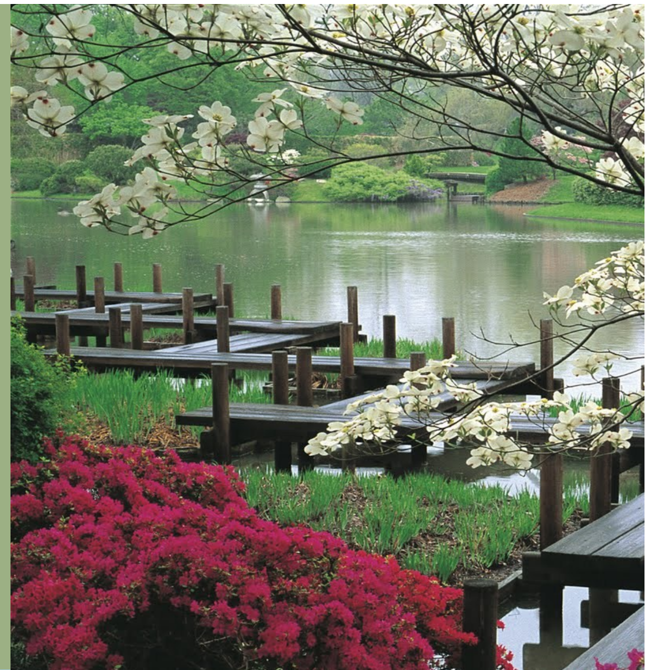
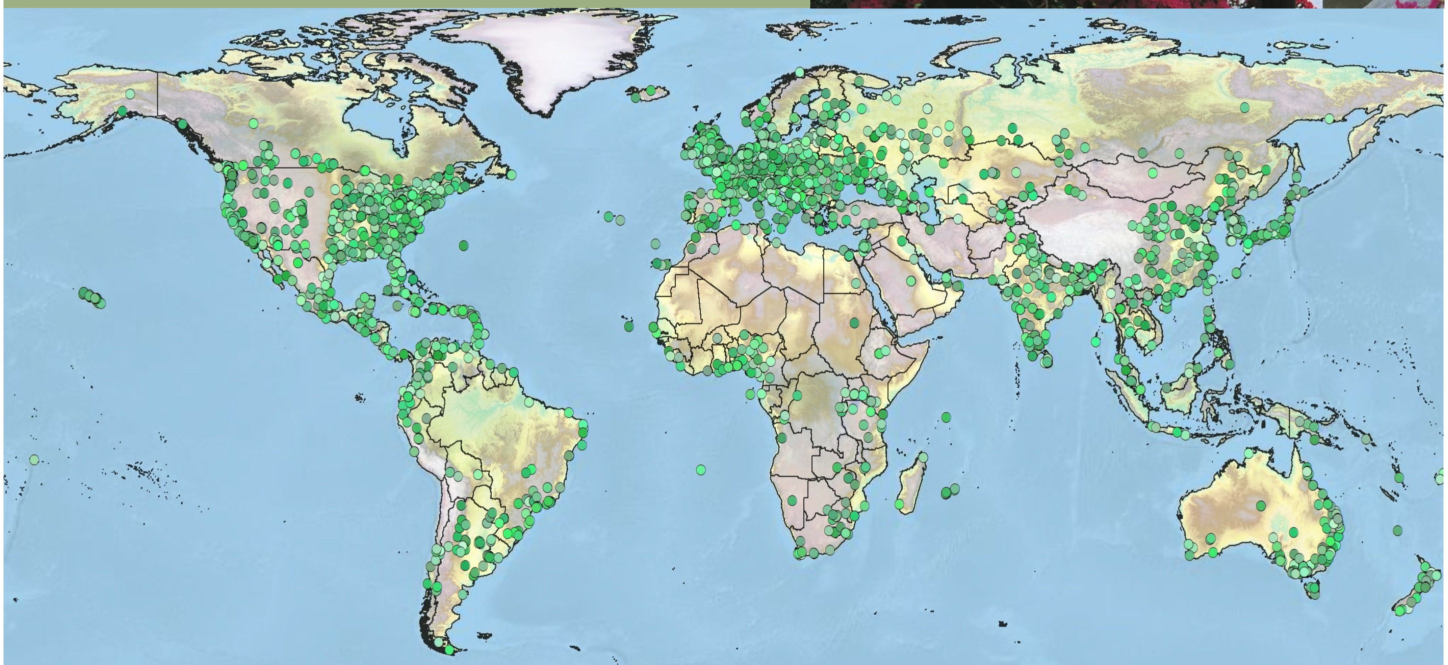
Chaperoned Managed Relocation





A Plan for Botanical Gardens to Facilitate Movement of Plants in Response to Climate Change

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MISSOURI BOTANICAL GARDEN

Chaperoned Managed Relocation: A Plan for Botanical Gardens to Facilitate Movement of Plants in Response to Climate Change

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Center for Conservation and Sustainable Development
Missouri Botanical Garden
POB 299
St. Louis, MO 63199 USA

Adam B. Smith
adam.smith@mobot.org

Matthew A. Albrecht
matthew.albrecht@mobot.org

Quinn G. Long
Quinn.long@mobot.org

Christine E. Edwards
Christy.edwards@mobot.org

This white paper is available on the Internet at www.~~~~~~~~~/~~~~~~~~~~.pdf.

Front cover:
Top right: The Japanese Garden at the Missouri Botanical Garden.
Middle: Map of the world's approx. 3150 botanical gardens. BGCI. 2013. GardenSearch online database. Botanic Gardens Conservation International. Richmond, U.K. Available at www.bgci.org/garden_search.php.
Bottom left: Inside the Climatron at the Missouri Botanical Garden (photo: Danielle Kiesler).

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MISSOURI BOTANICAL GARDEN

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Plants & Climate Change

In the coming century climate change is expected to occur at rates unprecedented within human experience. This poses special challenges to the diversity of life on Earth. Generally, species have three possible responses: move, adapt, or go extinct. In past periods of climate change most species responded by moving their ranges to match the location of their preferred climate. Adaptation also plays a role in responses to climate change, but may not be possible for some species that already have small populations and are threatened.

Plants shift their ranges generation-by-generation by dispersing seeds. Some of these land in newly favorable habitat, grow, and establish populations of their own which make more seeds. This has enabled plants to track shifting climates caused by Earth's natural rhythms, like the glacial cycles.

In contrast to the past, current rates of climate change are too rapid for most plant species to keep apace. Studies of contemporary migration by plants suggest that their rates of movement are on average about half of what is necessary to keep pace with the current pace of climate change. Climate change will likely only accelerate in the coming century, making the problem worse. Moreover, roads, farmland, cities, and other human environments have fragmented the natural landscape, making movement even harder. As a result, many plants will be left behind.

Kudzu, *Pueraria lobata*, a highly problematic invasive plant in the southeastern US. Photo: Alabama Forestry Commission.

A Problematic Solution

One solution to this dilemma is to manually transfer species from their current habitats to locations that become newly favorable as climate changes. This idea goes by many names, including assisted migration and conservation relocation, with different people preferring different terms. Here we use "managed relocation" to refer to intentional movement of plants from their current habitats to new habitats in locations where climate is becoming more favorable to them.

While promising, managed relocation is problematic because there are many risks involved with moving species outside their native ranges. Many examples demonstrate that even well-intentioned translocations have led to irreversible invasions. For example, prickly-pear *Opuntia* cacti introduced to Australia have caused immense economic damage. Likewise, translocated species can carry pests and diseases against which the flora of recipient regions have no defense. For instance, the chestnut blight *Cryphonectria parasitica* has nearly caused the global extinction of the American chestnut tree, which was once the most abundant tree in the Eastern US. Translocated species can also hybridize with other closely related species, leading to genetic "pollution," potentially reducing the viability of both species.

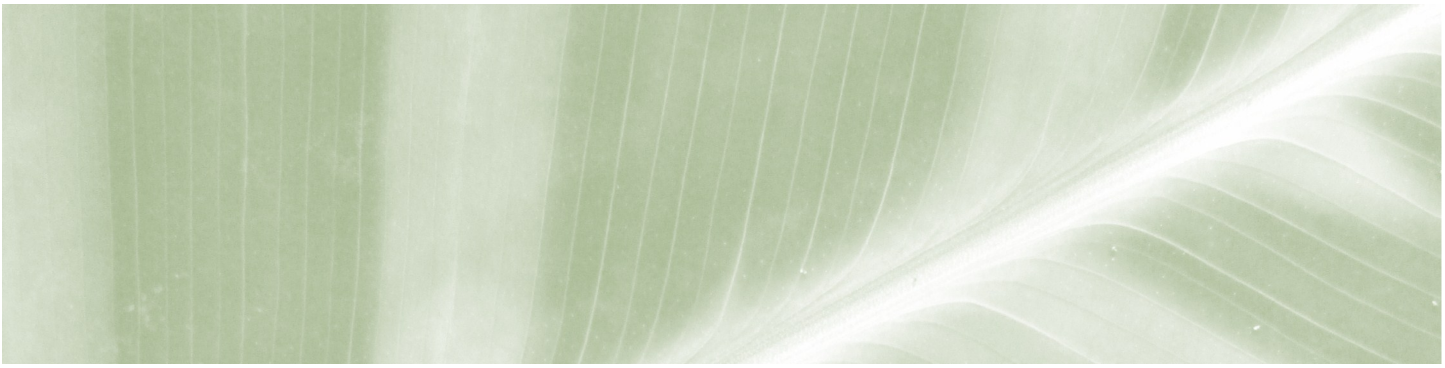
“Chaperoned” Managed Relocation: A Better Solution

Chaperoned managed relocation: The transfer of species outside their historic distributions into *ex situ* facilities for the purposes of ensuring their survival as climate changes.

In contrast to managed relocation where species would be transferred from one natural area to another, we propose a program of “chaperoned” managed relocation in which species would be transferred from natural areas to botanical gardens. As climate continues to change, populations would be transferred serially from garden to garden. Chaperoned managed relocation should only occur within each species’ “potential dispersal envelope,” meaning the area into which the species could be expected to naturally migrate, were climate change slower and habitats less fragmented by roads, fields, and cities.

Chaperoned managed relocation should be implemented within a rigorous framework for risk assessment and management to address the very real threats posed by transferring species beyond their natural boundaries. It should also be implemented within the context of integrated conservation planning (Box 2).

Chaperoned managed relocation offers many advantages that “unchaperoned” managed relocation does not (Box 3). The remainder of this document outlines the implementation of a set of best practices for chaperoning species in response to climate change.



Box 1: Conservation Biology and Botanical Gardens: Bridging Two Cultures

At the heart of both horticulture and conservation biology is an appreciation for the diversity of life on Earth. However, each field approaches plant life differently.

A primary tenet of conservation biology is preservation of species within their native habitats (*in situ* conservation). Some exceptions occur, such as when populations are raised in captivity for later release to augment declining populations in the wild. Regardless, species are generally not released into habitats outside their native ranges. Instead, they are kept in *ex situ* facilities like zoos, aquaria, or conservation gardens.

In contrast, horticulturists have transferred species, varieties, and cultivars across the world for centuries. Many of these plants have been the subjects of many generations of selective breeding so that they have new characteristics not found in nature and only nominally resemble their wild relatives . This diversity makes them very valuable in their own right for medicinal, ornamental, cultural, and commercial reasons.

The two cultures collide in these respects. Conservation biologists are loathe to transfer species outside their native ranges (or sometimes even within them), while horticulturalists have practiced translocation for centuries. Horticulturalists often use selective breeding to change characteristics of plants, thereby changing their genetic makeup. Meanwhile conservation biologists would prefer that “natural” processes shape the genetic makeup of species, and otherwise desire to maintain the highest possible levels of genetic diversity in a species so that natural selection has variation upon which to act.

We hope this plan helps bridge these two communities. To be credible within the conservation biology community, any system of managed relocation must address the risks of invasiveness, spread of pests and disease, and hybridization posed by moving species outside their native ranges. This generally entails a new way of operating for many botanical gardens, which in the eyes of conservation biology, have been relatively lax in screening for and managing these risks. Conservation within botanical gardens should also be done in coordination with other conservation agencies and organizations. At the same time, botanical gardens need to pursue their mission of displaying and raising plants for their cultural, aesthetic, medicinal, and economic value, and this often entails selective breeding and translocation.

Implementation

A Species-by-Species Basis

Although plants tend to separate into different "communities" (e.g., temperate forests vs. salt-marshes vs. alpine tundra), in the past species have responded individualistically to climate change. Thus, chaperoned managed relocation must be practiced on a species-by-species basis (Box 4). Collecting representatives of entire ecosystems that are threatened may be warranted, but each species should be assessed for its vulnerability and the risks it might pose.

Knowing Each Species' Natural History

Effective care of a species requires knowledge of its physiological requirements and ecological relationships within its natural community. It will be much easier to translocate species if we know the cues that trigger seed germination, agents of pollination and seed dispersal (e.g., wind or animals), soil preferences, phenology (timing of germination, flowering, and dormancy), mating system, dependence on disturbance like flooding or fire, and other aspects of a species' natural history. Moving species from natural environments to botanical gardens necessarily involves disrupting many of these relationships. However, understanding each species' natural history will enable trouble-shooting once they are in a garden and allow living collection managers to provide the environmental conditions needed for survival. If the species does go extinct in the wild, this information will be invaluable for restoration efforts.

Screening for Invasiveness, Pests and Disease, and Hybridization with Other Threatened Species

To date, there are no highly reliable methods for successfully predicting whether a species will become invasive or otherwise problematic. The best predictor of invasiveness is if the species is already invasive elsewhere, though by itself this is still a poor predictor. In instances where a species has not been translocated before, there is little guidance for assessing the risks it imposes. Thus, screening should be precautionary, assuming risk exists until it has been shown otherwise (Box 5).

Likewise, even non-invasive species can harbor pests and diseases or hybridize with other threatened plant species. These are also serious concerns which must be accounted for in a risk

Box 2: Integrated Conservation Planning

Chaperoned managed relocation is not a panacea. Rather, it is only part of an integrated strategy for conserving plant biodiversity. In many cases, chaperoned managed relocation may not be the most cost-effective or practical strategy to conserve species. Many other activities need to be pursued in conjunction with chaperoned managed relocation, including:

designation and management of protected areas

- re-connection of habitats fragmented by agriculture, roads, cities, etc.
- restoration of habitat and natural disturbance regimes like fire and flooding
- management of invasive species
- regulation of harvesting plants
- ecologically sound agricultural and rangeland management
- reintroduction of extirpated populations and augmentation of existing populations
- seed and tissue banking

Any strategy to conserve a region's biota should consider chaperoned managed relocation as just one of many options for protecting plants and their habitats. We do not consider chaperoned managed an equal alternative to conservation of wild populations of species in their native ranges (*in situ* conservation). Rather, like seed banks, it provides insurance against extinction in the wild. In contrast to seed banks, it provides another kind of insurance by allowing species the potential to adapt.

assessment and management framework. Often diseases spread to and hybridization occurs with closely related species. Hence one method for reducing risk is to remove closely related species in gardens to which species would be transferred.

Genetic Profiling of Source Populations and Ongoing Monitoring of Translocated Populations

Ideally translocated populations would represent the full genetic diversity of natural populations. However, if a small number of seeds, cuttings, or whole plants are used to start captive populations, they may not represent the full genetic diversity of their source populations. Even if they do, many gardens will only be able to host relatively small populations. Small populations are susceptible to losing genetic diversity from genetic drift, inbreeding, and natural selection.

Knowing the genetic diversity of a species' source population and monitoring the genetic diversity of translocated populations over time enables identification of potential problems related to erosion of genetic diversity. For example, in the US, Project Baseline (http://www.baselineseed bank.org/) is establishing a long-term seed bank against which to measure genetic change in common species. A similar approach could benefit rare species.

Wild-collected Accessions

To maintain the conservation value of captive populations, accessions should be "wild collected," meaning their original source should come directly from natural populations. Detailed guidelines exist for collection of wild-collected accessions. For example the Center for Plant Conservation and The European Native Seed Conservation Network have published recommendations for assessing specimen quality and collection of representative specimens in a manner that does not harm source populations. All national and international laws and agreements should be adhered to when collecting specimens from the wild.

Once in a garden, populations should be maintained in a manner respecting their wild-collection status. Careful labeling (perhaps even of individuals) is absolutely necessary. Crossing between wild-collected populations might be allowed or disallowed, depending on the conservation goals for the species. In some cases, wild-collected plants should not be allowed to cross with non-wild collected plants or wild-collected plants from populations that do not interbreed in the wild (i.e., progeny of unknown origin should be removed from the accession). This can be achieved by removing individuals of the same species from non-wild collected accessions in the same garden and removing progeny of wild collected accessions of unknown parentage from the accession. In most cases cross-breeding will be easiest to prevent if each garden harbors individuals sourced from different populations versus one garden having several populations of the same species. Alternatively, individual gardens could host different populations of the same species farther from

Box 3: "Chaperoned" managed relocation versus "unchaperoned" managed relocation

Most of the controversy over managed relocation has assumed that species will be "unchaperoned," meaning they would be transferred from one natural place to another. While chaperoned managed relocation will not alleviate all risks, it has several notable advantages over unchaperoned translocation.

Risk	Solution offered by chaperoned managed relocation
Transferred species may become invasive	On-going monitoring for invasiveness; ease of eradication if plants become problematic
Transferred species may spread novel pests or disease	On-going monitoring for pests and disease; well-developed horticultural techniques for disease prevention; relative ease of eradication compared to populations in natural settings
Transferred species may hybridize with other threatened species	Wild-collected accession management disallows progeny of crosses with non-wild collected accessions or wild-collected accessions of other populations; gardens can remove species with which target species might cross
Logistical requirements	Transplanting and care of populations in gardens much easier and regular than in natural settings
Identifying appropriate locations for transplantation	Much easier to transfer plants from garden to garden than locating natural areas with requisite permitting and adequate protection
Laws may restrict translocations across national/sub-national borders	Translocations much more acceptable within an institutional context

Box 4: What species are good candidates for chaperoned managed relocation?

Some species will be inherently insensitive to climate change, especially if they live in habitats that will be relatively unaffected by climate (e.g., freshwater springs). Other species will be able to migrate adequately to stay within their preferred climate. In general, good candidates for chaperoned managed relocation are species that are:

- sensitive to climate change
- unable to migrate
- rare and either declining or not reproducing in the wild
- are not responding to other conservation measures (Box 2)
- and are difficult to store in seed banks because their seeds are on the recalcitrant end of the orthodox-recalcitrant spectrum

Identification of candidate species is a difficult but necessary task before investing resources in a program of chaperoned managed relocation.

There are several frameworks for assessing species' vulnerability to climate change. In the US, one of the most commonly used frameworks is NatureServe's Climate Change Vulnerability Index (http://www.natureserve.org/prodServices/climatechange/ccvi.jsp), which estimates vulnerability using species' dispersal ability, exposure to past climatic variability, dependence on other species (like pollinators), restriction of specific habitats, and genetic variation (if known).

Other vulnerability assessments use species distribution modeling to estimate exposure to climate change. These can be incorporated with methods like those used by NatureServe to estimate overall vulnerability to climate change.

Risks to the system from which plants are taken must also be assessed. In some cases threatened animals may depend on target plant species. Likewise, there may be cultural objections to moving plants from/into a location.

These methods do not necessarily incorporate current threats to species (e.g., by invasive species). In some instances climate change could actually alleviate threats to some species (e.g., by disfavoring an invasive herbivore), but in many cases they may also worsen current threats.

one another than pollen would generally be expected to travel (i.e., off-site). In other cases, crossing can be used to enhance the viability of genetically depleted populations or when only very few individuals of a species remain.

Species might also hybridize with one another. To safeguard against this, gardens should consider removing from their living accessions species that are closely related to target species.

For the purposes of chaperoned managed relocation, species should be cared for in a manner that reflects the environment from which they came, while at the same time respecting the needs of the host garden. Decisions on allowable interventions should be made while ensuring the persistence of populations. For example, botanical gardens often irrigate their plants, but in the

Box 5: Screening for Risks of Invasiveness, Disease, and Threat of Hybridization

Although assisting species' migration in response to climate change is well-intentioned, it could easily cause more harm than it alleviates. Invasion, spread of pests and disease, and hybridization by translocated species are difficult and often impossible to manage once established. Thus, a preventative approach that carefully screens species for each of these risks is absolutely necessary.

Many introduced species do not demonstrate clear signs of invasiveness until many decades after they are transferred to a novel location. Thus, target species and their recipient ecosystems must continue to be monitored after transfer. Every plan should include contingencies and funding for eradication or sterilization if undesired effects occur.

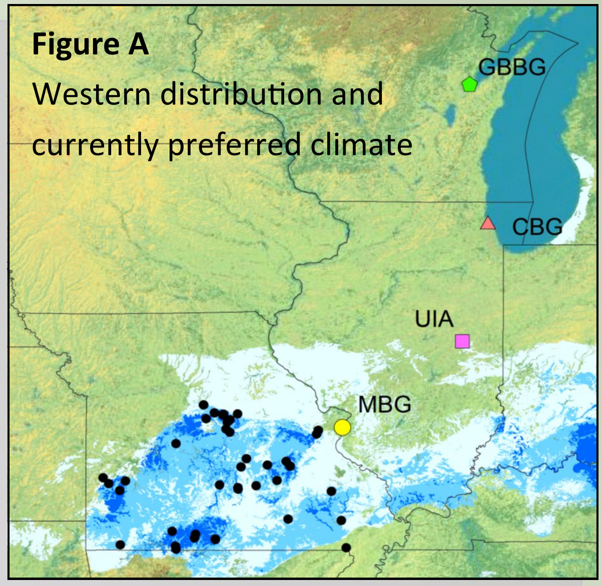
Worldwide, only only 2.5% of the world's 3163 botanical gardens report having an invasive-species policy and monitor for invasiveness, far too few for a credible program for chaperoned managed relocation. Both "donor" and "recipient" gardens should have a rigorous invasive species policy before engaging in chaperoned managed relocation or the transfer of propagules outside of their native range for any other purposes.

There are many frameworks for screening species for problems they might pose. Australia and New Zealand's national weed risk assessment programs are likely the most extensive and well tested.

Species can be problematic even when transferred only within their native countries. Thus, pre- and post-screening is necessary for all species transferred under a program of chaperoned managed relocation.

Within the conservation community managed relocation ("chaperoned" or not) is highly contentious because of the risks that transferring species could pose. Thus any program of chaperoned managed relocation must practice rigorous pre- and post-screening to be credible within the conservation community.

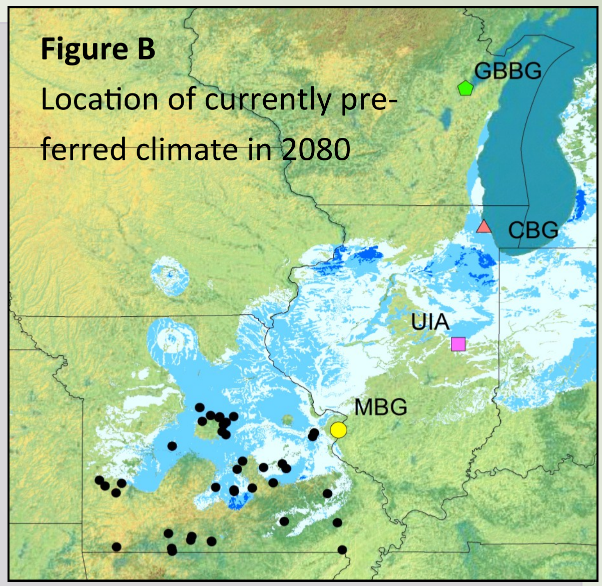
American chestnut, *Castanea dentata*, has become nearly extinct because of chestnut blight, *Cryphonectria parasitica*, a disease likely introduced by imported nursery stock. Photo: US Forest Service.

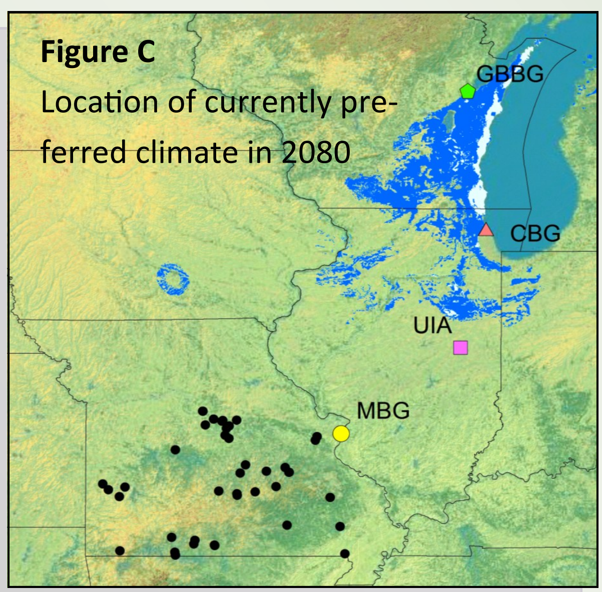


Box 6: An Example

Running buffalo clover, *Trifolium stoloniferum*, is an endangered plant protected under the US Endangered Species Act. Here we focus on populations at the western part of its range (see Figure A). Under a greenhouse gas emissions scenario similar to current emissions, the climate that currently extends over most of its range will move northwest (Figure B). If running buffalo clover depends on this environment for reproduction and survival, then populations in the current locations may decline more than they already have. The species generally lacks adaptations for long-distance dispersal, and the woodland habitat characteristic of its range is sparse in areas to which its preferred climatic envelope is expected to move.

Within the extent of the clover's future climatic envelope lie several botanical gardens, including the Missouri Botanical Garden (MBG), the University of Illinois Arboretum (UIA), the Chicago Botanic Garden (CBG), and the Green Bay Botanic Garden (GBBG). As climate changes each garden falls within the preferred climatic envelope of the species. Thus, a transfer of populations from one garden to the next would follow this "potential dispersal envelope" of the species.





wild plants rely on precipitation. However, to ensure endurance of a population irrigation may sometimes be required.

Development of a database that tracks species across the many decades they may be grown in botanical gardens is necessary. This database should be shared across gardens within a region to ensure each has access to information relevant to the populations it is hosting. The PlantSearch database of Botanical Gardens Conservation International could provide a foundation for such a resource.

Population Size

Almost without exception, the bigger a population is, the less likely it will go extinct and suffer from genetic drift, inbreeding, and bottlenecks. It will also be more likely to be representative of the original source population. Many gardens will be unable to host large populations of many species. This is likely one the greatest limitations of chaperoned managed relocation. However, even small populations will provide protection for species that may otherwise go extinct in the wild. This is a critical topic too voluminous to detail here. We recommend extended works on the subject such as *Ex Situ Plant Conservation* (especially Appendix 3) published by the Center for Plant Conservation.

Seed Banking

Chaperoned managed relocation should be viewed as a complementary activity to seed and pollen banking. Seed banks could provide propagules for trials to see if the climate in a garden is favorable to the species. Likewise, the longevity of species in seed banks can be enhanced by growing seeds out every few years to harvest more seed.

Chaperoned managed relocation should also be viewed as a secondary activity to banking seeds and pollen. Even if a species is not translocated, we encourage storage of seeds or viable material in a seed bank as an "insurance" policy in case it does become extinct in the wild. Likewise, if genetic erosion of translocated population occurs, individuals grown from the seed bank could help restore lost genetic diversity.

Managed Relocation Only within Each Species' "Potential Dispersal Envelope"

Species should only be transferred from garden to garden within the geographic region to which they could have migrated if climate change were slower and/or migration faster and human-made obstacles not in the way. Species should not be transferred across continents, between islands, and especially from mainland areas to islands (because the latter are especially susceptible to invasive species).

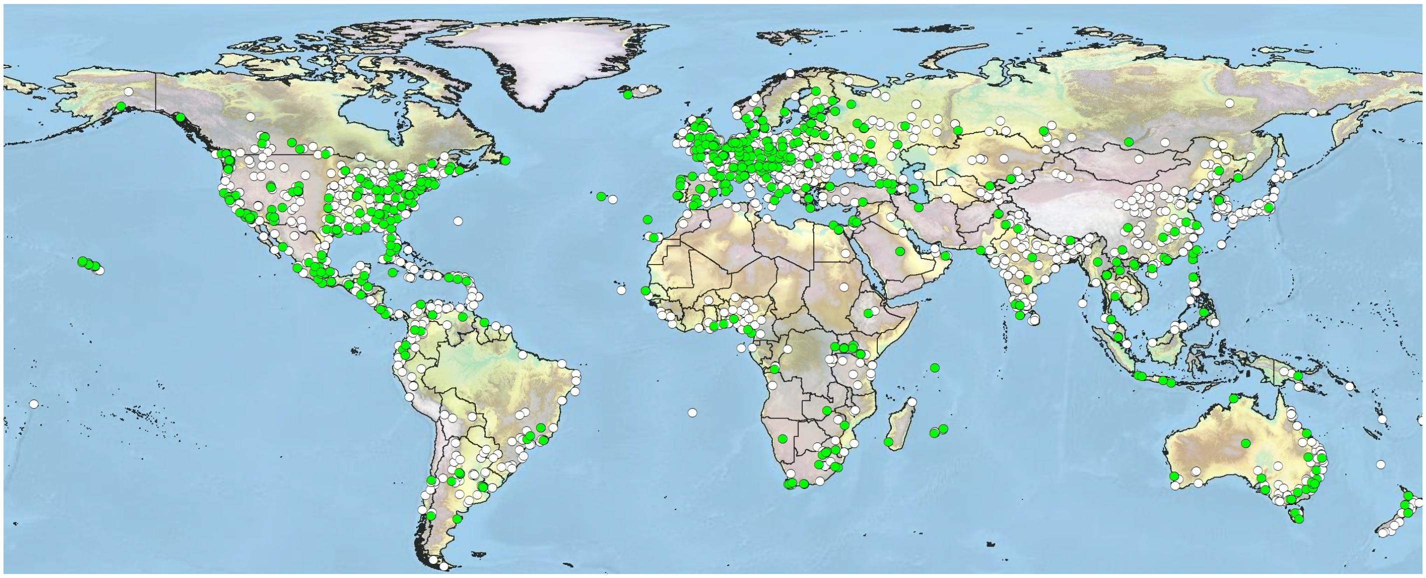


Figure 1 The distribution of botanical gardens across the world. Green dots represent gardens with self-reported conservation programs (18% of all gardens). The highest concentration of gardens is in the eastern US and western Europe. Many areas rich in plant diversity are not close to any garden. BGCI. 2013. GardenSearch online database. Botanic Gardens Conservation International. Richmond, U.K. Available at www.bgci.org/garden_search.php.

Estimating a species "potential dispersal envelope" is difficult but possible. Species distribution models can be used to estimate the location of each species' current and future preferred climates. Chaperoned managed relocation should only occur within this envelope (Box 6).

Transfer of species within their potential dispersal envelopes helps to control the risks they pose, but it does not eliminate them. For example, a species could be non-invasive within one part of this envelope but become invasive in another. Monitoring of risk should be ongoing, and transfer should be discontinued if it is likely the species would pose a risk to recipient locations.

In many cases the distribution of botanical gardens will not adequately cover species' potential dispersal envelopes (Figure 1). In some instances establishing new gardens may be possible, but in general this is a prohibitive solution. Thus, chaperoned managed relocation is but one of many strategies in a system of integrated conservation planning (Box 2).

Redundancy across Botanical Gardens

Despite best efforts, populations can go extinct, and botanical gardens can change missions or become defunct altogether. Thus we advise harboring multiple captive populations of the same species across multiple botanical gardens as "insurance."

Cooperation

Engaging in an effective, cautious program of chaperoned managed relocation will be challenging and resource-intensive. Thus it will be necessary to establish inter-garden cooperative agreements, working groups, and databases. Quite a few inter-garden organizations already exist that could provide the institutional framework for transfer of species within regions. These include the Center for Plant Conservation (US and Canada), gardens associated with the Chinese Academy of Sciences and Russian Academy of Sciences, and Botanic Gardens Australia and New Zealand.

Conservation within botanical gardens should be performed within the context of integrated conservation planning (Box 2). In almost all cases this will require coordination with conservation organizations, governmental agencies, and local universities.

Coincident Missions

To date, the mission of most botanical gardens focuses on the aesthetic, cultural, medicinal, and economic value of plants, not conservation. Gardens must balance conservation with all other mission objectives. While botanical gardens can play an important role in conservation of plant species, a concerted, integrated effort will be required (Box 2).

Box 7: What happens next?

“Chaperoning” managed relocation is intended to address the main risks of “unchaperoned” managed relocation. However, as climate change progresses, “chaperoned” species could be moved farther and farther away from their current ranges. When should species be reintroduced to the wild, or should they always remained under the care of their “chaperones?”

Every situation in which a species lives in captivity and has had its original habitat destroyed must address this dilemma. Even if humans severely restrict emissions of greenhouse gases, the climate of the next few centuries will be very different from today. Hence, there is no foreseeable future which replicates the conditions of the present.

So should we release plants into natural environments in which they did not evolve? Or should we keep them in captivity, viable but never “natural?” There is an emerging and vociferous debate in the scientific community over whether humanity should embrace the “Anthropocene,” a new geological, biological, and climatological era in which humanity is a key driver of erstwhile natural processes. This debate is hardly resolved, but its resolution—if any—will help us decide if species ushered into a program of chaperoned managed relocation should always remain chaperoned or be released into novel habitats. Regardless, we believe that under certain circumstances, a cautious and well-implemented program of chaperoned managed relocation offers a choice to future generations that a program of “unchaperoned” managed relocation—or extinction—do not. That choice is whether to maintain species that would have otherwise gone extinct in captivity or release them into the wild. Without chaperoned managed relocation, either option will be less likely.

Evaluation

Proper evaluation is necessary to know if a program is working, and if not, how it might be improved.

Are wild populations of target species moving? If not, are they declining?

Chaperoned managed relocation is intended to aid vulnerable species that are expected to be unable to migrate, adapt, or acclimate to climate change. However, our knowledge is incomplete, and species that we may assume to be dependent on humans for survival may actually fare better than expected. Hence, if species are unexpectedly doing well in the wild, then de-enlisting them from a conservation program may be warranted.

Are captive populations genetically similar to source populations, and if not, why?

Genetic monitoring of captive populations will be instrumental to understanding whether captive populations are representative of wild populations. Botanical gardens provide a very different habitat from most natural environments, so we should expect . Genetic monitoring over time will also enable detection of genetic declines arising from small population sizes. Genetic variation should always be compared to that of source populations, if possible. We advise monitoring of both neutral and adaptive genetic variation because they reflect different evolutionary processes.

Are captive populations persistent?

In general the persistence of captive populations will be evident. However, demographic assessments may reveal concerns that simple counts of individuals may not reveal. For example, populations may become increasingly composed of just a few older individuals, or individuals may grow but not reproduce. On-going demographic monitoring is required to assure that populations have the capacity to persist.