	2004	A	Smith et al. 2009
<i>Diuris magnifica</i>	Orchidaceae	Australia	HP	Int WHR	NS	D	Batty et al. 2006a
<i>Diuris micrantha</i>	Orchidaceae	Australia	HP	Int WHR	NS	D	Batty et al. 2006a

<i>Dodonaea subglaudivifera</i>	Sapindaceae	Australia	LLPP	Trans	1991	G	(CPCIRR: Jusaitis 1997; Jusaitis and Val 1997); Moritz and Bickerton 2010
<i>Echinacea laevigata</i>	Asteraceae	USA	HP, LLPP	Int WHR	2000	A, D, G	Alley and Affolter 2004; (CPCIRR: Alley et al. 2008)
<i>Echinacea tennesseensis</i>	Asteraceae	USA	SLPP	Reint	NS	G	(CPCIRR: A. Bishop)
<i>Erigeron parishii</i>	Asteraceae	USA	HP	Int WHR	1991	A, D, G	(CPCIRR: Mistretta and White 2001)
<i>Erigonum ovalifolium</i> var. <i>vineum</i>	Polygonaceae	USA	HP	Int WHR	1991	A, D, G	(CPCIRR: Mistretta and White 2001)
<i>Erodium macrophyllum</i>	Geraniaceae	USA	Ann.	Int	2001	A, G	(CPCIRR: Gillespie and Allen 2008)
<i>Erysimum menziesii</i>	Brassicaceae	USA	HP	Int	1985	A	Ferreira and Smith 1987
<i>Eurystylex coryledon</i>	Orchidaceae	Brazil	HP	Trans, Int WHR	2001	D	Jasper et al. 2005
<i>Fagus grandifolia</i> var. <i>mexicana</i>	Fagaceae	Mexico	WP, LLPP	Reint	2000	G	(CPCIRR: Alvarez-Aquino et al. 2004)
<i>Filago gallica</i>	Asteraceae	UK	Ann.	Reint/Int WHR	1994	A, D, G	(CPCIRR: Rich et al. 1999)
<i>Gladiolus imbricatus</i>	Iridaceae	Estonia	HP	Int	2003	A, G	(CPCIRR: Jogar and Moora 2008)
<i>Gomosa crispa</i>	Orchidaceae	Brazil	HP	Trans, Int WHR	2001	D	Jasper et al. 2005
<i>Grevillea calliantha</i>	Proteaceae	Australia	WP	Int WHR	1997	D	Cochrane et al. 2000
<i>Grevillea humifusa</i>	Proteaceae	Australia	WP	Int OHR	2003	A, G	(CPCIRR: L. Monks)
<i>Grevillea scapigera</i>	Proteaceae	Australia	WP	Int OHR	1996	D, G	Dixon and Krauss 2001; Dixon 2004; (CPCIRR: Dixon and Krauss 2008)
<i>Halragis eyreana</i>	Haloragaceae	Australia	HP	Trans	NS	G	(CPCIRR: M. Jusaitis)
<i>Hedyotis caerulea</i>	Rubiaceae	USA	HP	Int WHR, Trans	1994	D	Drayton and Primack 2000
<i>Helentium virginicum</i>	Asteraceae	USA	HP, ULPP	Int WHR	2003	A, D, G	(CPCIRR: Rimer and McCue 2005)
<i>Helianthemum apenninum</i>	Cistaceae	UK	P	NS	1955	D	BSBI Introductions Database
<i>Hibiscus waimeae</i> ssp. <i>hammerae</i>	Malvaceae	USA	WP, LLPP	Int	1997	A, G	(CPCIRR: D. Bender)
<i>Hieracium attenuatifolium</i>	Asteraceae	UK	P	Aug	1999	D	BSBI Introductions Database
<i>Holocarpha macradenia</i>	Asteraceae	USA	Ann.	Int	1999	A	Holl and Hayes 2006

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<i>Humboldtia smithiana</i>	Orchidaceae	Brazil	HP	Trans, Int WHR	2001	D	Jasper et al. 2005
<i>Hutera rupestris</i>	Brassicaceae	Spain	SLMP	NS	1976	D	Sainz-Ollero and Hernandez-Bermejo 1979
<i>Ipomopsis sancti-spiritus</i>	Polemoniaceae	USA	SLMP	Int OHR	1998	A, G	(CPCIRR: Sivinski and Tonne 2008)
<i>Ipsca malabarica</i>	Orchidaceae	India	HP	Int WHR, Reint	1995	A, D, G	CPCIRR: Gangaprasad et al. 1999; Martin 2003
<i>Iris lacustris</i>	Iridaceae	USA	HP	Int	1989	A	Simonich and Morgan 1990
<i>Isoetes louisianensis</i>	Isoetaceae	USA	HP	Aug, Int WHR	2008	G	(CPCIRR: A. Tiller, P. Faulkner)
<i>Isoetia medeoloides</i>	Orchidaceae	USA	HP	Trans	1986	A, G	(CPCIRR: Brumback and Fyler 1996)
<i>Ixiolena specis nova</i>	Asteraceae	Australia	HP	Int	1993	A	Morgan 1999
<i>Jacquemontia reclinata</i>	Convolvulaceae	USA	HP	Int WHR, Reint	2001	A, G, D	(CPCIRR: Maschinski et al. 2003; Thornton and Wright 2003; Wright 2003a, 2003b; Wright and Fidelibus 2004; Maschinski et al. 2004b; Maschinski and Wright 2006; Maschinski et al. 2006, 2007)
<i>Kobresia myosuroides</i>	Cyperaceae	USA	HP, ULPP	Trans	1973	G	(CPCIRR: May et al. 1982)
<i>Lambertia echinata</i> ssp. <i>echinata</i>	Proteaceae	Australia	WP	Aug	1997	D	Cochrane et al. 2000
<i>Lambertia fairallii</i>	Proteaceae	Australia	WP	Int OHR	2007	A, G	(CPCIRR: L. Monks)
<i>Lambertia orbifolia</i> ssp. <i>orbifolia</i>	Proteaceae	Australia	WP	Int WHR	1997	A, D, G	(CPCIRR: L. Monks); Cochrane et al. 2000
<i>Lantana canescens</i>	Verbenaceae	USA	WP	Int WHR, Reint	2005	A, G	(CPCIRR: Possley et al. 2009)
<i>Lasthenia conjugens</i>	Asteraceae	USA	Ann.	Reint	1999	A	Ramp et al. 2006
<i>Leionema equestre</i>	Rutaceae	Australia	LLPP	Trans	1992	G	(CPCIRR: Jusatis 1991, 1996, 1997)
<i>Lepanthes eltoroensis</i>	Orchidaceae	USA	HP	Trans	1999	A	Tremblay 2008
<i>Lepidium hyssopifolium</i>	Brassicaceae	Australia	HP	Int	1993	A	Morgan 1999

<i>Lepismium cruciforme</i>	Cactaceae	Brazil	P	Trans, Int WHR	2001	D	Jasper et al. 2005
<i>Lepismium houlettianum</i>	Cactaceae	Brazil	P	Trans, Int WHR	2001	D	Jasper et al. 2005
<i>Lepismium lumbricoides</i>	Cactaceae	Brazil	P	Trans, Int WHR	2001	D	Jasper et al. 2005
<i>Lepismium warmingianum</i>	Cactaceae	Brazil	P	Trans, Int WHR	2001	D	Jasper et al. 2005
<i>Lilaeopsis schaffneriana</i> ssp. <i>recurva</i>	Apiaceae (alt. Umbelliferae)	USA	HP	Reint	2003	A, G	(CPCIRR: Titus and Titus 2008)
<i>Lilium occidentale</i>	Liliaceae	USA	HP, LLPP	Int WHR	1996	A, G	CPCIRR: Guerrant 1996c, 2001; Guerrant and Friedler 2004; Yandell 1997
<i>Lindera melissifolia</i>	Lauraceae	USA	P	Int WHR	1990	D	Smith 2003
<i>Linnaea borealis</i>	Caprifoliaceae	UK	HP	Int WHR	1999	A, D	Kohn and Lusby 2004
<i>Linum carteri</i> var. <i>carteri</i>	Linaceae	USA	HP	Aug	2006	A, G	(CPCIRR: Maschinski et al. 2007)
<i>Liparis loeselii</i>	Orchidaceae	UK	HP	Int WHR, Trans	2005	D	Land, pers. comm.
<i>Lobelia cardinalis</i>	Campanulaceae	USA	HP	Int WHR	1994	D	Drayton and Primack 2000
<i>Lobelia urens</i>	Campanulaceae	UK	HP	NS	1968	D	BSBI Introductions Database
<i>Lupinus guadalupensis</i>	Fabaceae	USA	Ann.	Int OHR	1995	A, G	(CPCIRR: Helenurm 1998)
<i>Lupinus sulphureus</i> ssp. <i>kincaidii</i>	Fabaceae	USA	HP	Int	1997	A, G	(CPCIRR: Thorpe et al. 2008b)
<i>Lurontium natans</i>	Alismataceae	UK	P	NS	1983	D	BSBI Introductions Database
<i>Lysimachia asperulifolia</i>	Primulaceae	USA	HP	Trans	2004	A, G	(CPCIRR: M. Kunz)
<i>Maxillaria ferdinandiana</i>	Orchidaceae	Brazil	HP	Trans, Int WHR	2001	D	Jasper et al. 2005
<i>Maxillaria juergensii</i>	Orchidaceae	Brazil	HP	Trans, Int WHR	2001	D	Jasper et al. 2005
<i>Maxillaria picta</i>	Orchidaceae	Brazil	HP	Trans, Int WHR	2001	D	Jasper et al. 2005
<i>Melampyrum pratense</i>	Scrophulariaceae	UK	Ann.	Trans, Int WHR	1985	D	Waller 2005
<i>Melampyrum sylvaticum</i>	Scrophulariaceae	UK	Ann.	Int WHR	2005	D, G	(CPCIRR: Dalrymple et al. 2008)
<i>Myricaria laxifolia</i>	Myricaceae	China	WP	Trans, Int WHR	2002	D	Chen et al. 2005
<i>Nepeta rtanjiensis</i>	Lamiaceae	Serbia	HP	Int WHR	2004	A, D	Misic et al. 2005
<i>Okenia hypogaea</i>	Nyctaginaceae	USA	Ann.	Aug	2003	A, G	(CPCIRR: Maschinski et al. 2004b; Pipoly et al. 2006)
<i>Oncidium flexuosum</i>	Orchidaceae	Brazil	HP	Trans, Int WHR	2001	D	Jasper et al. 2005
<i>Oncidium macronix</i>	Orchidaceae	Brazil	HP	Trans, Int WHR	2001	D	Jasper et al. 2005
<i>Oncidium riograndense</i>	Orchidaceae	Brazil	HP	Trans, Int WHR	2001	D	Jasper et al. 2005

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<i>Oryza rufipogon</i>	Poaceae	China	HP	Reint	1993	D	Liu et al. 2004
<i>Osmorhiza claytonii</i>	Apiaceae	USA	HP	Int WHR, Trans	1994	D	Drayton and Primack 2000
<i>Pamassia caroliniana</i>	Saxifragaceae	USA	HP	Int OHR	1995	D	Glitzenstein et al. 2001
<i>Passiflora sexflora</i>	Passifloraceae	USA	HP	Reint	2006	A, G	(CPCIRR: Possley et al. 2007; Possley and Maschinski 2009)
<i>Pediocactus knowltonii</i>	Cactaceae	USA	WP	Reint	1991	A, G	(CPCIRR: Cully 1996; Sivinski 2008)
<i>Phebalium glandulosum</i>							
<i>ssp. glandulosum</i>	Rutaceae	Australia	LLPP	Trans	NS	G	(CPCIRR: Jusaitis 1996, 1997)
<i>Phorodendron rubrum</i>	Viscaceae	USA	WP	Aug	2001	A, G	(CPCIRR: J. Duquesnel)
<i>Phymatidium delicatulum</i>	Orchidaceae	Brazil	HP	Trans, Int WHR	2001	D	Jasper et al. 2005
<i>Pinus torreyana</i>	Pinaceae	USA	WP	Reint	1994	D	Ledig 1996
<i>Plantago sparsiflora</i>	Plantaginaceae	USA	HP	Int WHR	1998	D	Glitzenstein et al. 2001
<i>Platanthera leucophaea</i>	Orchidaceae	USA	HP	Int WHR	1981	A, G	(CPCIRR: T. Bittner); Packard 1991
<i>Pleurothallis aveniformis</i>	Orchidaceae	Brazil	HP	Trans, Int WHR	2001	D	Jasper et al. 2005
<i>Polystachya estrellensis</i>	Orchidaceae	Brazil	HP	Trans, Int WHR	2001	D	Jasper et al. 2005
<i>Posidonia australis</i>	Posidonaceae	Australia	HP	Aug	1999	D	Meehan and West 2002
<i>Potentilla robbinsiana</i>	Rosaceae	USA	HP	Reint	1986	A, G	(CPCIRR: Brumback et al. 2004)
<i>Primula vulgaris</i>	Primulaceae	Poland	HP	Reint	1993	D	Kucharczyk and Teske 1996
<i>Prostanthera eurybioides</i>	Lamiaceae	Australia	WP	Int WHR	1996	A, D	Jusaitis 2005
<i>Prostanthera eurybioides</i>	Labiatae	Australia	LLPP	Aug	1996	G	(CPCIRR: Jusaitis 2005)
<i>Pseudophoenix sargentii</i>	Areaceae	USA	WP	Aug, Int WHR	1991	A, D, G	(CPCIRR: Maschinski and Duquesnel 2007)
<i>Psoralea tenax</i>	Fabaceae	Australia	HP	Intro	1993	A	Morgan 1999
<i>Pterostylis arenicola</i>	Orchidaceae	Australia	HP	Trans	1995	G	(CPCIRR: M. Jusaitis)
<i>Ptilimnium nodosum</i>	Apiaceae	USA	HP	Int WHR	2006	A, G	CPCIRR: Box 2.1, this volume
<i>Ptilotus erubescens</i>	Amaranthaceae	Australia	HP	Int	1993	A	Morgan 1999
<i>Pultenaea trichophylla</i>	Leguminosae	Australia	LLPP	Aug	1991	G	(CPCIRR: Jusaitis 1997; Jusaitis and Val 1997)

<i>Purshia subintegra</i>	Rosaceae	USA	WP	Aug, Int WHR	1997	A, G	(CPCIRR: Baggs and Maschinski 2000; Maschinski et al. 2004a) (CPCIRR: Alvarez-Aquino et al. 2004)
<i>Quercus acutifolia</i>	Fagaceae	Mexico	WP, LLPP	Reint	2000	G	(CPCIRR: Pence, Murray et al. 2008)
<i>Ranunculus aestivalis</i>	Ranunculaceae	USA	HP	Aug, Int WHR	2007	G	(CPCIRR: Pippy et al. 2005) Jasper et al. 2005
<i>Remirea maritima</i>	Cyperaceae	USA	HP	Aug	2003	A, G	Jasper et al. 2005
<i>Rhipsalis cereuscula</i>	Cactaceae	Brazil	P	Trans, Int WHR	2001	D	Jasper et al. 2005
<i>Rhipsalis floccosa</i>	Cactaceae	Brazil	P	Trans, Int WHR	2001	D	Jasper et al. 2005
<i>Rhipsalis teres</i>	Cactaceae	Brazil	P	Trans, Int WHR	2001	D	(CPCIRR: Braham et al. 2006)
<i>Rhus michauxii</i>	Anacardiaceae	USA	WP	Reint, Aug	1998	G	Morgan 1999; (CPCIRR: Morgan 2000)
<i>Rutidosia leptorrhynchooides</i>	Asteraceae	Australia	HP	Aug, Int WHR	1987	A, G	(CPCIRR: Maschinski 2001)
<i>Salix arizonica</i>	Salicaceae	USA	WP	Aug	1995	A, G	Mardon 2003
<i>Salix lapponum</i>	Salicaceae	UK	WP	Aug	1991	D	Mardon 2003
<i>Salix myrsinifolia</i>	Salicaceae	UK	WP	Aug	1991	D	BSBI Introductions Database
<i>Salvia pratensis</i>	Lamiaceae	UK	HP	Aug	1999	D	Drayton and Primack 2000
<i>Sanguinaria canadensis</i>	Papaveraceae	USA	HP	Int WHR, Trans	1994	D	Sheridan and Penick 2000
<i>Sarracenia flava</i>	Sarraceniaceae	USA	HP	Int WHR	1998	D	Drayton and Primack 2000
<i>Saxifraga virginienis</i>	Saxifragaceae	USA	HP	Int WHR, Trans	1994	D	(CPCIRR: D. Bender)
<i>Schiedea spergulina</i>	Caryophyllaceae	USA	HP	Aug	2007	A, G	Obee and Cartica 1997
var. <i>leiopoda</i>	Scrophulariaceae	USA	HP	Aug	1995	A	Leonard 2006a, 2006b
<i>Schwalbea americana</i>	Caryophyllaceae	UK	HP	Reint	1995	D	BSBI Introductions Database
<i>Scleranthus perennis</i>	Asteraceae	UK	HP	Int	1996	D	Morgan 1999
ssp. <i>prostratus</i>	Asteraceae	Australia	HP	Int	1993	A	(CPCIRR: May et al. 1982)
<i>Senecio paludosus</i>	Rosaceae	USA	HP, ULPP	Trans	1973	G	(CPCIRR: Kephart 2004; Lofflin and Kephart 2005)
<i>Senecio macrocarpus</i>	Caryophyllaceae	USA	HP, SLPP	Aug, Int WHR	1998	A, D, G	(CPCIRR: H. Alley)
<i>Sibbaldia procumbens</i>	Caryophyllaceae	USA	SLMP	NS	2004	G	Glitzenstein et al. 2001
<i>Silene douglasii</i> var. <i>oraria</i>	Poaceae	USA	HP	Int WHR	1997	D	Jasper et al. 2005
<i>Silene regia</i>	Poaceae	USA	HP	Trans, Int WHR	2001	D	
<i>Sorghastrum nutans</i>	Orchidaceae	Brazil	HP				
<i>Specklinia malmeana</i>							

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<i>Specklinia pabstii</i>	Orchidaceae	Brazil	HP	Trans, Int WHR	2001	D	Jasper et al. 2005
<i>Stephanomeria malheurensis</i>	Asteraceae	USA	Ann.	Reint, Int OHR	1987	A, G	(CPCIRR: Brauner 1988; Parenti and Guerrant 1990; Guerrant 1996b; Guerrant and Pavlik 1998; Currin et al. 2007; Currin and Meinke 2008)
<i>Symonanthus bancroftii</i>	Solanaceae	Australia	HP	Reint	2002	G	(CPCIRR: Bunn and Dixon 2008)
<i>Symplocos coccinea</i>	Symplocaceae	Mexico	LLPP	Reint	2000	G	(CPCIRR: Alvarez-Aquino et al. 2004)
<i>Syzygium travancoricum</i>	Myrtaceae	India	WP	Aug	1999	D	Anand et al. 2004
<i>Taraxacum palustre</i>	Asteraceae	UK	HP	Reint	1998	D	BSBI Introductions Database
<i>Tephrosia angustissima</i> var. <i>corallicola</i>	Fabaceae	USA	HP	Int WHR	2003	A, G	(CPCIRR: Wendelberger and Ma-schinski 2006)
<i>Tetranneuris herbacea</i>	Asteraceae	USA	HP	Int	1988	A	McClain and Ebinger 2008
<i>Teucrium scordium</i>	Lamiaceae	UK	HP	Int	1998	A	Beecroft et al. 2007
<i>Thlaspi perfoliatum</i>	Brassicaceae	UK	Ann.	NS	NS	D	Rich et al. 1998, Plantlife data
<i>Tillandsia geminiflora</i>	Bromeliaceae	Brazil	HP	Trans, Int WHR	2001	D	Jasper et al. 2005
<i>Tillandsia stricta</i>	Bromeliaceae	Brazil	HP	Trans, Int WHR	2001	D	Jasper et al. 2005
<i>Tillandsia tenuifolia</i>	Bromeliaceae	Brazil	HP	Trans, Int WHR	2001	D	Jasper et al. 2005
<i>Tillandsia usneoides</i>	Bromeliaceae	Brazil	HP	Trans, Int WHR	2001	D	Jasper et al. 2005
<i>Trichocentrum pumilum</i>	Orchidaceae	Brazil	HP	Trans, Int WHR	2001	D	Jasper et al. 2005
<i>Trifolium stoloniferum</i>	Fabaceae	USA	HP	Trans, Int	1990	A, G	Smith 1998; (CPCIRR: D. White, D. Osbourne)
<i>Trimia glauca</i>	Apiaceae	UK	HP	NS	1955	D	BSBI Introductions Database
<i>Veronica spicata</i>	Plantaginaceae	UK	HP	NS	1955	D	BSBI Introductions Database
<i>Verticordia albida</i>	Myrtaceae	Australia	WP	Int WHR	2004	A, G	(CPCIRR: L. Monks)
<i>Vitis vinifera</i>	Vitaceae	France	WP	NS	1992	D	Arnold et al. 2005
<i>Vriesea friburgensis</i>	Bromeliaceae	Brazil	HP	Trans, Int WHR	2001	D	Jasper et al. 2005
<i>Vriesea platyneura</i>	Bromeliaceae	Brazil	HP	Trans, Int WHR	2001	D	Jasper et al. 2005







**Acclimatization:** The habituation of a plant's physiological response to environmental conditions (Begon et al. 1990).

**Adaptation:** Changes in the morphology or physiology of a plant via natural selection.

**Adaptive management:** A systematic process of continually improving management policies and practices by learning from the outcomes of existing programs (IUCN 1998a).

**Assisted colonization:** See *Managed relocation*.

**Assisted migration:** See *Managed relocation*.

**Augmentation:** The addition of individuals to an existing population, with the aim of increasing population size or diversity and thereby improving viability. Also called enhancement, reinforcement, or restocking (Falk et al. 1996).

**Best practice:** A superior or innovative method that contributes to the improved performance of an organization and is usually recognized as best by peer organizations. It implies accumulating and applying knowledge about what works and what does not work in different situations and contexts, including learning from experience, in a continuing process of learning, feedback, reflection, and analysis on what works, how, and why (IUCN 1998a).

**Bioclimatic envelope:** Typically derived by examining statistical correlations between existing species distributions and environmental variables to define a species' tolerance. Envelopes of tolerance are then drawn around existing ranges. With temperature, rainfall, and salinity forecasts, new range boundaries can be predicted.

**CPC:** Center for Plant Conservation, an organization dedicated to the conservation and restoration of imperiled native plants of the United States.

- Dioecious:** Having male and female reproductive organs on separate plants.
- Endemic:** A species native to and restricted to a particular geographic region. Highly endemic species are especially vulnerable to extinction if their natural habitat is eliminated or significantly disturbed (IUCN 1998a).
- Enhancement:** See *Augmentation*.
- Evolution:** Changes in the frequency of genes in a population over time; descent with modification.
- Ex situ:** The conservation of components of biological diversity outside their natural habitats (IUCN 1998a).
- Fitness:** The relative contribution an individual makes to the gene pool of the next generation (Begon et al. 1990).
- Fundamental niche:** The potential range of all biotic and abiotic conditions under which an organism can have a positive population growth rate. The Hutchinsonian fundamental niche can be conceptualized as the  $n$ -dimensional hypervolume.
- Geitonogamous:** Reproducing through self-pollination; one flower is pollinated by pollen from another flower on the same plant.
- Gene flow:** The spread of genes across and between populations as a result of cross fertilization or seed introductions (Begon et al. 1990).
- Genetic drift:** Random changes in gene frequency within a population resulting from sampling effects rather than natural selection (Begon et al. 1990).
- Hermaphrodite:** A plant that has perfect flowers and can self-pollinate.
- Historic range:** The geographic area where a species was known or believed to occur within historic time (USFWS 1999).
- Inbreeding depression:** A loss of vigor among offspring occurring when closely related individuals are crossed, resulting from the expression of deleterious genes in the homozygous state and from a low level of heterozygosity (Begon et al. 1990).
- Introduction:** The intentional or accidental dispersal by human agency of a living organism outside its historically known native range (IUCN 1998a).
- Invasive species:** Introduced species that increases in abundance at the expense of native species (Primack 2006).
- Iteroparous:** Capable of reproducing more than once (Silvertown 1982).
- IUCN:** International Union for Conservation of Nature, the world's oldest and largest global environmental network, focused on sustainable development and the environment.
- Lambda ( $\lambda$ ):** Annual population growth rate or  $\lambda_t = N_{t+1}/N_t$
- Managed relocation:** The deliberate introduction of organisms outside their native ranges to counteract the negative effects of climate change. Goals of man-

aged relocation include reducing extinction risk, increasing evolutionary potential, and enhancing ecosystem services (Hellmann et al. 2008; Managed Relocation Working Group 2008).

**Metapopulation:** A system of connected, spatially distinct subpopulations (IUCN 1998a).

**Mitigation:** An action that is intended to offset environmental damage (SER 2002).

**Monoecious:** Having female and male reproductive parts on the same plant.

***n*-dimensional hypervolume:** All aspects of the environment, physical and biological, are included in the niche (e.g., temperature tolerance, water requirements, competition, predation). Hutchinson (1957) mathematically described the hypervolume in *n*-dimensional space along *n* axes corresponding to environmental variables that permit a species' population growth rate to be positive indefinitely.

**Native plant:** A species that occurs naturally in an area.

**Natural range:** The geographic area within which a species can be found. Sometimes a distinction is made between a species' natural range and the places to which it has been introduced by human agency (deliberately or accidentally), as well as where it has been reintroduced after extirpation.

**Niche:** See *Fundamental niche* and *Realized niche*.

**Outbreeding depression:** A reduction in vigor or fertility (fitness) resulting from hybridization between genetically distinct individuals or populations of the same species. The loss in vigor is thought to be caused by breaking up co-adapted gene complexes.

**Outplanting:** Movement of plants from an ex situ location to an in situ location (Falk et al. 1996).

**Phytosanitary:** Any measure applied (a) to protect human, animal, or plant life or health (within a Member's Territory) from the entry establishment or spread of pests, diseases, or disease-carrying organisms; or (b) to prevent or limit other damage (within the Member's Territory) from the entry, establishment, or spread of pests (IUCN 1998a).

**Population:** A group of individuals of the same species that have the ability to genetically interact and inhabit a defined geographic area.

**Population growth rate:** Change in population size from one time to another. A positive population growth rate indicates an increasing population, whereas a negative population growth rate indicates a declining population. See *Lambda*.

**Practitioner:** A person involved with all aspects of plant reintroduction, including planning stages and actual placement of plants in the ground.

- Raunkiaer plant life forms:** A system for categorizing plants using life form categories, particularly related to locations of perennating buds, devised by Christen C. Raunkiaer (1934).
- Realized niche:** The subset of a fundamental niche remaining after competitive exclusion (Hutchinson 1957). The niche is separate from but can be mapped onto the physical space where an organism lives.
- Rehabilitation:** Reestablishment of part of the productivity, structure, function, and processes of the original ecosystem (IUCN 1998a).
- Reinforcement:** See *Augmentation*.
- Reintroduction:** The release of individuals into a formerly occupied area after the native population has been lost or become extinct. Also known as reestablishment (IUCN 1998a).
- Relative risk ratio:** In statistics and mathematical epidemiology, relative risk (RR) is the risk of an event (or of developing a disease) relative to exposure. Relative risk is a ratio of the probability of the event occurring in the exposed group versus a group that was not exposed.
- Resilience:** The ability of an ecosystem to regain structural and functional attributes that have suffered harm from stress or disturbance (SER 2002).
- Resistance:** An ecosystem's ability to maintain its structural and functional attributes in the face of stress and disturbances (SER 2002).
- Restocking:** See *Augmentation*.
- Restoration:** The process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed (SER 2002).
- SER:** Society for Ecological Restoration, an organization providing a source for expertise on restoration science, practice, and policy.
- Stability:** The ability of an ecosystem to maintain its given trajectory despite stress; it denotes dynamic equilibrium rather than stasis. Stability is achieved in part on the basis of an ecosystem's capacity for resistance and resilience (SER 2002).
- Translocation:** The deliberate and mediated movement of wild individuals or populations from one part of their range to another (IUCN 1998a).
- Transplanting:** See *Outplanting*.
- USFWS:** The US Fish and Wildlife Service, a federal agency charged with working with others to conserve, protect, and improve fish, wildlife, and plants and their habitats for the continuing benefit of the American people.
- Vital rate:** The rate of change in factors such as fecundity, growth, and survivorship in a population. Even when population numbers are stable, there may be changes in the vital rates.

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