How to Get Plants into the Conservationists' Ark

The diversity of plant genetic and reproductive systems complicate efforts to save endangered species, sometimes making the job easier, sometimes more difficult

Narthecium americanum: *A showy lily relative*

"WE ARE LIVING IN AN ERA of mass extinction that is primarily due to large-scale habitat destruction caused by human activity," declared Alan Templeton of Washington University. Although biologists have lately come to realize that this diagnosis applies to all corners of the living world, Templeton made the comment at a recent meeting on the conservation issues of rare plants, organized by the Center for Plant Conservation (CPC)*. "In the growing awareness of habitat destruction and subsequent extinctions, plant conservation biology has been somewhat neglected," says Donald Falk, director of CPC, which is a nonprofit organization based in Jamaica Plain, Massachusetts.

The recent meeting follows closely on the publication by the center of a survey showing that between now and the year 2000 some 680 plant species native to the United States will probably become extinct, a figure more than three times greater than the total for the preceding two centuries. (See *Science*, 16 December, page 1508.)

What is to be done? "The best remedy to prevent extinction is habitat preservation," said Templeton. "Such a strategy not only preserves species that have been targeted because they are endangered, but it preserves the entire ecological community in which the species lives, which will often include additional endangered species that we are not even aware of."

But Templeton is a realist, and acknowledges that in many cases habitat preservation is not an option, at least not with current trends of urban and agricultural expansion and natural resources exploitation. "In such cases, offsite breeding of cultivated populations is needed either to preserve a species that has gone totally extinct in nature or to provide a backup for habitat preservation efforts."

In the longer term scheme of things, the maintenance of endangered plant species in botanic gardens is viewed as an interim measure. "It is ultimately hoped that cultivated populations can be released back into preserved or restored habitats," noted Templeton. "Hence, the goal of such breeding programs is to preserve the species in captivity until habitat restoration allows its release back into nature."

Habitat restoration is a controversial topic among ecologists, and so too is the means by which endangered species can be collected, maintained, and ultimately released into such habitats. This latter enterprise—the stocking of the conservationists' ark—was the focus of the recent CPC meeting, with population genetics a key issue. Two critical factors emerge in ensuring the proper rescue of endangered plants (and animals too, for that matter), Falk told *Science*.

First is an understanding of the popultion genetic pattern of the species to be collected. This is important not only in ensuring that a genetically representative sample is preserved but also because the population genetic pattern will determine how collection must be done. Second is the maintenance of the species in cultivation so that its genetic package will not suffer, thus maximizing the chance of survival on reintroduction into a wild habitat.

For many participants at the CPC meeting, the difficulties of maintaining the genetic integrity of cultivated plants emerged as *the* major problem facing plant conservation biologists. Spencer Barrett and Joshua Kohn of the University of Toronto spoke for many when they said: "A major challenge of ex situ conservation will be to ensure that sexually propagated samples of rare plants do not become museum specimens incapable of surviving under natural conditions." This danger arises from a process they describe as "unconscious domestication."

A tenet of Falk's is: "good science is the foundation of good conservation." But, as Eric Menges of the Archbold Biological Station, Florida, noted at the recent meeting, "conservation biology . . . is a crisis-oriented science." As a result, biologists are often forced to act quickly, often with inadequate theoretical models and inadequate data. And for the botanist there is the additional frustration that theoretical and practical attention has focused mainly on animals, making the collection of information on plants yet more crucial. "Our task is to construct the models and collect the data at the same time as we tackle specific conservation projects," says Falk.

For instance, the restoration of a habitat offers opportunities beyond creating an ecological community. "What to a conservationist would look like a restoration project, to a population biologist would look like an empirical test of the demographics and genetics of small populations," says Falk. And the biology of small populations is central to much of conservation science.

It is true that a plant species may be endangered for any one of several different reasons—such as narrow geographic range or narrow habitat specialization—not all of which involve small populations. Nevertheless, small population size is a leading cause of plant rarity, and once in cultivation, small population size becomes a fact of life and of continued survival. Hence the need to understand the demographic and genetic consequences of small populations.

The central issue in demographics is a measure known as minimum viable population (MVP), a subject of intense interest and research on animal species but of hardly any on plants. The MVP gives "an estimate of the minimum population size necessary to have an acceptably low probability of extinction," explained Menges. "MVP analyses for plants will necessarily differ from animal populations, simply because of the differences between plants and animals."

Animal and plant species face the same kinds of uncertainties—stochasticities—that can edge a population to extinction, four in all. First is environmental stochasticity, which refers to "variation in time in the population's operational environment." Small populations are at greatest risk here. Second is natural catastrophe, such as flood,

*"The genetics and population biology of rare plants," Missouri Botanic Garden, 9 to 11 March.

known only in wetlands of the New Jersey Pine Barrens.

fire, and other major external perturbations, any of which can affect small and large populations alike. Third is demographic stochasticity, "where chance events affect the survival and reproductive success of individuals." Again, small populations are most vulnerable. Last is genetic stochasticity, caused when small populations become genetically depauparate.

"As analyses of minimum viable population size for plant species are developed, they will differ considerably from those of animals," predicted Menges. The reason is that plants possess a range of characteristics that are absent in animals and will influence the population viability in important ways.

The most obvious difference is that plants are sessile organisms whereas the great majority of animal species move about, a difference that makes plant populations more vulnerable to a range of influences. Balancing this to some degree is the great plasticity plants possess in the face of changing environmental conditions. Other differences include the fact that plants often grow clonally, can exist for long periods as dormant underground structures or seeds, and have a tremendous diversity of breeding systems and life histories.

As a result, MVP analyses for plants are certain to be different—and probably more complicated—than those for animals. However these calculations turn out, Menges predicts that "environmental stochasticity and natural catastrophe will be the primary threats to most plant populations."

Biologists have known for some time that the degree of genetic variation within a species can be crucial to its survival. "Loss of variation is thought to reduce the ability of populations to adapt to changing environments and to increase their susceptibility to pest and disease pressures," explained Barrett and Kohn. Indeed, Templeton characterizes loss of variation in a species as a "partial extinction." Genetic variation is the currency of future evolution.

From the conservationist's point of view, maintenance of natural variation in cultivated populations can determine the success or failure of a conservation effort. "Restored environments will undoubtedly differ from the original habitats and communities," observed Templeton. "It is therefore critical that the released populations have sufficient genetic variability to provide adaptive flexibility in an uncertain future."

Most species naturally have a considerable amount of genetic variation, but they may differ in the way in which the variation is distributed among the existing populations. For instance, if the species is essentially a single population, with migration and gene flow occurring over large areas, then each individual's genetic package contains a fairly extensive share of the overall variation. With just a few individuals the great majority of the species' overall variation is represented. In this case, collection for offsite cultivation would be rather straightforward.

When a species is fragmented into rather isolated populations, a different picture emerges. Here, each population may be genetically rather uniform but different from neighboring populations. In which case, the all important genetic variation is distributed between populations, not within them. A collection taken from just one population for the purposes of conservation would therefore be genetically impoverished. "Without a knowledge of how the species' genetic diversity is divided within and between local populations, it is impossible to design a sampling program that will preserve a substantial portion of the species' genetic diversity," stated Templeton.

When establishing an offsite population, conservationists prefer to be able to collect a genetically representative sample of the species in question, and in numbers sufficient to maintain a viable population. But, as already noted, conservation biology is a crisis science, and sometimes a population will have crashed to pathetic numbers before action is taken: a good example is the California condor. When this happens the conservation biologist is putting into action what sometimes occurs in nature: a founder event, in which a new population is established from a very few individuals. And the danger is the same in each case, that is, the loss of genetic variation.

Trifolium stoloniferum: *The running buffalo clover, thought to be extinct but rediscovered in 1983.*

Templeton described such a case in which he was involved, the Speke's gazelle. Starting with just one male and three females, Templeton and his colleagues managed to establish a large population, with the loss of remarkably little genetic variation. This was achieved by pushing for a very rapid population increase, as suggested by population genetic theory.

The great danger with small breeding populations is genetic drift, in which the loss of some alleles and the fixation of others occurs simply through the roll of the genetic dice. The genetic character of the population may therefore shift rapidly. Another source of problems, of course, is inbreeding, which may yield offspring with low fertility or viability because of the exposure of normally masked deleterious alleles.

Management of artificial breeding programs therefore has to be intense in order to maintain genetic variation. But this intensity can bring with it other dangers, namely the trap of unconscious domestication. "Unfortunately, as long as the breeding populations in captivity are genetically variable, they will have the capacity to adapt to the captive environment," explained Templeton. "Guarding against inadvertent selection for domestication can help, but we simply cannot anticipate or monitor all the ways in which a population can adapt to a captive environment."

Once again, because of the great variety of reproductive systems in plants, the problems faced in artificial breeding programs will overlap with but not be identical to those of animal breeding. In many instances, these differences make plants better candidates for offsite cultivation. But in some cases plants may be more vulnerable, such as when closely related species are destroyed through readily achieved hybridization that usually does not occur in the wild.

In addition to "a critical role for genetic surveys of natural populations in plant conservation," Templeton concludes that "much more effort will generally be required for plants before the breeding program can even be initiated, and the sampling strategies will often have to be more complex."

■ ROGER LEWIN