Endangered Plant Conservation: Managing for Diversity

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INTRODUCTION

The past century is vivid evidence of the human tendency to "live as if tomorrow will never come." We are awakening from the pleasant dream of unlimited resources to find our wildlands disappearing along with the animals and plants inhabiting them. Only slowly are we making the necessary societal commitment to set aside natural areas and to learn how to manage them. At the species level the problem is no less formidable; about 3000 of the approximately 25,000 species, subspecies, or varieties of plants native to the United States are at risk of extinction in the wild. For an estimated 200 species, we are too late; they are already extinct. Other species survive in cultivation, but their native habitats are gone.

It is under these circumstances that botanic gardens find themselves becoming partners with those who conserve our natural heritage. Botanic gardens have many skills to lend to the effort including knowledge of plant propagation and growth, research facilities, and dedicated staff. Techniques such as cryogenic seed storage, tissue culture micropropagation, and isoenzyme analysis may seem like methods of the future, but such tools will be an essential part of the conservation repertoire if we are to ensure the survival of rare plants and plant communities in the United States. As conservationists, we believe that tomorrow really will come.

An overview of cooperation between onsite and offsite natural resource management is given in Falk (1987a), an earlier article in the *Natural Areas Journal*. This article provides specific examples of how botanic gardens are helping to conserve rare plants, especially through the auspices of the Center for Plant Conservation (CPC). The CPC's program is aimed at encouraging botanic gardens to develop cohesive conservation projects. The program is part of an overall goal of integrated conservation strategies, which incorporate site protection, habitat management, and offsite backup and research. We believe that such integrated strategies are ultimately the most effective approach to preventing extinction.

THE CENTER FOR PLANT CONSERVATION

Founded in 1984, the CPC is the first private conservation organization in the world dedicated to offsite germplasm conservation of the nation's rare flora (Thibodeau and Falk 1987). Its network includes nineteen regional botanical gardens and arboreta (Figure 1), each with a strong commitment to plant conservation. The CPC's objective is to create offsite germplasm collections (collections of seeds, living plants, tissue culture, pollen, and other plant material containing genetic information) of rare and endangered native plants in each region of the United States, so that there will be at least one site where any endangered species can be safely grown to ensure survival. Methods include collection and propagation, seed storage, maintenance of living plants in cultivation, and research on reproduction and growth. Collections are designed to represent the genetic composition of the wild populations to the greatest extent feasible. The collections thus act as a resource for the future, specifically for research into the plants' reproduction and biology or for carefully planned reintroductions into native habitats. Throughout the process the CPC works closely with other plant conservation professionals, both in identifying the highest priority taxa for offsite conservation and in developing strategy for offsite germplasm collection.

A basic part of the CPC's mission is to cooperate with agencies managing wild populations and their habitat. The old dichotomy of "in situ versus ex situ" is dissolving gradually as evidence accumulates that cooperative programs can be more successful than any single method applied alone. This trend toward integrated conservation strategies (Falk 1987a, 1987b) may represent one of the most significant developments in conservation methodology.

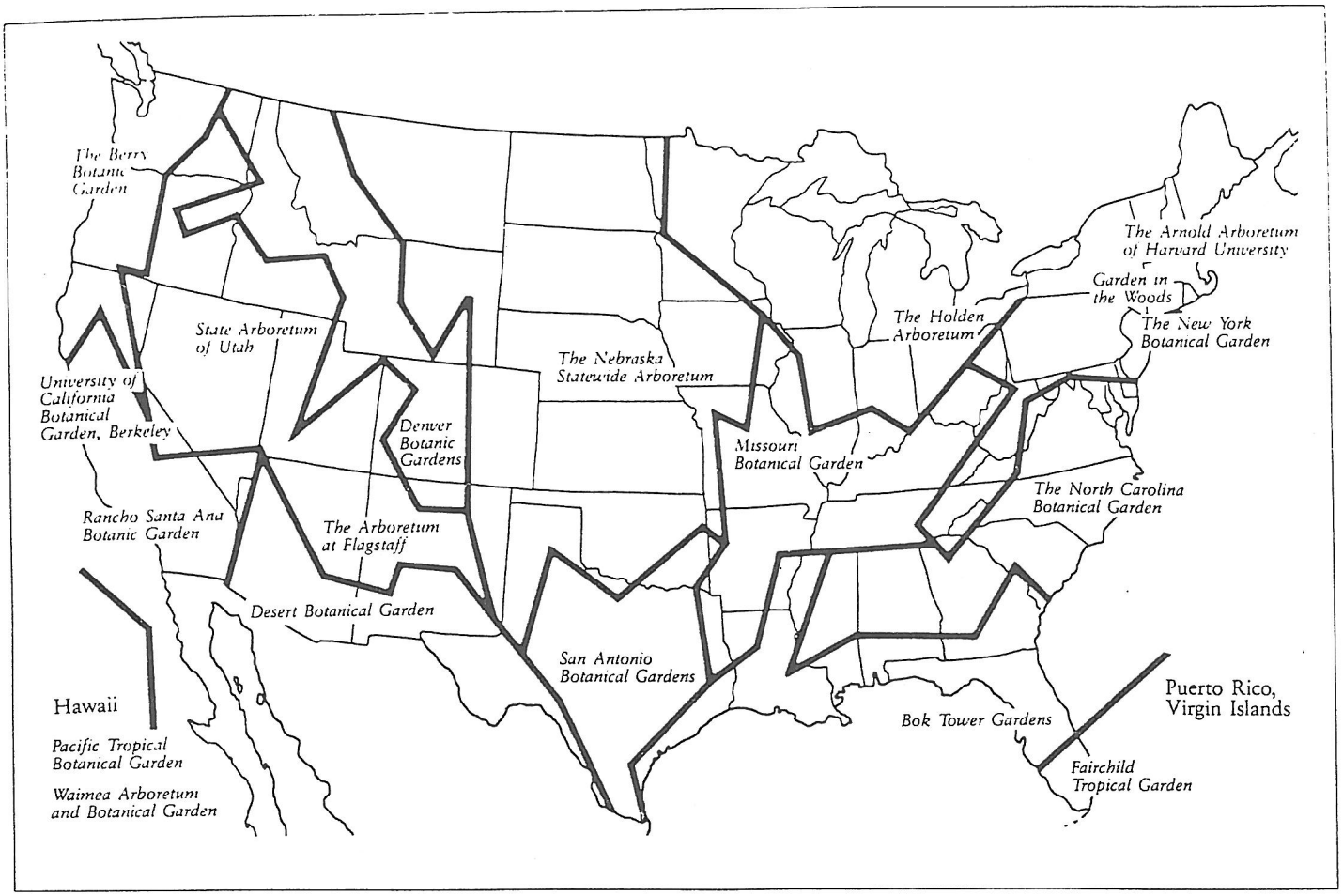

FIGURE 1. Participating institutions of the Center for Plant Conservation.

CURRENT COOPERATIONS IN ENDANGERED SPECIES MANAGEMENT

Following are examples of how botanic gardens and arboreta are carrying out plant conservation efforts in the United States today. Activities range from active management of natural areas to seeking information on conservation priorities. Many of the examples cited in this article predate the CPC or have proceeded independently of its efforts; no implication is made that all the cited projects are associated with the CPC at the present time.

Management of Natural Areas

Botanical gardens often manage large tracts of land. It is not surprising, therefore, to learn that rare species have been identified on land owned by several botanical gardens. Other gardens have contracts to manage lands or species not under their direct control.

Bok Tower Gardens in central Florida discovered two rare species on their 12-ha (30-acre) nature preserve while conducting a survey in 1985 (Anonymous 1986a). The extremely rare clasping warea, *Warea amplexifolia*, occurs in only a few other locations. Additionally, botanists found nearly twenty scrub plums, *Prunus geniculata*. Both species are found only in central Florida's scrub pine habitats. As part of the CPC's program, Bok Tower collected seeds from the natural populations and is maintaining cultivated populations. The CPC's scientific Advisory Council approved the plans for maintaining separate collections but cautioned against growing plants from other populations of either species at Bok Tower so as not to affect the genetics of the wild populations found close by. In addition to land owned directly, Bok Tower Gardens manages the nearby Tiger Creek Preserve for the Florida Field Office of The Nature Conservancy, which is habitat to several rare Florida species.

Another example is the Pacific Tropical Botanical Garden in Kauai, Hawaii, which owns several natural areas on Kauai and other islands. One area near Kona on the island of Hawaii is home to several rare plants, including *Kokia drynarioides, Nothocestrum breviflorum, Dracaena hawaiiensis,* and *Colubrina oppositifolia* (T. Flynn, pers. comm.)

The Denver Botanic Gardens manages three off-site properties, including the 8-ha (20-acre) Walter S. Reed site in the montane zone of Upper Bear Creek Canyon in the Front Range, the 65-ha (160-acre) Mt. Goliath Alpine Unit on the slopes of Mount Evans, and the 283-ha (700-acre) Chatfield Arboretum in Jefferson County southwest of Denver. Together these three sites provide opportunities for field research and education,

in addition to being significant natural areas in their own right.

Recommending Target Species

Developing a program involves establishment of priorities. Since the CPC's program has a national scope, it is important to determine clear criteria for selecting target projects in any given year. The CPC's approach has been to integrate existing national endangerment rankings with other data collected specifically for and by the center. The published listings of the U.S. Fish and Wildlife Service in the *Federal Register* are a basic source, as are the global ranks assigned by The Nature Conservancy. The question is how to select the most important plants for collection and research in any given year from this data set of more than 5100 listings. To aid answering this question, the CPC has been conducting a national survey of 120 regional botanists, asking them to identify species that may be facing extinction in ten years or less. More than 200 plants have been identified as this close to extinction; these taxa naturally will have the highest priority for the CPC program in the coming years.

Conservation Collections

Several examples in this article describe conservation efforts that could proceed only because plants had been collected previously and established in a permanent living collection (see the descriptions of projects for *Kokia cookei*, and *Arctostaphylos uva-ursi* var. *leobreweri*). For this reason, the establishment of offsite conservation collections is the primary focus of the CPC's efforts.

Conservation collections that provide some insurance against total extinction may now be found at botanic gardens in all parts of the United States. Extremely rare plants such as Peter's mountain mallow (*Iliamna corei*), running buffalo clover (*Trifolium stoloniferum*), Texas snowbells (*Styrax texana*), Knowlton's cactus (*Pediocactus knowltonii*), Tennessee purple coneflower (*Echinacea tennesseensis*), Florida torreya (*Torreya taxifolia*), and the blowout penstemon (*Penstemon haydenii*) are protected in permanent living collections or in seed banks. Such collections are most effective when they are maintained as part of a coordinated, comprehensive program such as that of the Center for Plant Conservation.

Endangered species can be maintained at botanic gardens or in seedbanks for long periods of time, although long-term maintenance can present formidable technical, scientific, and institutional difficulties (Elias 1987b). One of the basic roles of the Center for Plant Conservation is to encourage institutional commitment to conservation programs, along with providing technical and financial assistance.

The first instance of an American species saved from extinction through conservation collection was the Franklin tree, *Franklinia alatamaha*. The tree was extirpated from its only known wild location in Georgia in the late nineteenth century but exists today in many cultivated collections. One such collection is at The Arnold Arboretum of Harvard University; the large shrubs in the collection are probably genetically close to those once occurring in the wild.

Several plants face imminent extinction in the wild with little or no hope of saving their natural habitats. In such cases offsite conservation collections may offer the only hope for perpetuation of many species. Conserved germplasm will be available for reestablishment into the wild if and when suitable circumstances develop. Following are examples of three Hawaiian conservation collections.

A single tree in a degraded habitat is all that remains of the palm, *Pritchardia munroii*. Although the plant produces seeds prolifically, both the seeds and seedlings are consumed by domestic and wild animals, preventing seedling establishment. Seeds from this lone survivor have been collected and are being grown at the Waimea Arboretum and Botanical Garden.

Also grown at Waimea is a rare mallow, *Hibiscus brackenridgei* var. *mokuleina*. Most wild plants in this taxon already have disappeared from known sites. The one remaining population is in such poor condition that Waimea's director, Keith Woolliams, estimates that it will only survive for one or two more years. Botanists are searching for additional populations but so far have been unsuccessful. Meanwhile, Waimea has collected propagules from the current site and already has material from another location, now extirpated.

Another plant grown at Waimea is Cook's kokia, *Kokia cookei*. This tree, now extinct in the wild, bears beautiful large red flowers. Before the tree became extinct in the wild, Waimea collected cuttings and established a cultivated population. Only seven trees remain of the species, all in cultivation at the arboretum.

Rescue and Mitigation

When efforts to save a population in the wild fail, salvage of the plants is sometimes still possible. Few biologists feel that salvage efforts are likely to conserve a species in the wild, since specific habitat requirements may be lacking in the sites to which they are moved. The shock of transplantation and establishment can further threaten the survival of individual plants. Nonetheless, where extremely rare species are concerned it is better to retain living plants if at all possible. Several recent examples of salvage and transplantation will show how the process works.

Barrett's penstemon, *Penstemon barrettiae*, is a beautiful rare plant endemic to the Columbia River Gorge. One recently discovered population grew on a cliff near the Bonneville Dam. The Corps of Engineers (COE) had scheduled a new navigation lock before the plants were discovered, and no site alternative for the lock existed. Since the species is not listed under the U.S. Endangered Species Act, the COE was under no obligation to protect the site or the species. But the

Photo by Linda R. McMahan

FIGURE 2. Rescued cuttings of Barrett's penstemon, *Penstemon barrettiae*, at The Berry Botanic Garden.

Corps of Engineers proposed that cuttings of the plants be taken for incorporation into garden beds on the dam property. The Berry Botanic Garden in Portland, Oregon, undertook the project, which was paid for by the COE and aided by volunteers (Figure 2). In May 1987 and March 1988 the plants (progeny by cuttings from the original population) were transplanted into the prepared beds. Additionally, plants were reestablished on one natural rock face that had been spared blasting (J. Kierstead, pers. comm.). Backup cuttings and seeds also are maintained at the Berry Garden to help preserve the gene pool of this particular population. Further information on this effort can be found in Schwartz (1988), Kierstead (1986), and Anonymous (1986b).

Another example (Wallace and McMahan 1988) is the Florida goldenaster, *Chrysopsis floridana*. In 1987 Bok Tower Gardens in central Florida collected seed of this species from a site that was slated for residential development. The parks departments for several nearby counties were interested in the species. Bok Tower Gardens supplied more than a thousand seedlings of this attractive species for planting into natural sites not far from the original site. The plants are being monitored to determine the success of the program.

The plant rescue project at the North Carolina Botanical Garden in Chapel Hill has been operating for more than sixteen years and is probably the most established garden-based rescue program in the country. Using staff and volunteers, the garden has rescued plants on dozens of sites scheduled for destruction. Garden collectors obtain the permission and cooperation of the landowner, often removing blocks of soil or sod for replanting. Rescue projects have included the white wicky (*Kalmia cuneata*), least trillium (*Trillium pusillum*), and Oconee bells (*Shortia galacifolia*). One rescue of the latter species involved relocation of more than 2500 plants to a protected site at the garden. Ironically, the population was threatened by expansion of a recreational hiking trail by a local utility.

In a similar case, Holden Arboretum in Mentor, Ohio, recently undertook the rescue of plants from a doomed population of the lake iris, *Iris lacustris* (Figure 3). The population was being destroyed by a highway-widening project of the state of Michigan, and all efforts to protect the population had failed. With the help of the Michigan Department of Natural Resources, the arboretum obtained bulbs to establish a permanent germplasm collection.

Reintroduction

Reintroduction, as defined in part one of this series, refers to returning a taxon to a habitat where it was once known to occur but from which it has been extirpated. One recent reintroduction for *Stephanomeria malheurensis* was described in the first article in this series (Falk 1987a).

The Center for Plant Conservation does not undertake reintroductions on its own but does provide material to natural resource agencies managing natural areas or restoring endangered plant species. Reintroduction to a documented site is unlikely to cause genetic contamination of wild populations if done correctly, although proper precautions need to be taken (International Union for Conservation of Nature 1984).

A striking example of the reintroduction of a species extinct in the wild is the work of Tilden Regional Botanical Garden in Berkeley, California, with *Arctostaphy-*

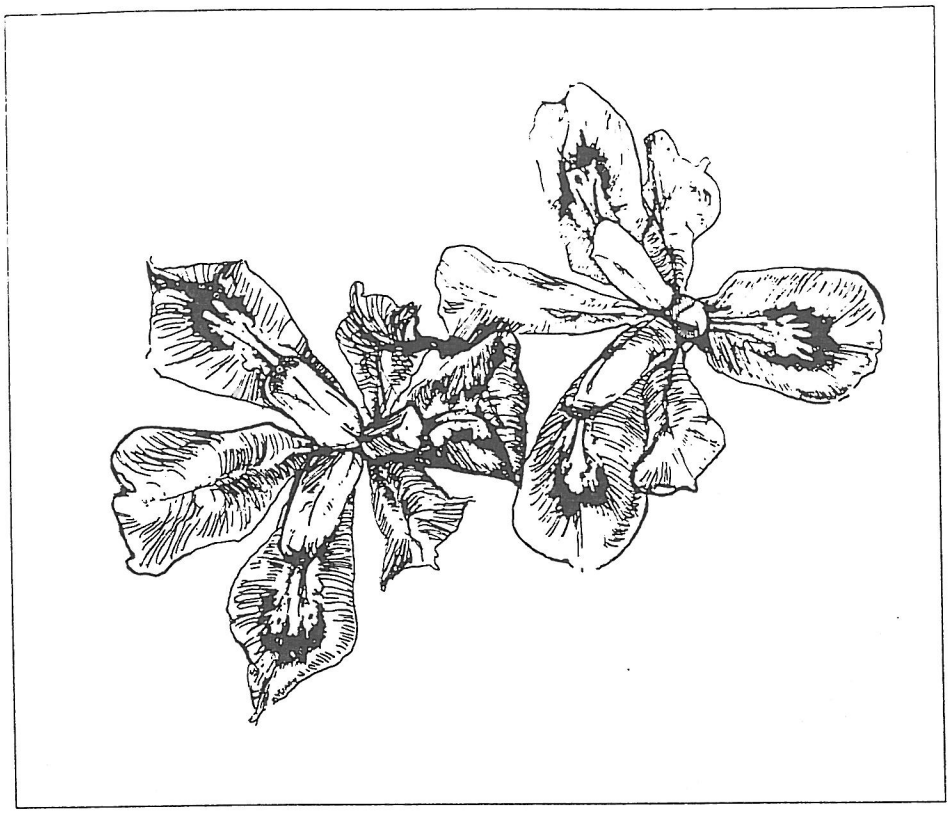

FIGURE 3. Flowers of the lake iris, *Iris lacustris* (shown actual size). Art by Adel Hager.

los uva-ursi var. *leobreweri*. The only remaining population of this species, on San Bruno Mountain south of San Francisco, was destroyed by fire in the 1960's. Fortunately the garden had collected material from the site previously and maintained it in cultivation, thus preventing total extinction. In 1987 the garden began propagating plants for reintroduction near the original site, in cooperation with the state/county park in which the plants originally were found. The project will continue as a cooperative effort until the population is reestablished and requires only ongoing monitoring by the land managing agency (S. Edwards and A. Seneres, pers. comm., see also Reid and Walsh 1987).

Introductions

Introductions into new habitats are undertaken when there are only a few extant populations or individuals left in the wild. Botanists use introductions to increase the chances of the species' survival in the wild. All such introductions must be considered experimental at present; until we have completed many years of monitoring, we cannot declare them successful.

An introduction into a new habitat recently was undertaken for Texas snowbells, *Styrax texana*. The project was proposed and funded by the U.S. Fish and Wildlife Service, and much of the work was carried out by the San Antonio Botanical Gardens (Cox 1987). Texas snowbells are one of Texas' rarest plants. The shrub, bearing attractive bell-shaped white flowers each spring, is known from fewer than thirty individual plants in the wild, which grow along cliffs of spring-fed streams of the Texas hill country (Figure 4). The existing populations, all on private land, are out of reach of the native and exotic herbivores that threaten their survival. In 1986 and 1987 staff at the San Antonio Botanical Gardens collected seed from wild plants. Germination proved to be extremely successful, and twenty-five plants were introduced into each of two new sites in fall 1987. These new populations, introduced into sites where the species was not known to occur previously, are being monitored closely by a botanist. Survival was high in the first few months after transplantation, but monitoring will continue for many years. In related efforts the landowner of the largest natural population of Texas snowbells recently agreed with The Nature Conservancy to allow fencing of the population to protect it from grazing herbivores.

An experimental introduction of the tiny endangered Knowlton's cactus, *Pediocactus knowltonii*, is showing marked success after two years (P. Knight, pers. comm.). The species is now known from only one site in New Mexico, a location well-known to commercial and private collectors interested in the species. Since the land is under the management of The Nature Conservancy, the major threat at present is from collectors. In 1984 the U.S. Fish and Wildlife Service and the New Mexico Natural Resources Survey teamed up to introduce the cactus into a new location with geography, soils, and climate nearly identical to the known habitat. Cuttings were taken from plants at the known locality and rooted in small pots. Although the propagation was done under contract with a private nursery, techniques were similar to those employed by botanic gardens. After a season in the greenhouse the plants were transplanted into the new site in a grid pattern set up to facilitate monitoring of the new population. After two years, survival is over 80 percent, leading to guarded optimism about the survival of the introduced population. Botanists will continue to monitor the population for survival and seedling production.

Revegetation and Enhancement of Existing Populations

In many cases a conservation strategy focuses on enhancement of a population that has been damaged, often by grazing or off-road-vehicle use. Plants in naturally unstable environments such as dunes or talus slopes may be particularly prone to disruption. In such cases mate-

Photo by Linda R. McMahan

FIGURE 4. Wild *Styrax texana* in the Texas hill country.

rial (seeds or cuttings) may be taken from the site, propagated, and replanted onsite to help reestablish the population.

A case in point is the restoration of a Vermont population of *Hudsonia tomentosa*, a state endangered species found on land owned by The Nature Conservancy (TNC). Off-road-vehicles had nearly destroyed the population when TNC arranged for propagation of cuttings taken from the remaining plants. The rooted cuttings later were transplanted back to the original location, helping to reestablish the population. Such efforts are especially reliable because the propagated material is genetically consistent with the site's genome. This is an important consideration in cases where there is genetic variability between populations. Whenever possible, revegetation projects should use material taken from the site itself. Another excellent example of enhancement of an existing population of an endangered species, *Erysimum menziesii*, is provided in Ferreira and Smith (1987).

Population enhancement often relies on research to guide project design. A particularly cogent example is presented by the Catalina mahogany (*Cercocarpus traskiae*), as related by Rieseberg (1988). The Catalina mahogany is known from only seven plants confined to a single canyon on the southwest side of Santa Catalina Island off the coast of southern California. Once consisting of forty trees, the population declined through overgrazing and soil loss caused by large herds of sheep and feral pigs. Active management of the seven remaining individuals began with fencing of two trees in the late 1970's by the Santa Catalina Conservancy. More extensive fencing was added in 1985. In 1987 the Rancho Santa Ana Botanic Garden began working closely with the Santa Catalina Conservancy to perpetuate the species. Using isoenzyme studies, they determined that only five of the seven trees were truly *C. traskiae*. The other two were hybrids with the more common mountain mahogany, *C. betuloides* ssp. *blanchae*. The chemical study confirmed what biologists had suspected from examining the trees morphologically. Armed with this knowledge of the trees' parentage, the Santa Catalina Conservancy will reintroduce rooted cuttings of the five true trees to help build back the population. If they had used cuttings from all seven trees, Rieseberg believes that "Catalina mahogany might be lost. . . and that our management efforts might actually be speeding up the loss."

Enhancement projects also can involve transplanting common species to stabilize or revegetate a site, making it more hospitable for rare species. Such projects more correctly fall into the category of habitat restoration.

Restoration

The field of habitat restoration, or restoration ecology, is attaining increasing importance in plant protection efforts, for

it is on a restored habitat that the survival of many rare species may depend (Falk, in press). Restoration was recently the subject of a national conference (Berger, in press) and may represent one of the most synthetic conservation disciplines. Its original focus on severely degraded sites may find applications in endangered species preservation. For instance, a West Virginia site that had been destroyed by coal mining underwent a restoration that included establishment of the rare *Marshallia grandiflora*. Plants were collected, propagated in a greenhouse, and grown in a nursery to a size suitable for reintroduction (L. E. Morse, pers. comm.). Another example of habitat restoration efforts providing suitable sites for reestablishment of rare plants is described in Reid and Walsh (1987).

Management Research

As important participants in integrated conservation strategies, botanic gardens have a responsibility to assist in the management and preservation of wild populations as well as maintain their own cultivated collections. One of the most useful contributions is to conduct rare plant research specifically designed to aid preserve managers.

An interesting current example involved the rare Peter's Mountain mallow (*Iliamna corei*), known from only one site with four plants in Giles County, Virginia. In cooperation with the Virginia Chapter of The Nature Conservancy, botanists at the Virginia Polytechnic Institute (Blacksburg, Virginia) and the North Carolina Botanic Garden (Chapel Hill, North Carolina) are studying seed germination, seedling establishment, flowering, and seed set in an effort to understand how the habitat should be managed to allow the population to regenerate naturally. The flowers presently abort before producing viable seed, indicating possible inbreeding sterility. In addition there are some indications that leaf litter at the site is inhibiting growth of the population, since there are substantial numbers of seeds in the duff layer that are not germinating (F. Cooper, pers. comm.).

The Plymouth gentian (*Sabatia kennedyana*) is another example being studied at the Garden in the Woods of the New England Wild Flower Society (Framingham, Massachusetts). The plant occurs naturally on pond edges in coastal Massachusetts, in what NEWFS propagator William Brumback describes as "alternating flood/bake conditions." Brumback found a way to germinate seeds in the garden and in so doing determined that the plant is monocarpic. This discovery has significant management implications because the soil seed bank therefore must constitute a large proportion of the species' total genome (W. Brumback, pers. comm.).

Management-related offsite research is being conducted on several other species such as *Lilium grayi* (North Carolina Botanical Garden), and *Aconitum noveboracense* (Cornell Plantations).

Basic Research

Botanic gardens and arboreta also conduct basic plant science research. Several United States gardens working with rare plants in the CPC's network are university-affiliated, including The Arnold Arboretum of Harvard University, the North Carolina Botanical Garden (University of North Carolina), the Rancho Santa Ana Botanic Garden (Claremont Colleges), the Nebraska Statewide Arboretum (University of Nebraska), the University of California Botanical Garden (University of California, Berkeley), and the Utah Statewide Arboretum (University of Utah). Others, such as the Missouri Botanical Garden and the New York Botanical Garden, are independent but have a strong institutional tie to a university for teaching and research. And several gardens, notably the Fairchild Tropical Garden and the Pacific Tropical Botanical Garden, maintain research programs that are entirely internally managed. All of these have the potential to develop plant research programs that can significantly contribute to biologically sound conservation.

Research into the basic biology of rare plants includes studies in systematics, physiology, reproductive systems, and autecology, as well as horticulture. An excellent example is work carried out at The Arboretum at Flagstaff, Arizona, on mycorrhizal associations in several members of the genus *Pediocactus*. Arboretum staff have undertaken field collecting and propagation in cooperation with the regional office of the U.S. Fish and Wildlife Service, the state of New Mexico, The Nature Conservancy, and a private nursery (Olwell et al. 1987). In 1985 the roots of Peeble's Navajo Cactus (*Pediocactus peeblesianus* var. *peeblesianus*) were observed to be heavily colonized by the fungus *Glomus deserticola*. Since then the arboretum has been conducting cultivation studies to determine the fungal symbiont's effect on the cactus' germination and growth rate. This previously undocumented symbiosis thus may have both basic and applied research interest (Milne 1987). Related research by Barbara Phillips at the Museum of Northern Arizona with *P. peeblesianus* var. *peeblesianus* has demonstrated that the species is an obligate outcrosser, a formerly unrecognized characteristic (B. G. Phillips, pers. comm., Butterwick 1987).

From a conservation perspective, however, the most promising — and vital — realm of research concerns the distribution of genetic variation in populations of rare plants. For example, in species that typically self-fertilize it has been shown that genetic differences between populations are characteristically greater than for outcrossing taxa (Hamrick 1983). Such patterns of genetic variation have enormous implications for the design of representative offsite germplasm collections, since they have a direct bearing on the number of sites that should be sampled and the size of the collections to be made. The problem in designing such strategies for rare plants is that, at the present time, so little data are available regarding genetic variation in rare plants that it is nearly impossible to construct a biologically sound program (see Soulé 1986).

To address this need the Center for Plant Conservation is undertaking a one-year

study program in genetic variation in rare plant species, to be concluded by a conference on the subject in March 1989. The purpose of the conference will be to bring the current state of knowledge in population biology and genetics to bear on conservation strategy and to advance the level of understanding in the conservation community.

Economic Research

Of the more than 1000 genera represented in the CPC's data base, more than two-thirds are congeners of plants with current or near-term economic potential. This includes crop genera (*Trifolium, Amaranthus, Zizania*); fruits, seeds, and nuts (*Vaccinium, Helianthus, Prunus*); forest products (*Pinus, Abies, Picea, Betula, Quercus*); and industrial products and pharmaceuticals (*Lesquerella, Limnanthes, Astragalus*). There are also hundreds of endangered plants in horticulturally popular genera (*Iris, Lilium, Rosa, Rhododendron, Penstemon, Magnolia, Fremontodendron, Carpenteria*) and families (Cactaceae, Orchidaceae). Botanic gardens can play a key role by providing research-quality germplasm collections for screening programs.

In part to advance the systematic assessment of rare native plants for economic potential, the CPC has signed a cooperative agreement with the U.S. Department of Agriculture, National Plant Germplasm System (NPGS). Under this agreement the CPC and the NPGS will work jointly to store seeds of endangered native species and to develop material for USDA research in economic botany.

CONCLUSION

The conservation community is changing dramatically. Not only new institutions, but new kinds of institutions are becoming involved at a basic level. The entry of botanic gardens and arboreta into conservation in the mid-1980's has opened up new possibilities for cooperative projects in introduction, enhancement, restoration, and research into the dynamics of plant communities and endangerment. Until recently such projects in botanical gardens were scattered, with no means to develop and apply consistent standards. As the Center for Plant Conservation and the botanical garden network gain experience in this area, they will become stronger allies in the fight against plant species extinction.

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