

Chapter 4

# Interventions To Maintain Biological Diversity

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# Interventions To Maintain Biological Diversity

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## HIGHLIGHTS

- Four management systems are used to conserve diversity: 1) managing ecosystems, 2) managing populations and species in natural or seminatural habitats, 3) maintaining and propagating living organisms offsite as in zoos or botanic gardens, and 4) storing seeds or other germplasm, usually with refrigeration or freezing.
- The four systems for maintaining diversity are complementary, but linkages between the strategies (e.g., between zoos and nature reserves) are less well developed than they could be to maximize conservation efforts.
- Biological, political, and socioeconomic factors must be evaluated to choose the best mix of management interventions. Because the importance of maintaining diversity has only recently begun to attract widespread recognition, scientific methods for evaluating trade-offs are at an early stage of development. Methods for evaluating socioeconomic factors seem to lag behind development of biological methods.

The majority of plants, animals, and microbes survive without any specific human interventions to maintain them. However, as natural areas continue to be modified—through fragmentation of habitats, for example—their survival and, in turn, maintaining biological diversity

will increasingly depend on active management. A spectrum of technologies—broadly defined to include management systems and other means by which knowledge is applied—can be used to maintain diversity.

## MANAGEMENT SYSTEMS TO CONSERVE DIVERSITY

Two general approaches are followed in maintaining diversity: 1) onsite maintenance, which conserves the organism in its natural setting; and 2) offsite maintenance, which conserves it outside its natural setting. Onsite maintenance can focus either on an entire ecosystem or on a particular species or population. And offsite maintenance can focus on living collections or on stored germplasm. These four broad management systems are necessary components of an overall strategy to conserve diversity. Conservation objectives can be enhanced by any combination of the four systems and by im-

proving the linkages between them to take advantage of their potential complementariness.

Table 4-1 lists some technology programs associated with each management system. [In general, the technologies on the right side of the table entail more human intervention,

### Onsite Ecosystem Maintenance

Where the conservation objective is to maintain as much biological diversity as possible, the only practical and cost-effective approach

**Table 4\*1.—Examples of Management Systems To Maintain Biological Diversity**

Onsite		Off site	
Ecosystem maintenance	Species management	Living collections	Germplasm storage
National parks	Agroecosystems	Zoological parks	Seed and pollen banks
Research natural areas	Wildlife refuges	Botanic gardens	Semen, ova, and embryo banks
Marine sanctuaries	<i>In-situ</i> genebanks	Field collections	Microbial culture collections
Resource development planning	Game parks and reserves	Captive breeding programs	Tissue culture collections
		Increasing human intervention —————*	
- ————— Increasing natural processes			

SOURCE Office of Technology Assessment, 1986

is to maintain ecosystem diversity. Offsite maintenance cannot accomplish this objective because many species cannot live outside their natural habitats. An ecosystem approach allows processes, such as natural selection, to continue. Survival, for some species, depends on complex interactions with other species in their habitats. Maintaining diverse ecosystems also continues ecological processes, such as nutrient cycling, that typically depend on the interaction of numerous species (5).

programs to maintain a diversity of ecosystems usually identify different ecosystem types and then attempt to preserve a sample of each type (see ch. 5). Some types, such as cloud forests, are rare and confined to small areas. These are especially vulnerable and receive special emphasis in some conservation programs.

The ecosystem approach is used not only for natural areas but also for traditional agricultural ecosystems. Pressures to modernize these "agroecosystems" threaten the characteristically high levels of crop and livestock genetic diversity these systems represent—and upon which modern agricultural systems continue to depend.

### Onsite Species Maintenance

When the objective is to maximize direct benefits from diversity, such as production of an optimal mixture of game, fish, timber, and scenic values, then the preferred approach is often to manage particular species and their habitats. Managing at the population level is preferred when the objective is to avert extinction of a rare or threatened species or subspecies.

Because managing all species would be impossible, biological, political, and economic factors determine which species will receive direct attention. Preference is given to species with recognized economic value, for example.

Noncommercial species that are rare and endangered also are given management attention to ensure survival of wild populations. Similarly, species that provide important indirect benefits, such as pollination or pest control, may receive attention. Ideally, management should also focus on keystone species, i.e., those with important ecosystem support or regulatory functions.

### Offsite Maintenance in Living Collections

Zoological parks, botanic gardens, arboreta, and field collections are common homes for living collections. Living collections serve several conservation objectives. Zoos and botanic gardens can propagate species threatened with extinction in the wild, sometimes enabling the repopulation of a newly protected or restored habitat. Arboreta and living collections kept at places like agricultural research stations maintain the genetic diversity of plants not amenable for germplasm storage as well as numerous livestock varieties that are not commercially popular but are culturally significant or are needed for research and breeding programs.

The number of species maintained in living collections is limited by the size of the facilities and the relatively high maintenance cost

per species. Managers of offsite collections face the dilemma of maintaining populations large enough to ensure viability and at the same time providing refuge to as many species as possible.

Historically, the primary objectives of living collections have been research and display. However, growing concern over the loss of biological diversity is leading to greater efforts to develop collections for their conservation potential. Offsite facilities are also used to breed and propagate organisms, so they no longer rely solely on collecting from the wild to replenish their stocks. Instead, they can make a positive, direct contribution to species' survival.

### Offsite Maintenance in Germplasm Storage

Storage of dormant seeds, embryos, and clonal materials, or germplasm storage, is the most

cost-effective method to preserve the genetic diversity of the thousands of agricultural varieties and their wild relatives when biological factors allow (5). As farmers increasingly abandon the traditional varieties in favor of genetically uniform, modern ones, the preservation of diverse, locally adapted crops will depend heavily on offsite storage (1).

The need to maintain a convenient source of germplasm for breeding purposes and the ability to draw on germplasm from different geographic areas are important objectives met by the offsite storage systems (see ch. 7). Germplasm storage is also the principal method for maintaining identified strains of microbes (see ch. 8). And it is increasingly used to store wild plant species and a few wild animal species.

## DECIDING WHICH MANAGEMENT SYSTEM TO APPLY

The efficacy of onsite and offsite technologies depends on biological, political, and economic factors. The following four chapters in this report examine how these various considerations determine which technologies are applied. General observations on how these factors help match management systems to conservation objectives are considered here. (See table 4-2 for a summary of objectives, )

Biological considerations are central to the objectives and choice of systems. Because not all diversity is threatened, the task of maintaining it can focus on the elements that need special attention. Biological uniqueness is important in setting priorities for conservation programs. A unique species—one that is the only representative of an entire genus or family, for example, or a species with high esthetic appeal—may be the focus of intensive conservation management either onsite, offsite, or both.

Biological uniqueness can present problems in applying conservation technologies, because species-specific research is often required to

develop management or recovery plans (ch. 5). Species with unique reproductive physiology, for example, often cannot be maintained offsite until a considerable investment has been made in developing propagation techniques (ch. 6).

Political factors also influence conservation objectives and management systems. Commitments of government resources, policies, and programs determine the focus of attention and, to a large extent, such commitments reflect public interests and support. For example, in the United States a disproportionate share of resources is devoted to conservation programs for a select few of the many endangered species. Substantial sums have been spent in 11th-hour efforts to save the California condor and the black-footed ferret, while other endangered organisms such as invertebrate species receive little notice.

National instability may also threaten biological resources either directly in the cases of civil strife or warfare or indirectly through encouraging neglect. Such cases warrant special efforts

**Table 4-2.—Management Systems and Conservation Objectives**

Onsite		Off site	
Ecosystem maintenance	Species maintenance	Living collections	Germplasm storage
Maintain:	Maintain:	Maintain:	Maintain:
• a reservoir or “library” of genetic resources	• genetic interaction between semidomesticated species and wild relatives	• breeding material that cannot be stored in genebanks	• convenient source of germplasm for breeding programs
• evolutionary potential	• wild populations for sustainable exploitation	• field research and development on new varieties and breeds	• collections of germplasm from uncertain or threatened sources
• functioning of various ecological processes	• viable populations of threatened species	• off site cultivation and propagation	• reference or type collections as standard for research and patenting purposes
• vast majority of known and unknown species	• species that provide important indirect benefits (for pollination or pest control)	• captive breeding stock of populations threatened in the wild	• access to germplasm from wide geographic areas
• representatives of unique natural ecosystems	• “keystone” species with important ecosystem support or regulating function	• ready access to wild species for research, education, and display	• genetic materials from critically endangered species

SOURCE: Office of Technology Assessment, 1986

to collect an endangered species or germplasm and maintain it outside the country to ensure survival and to facilitate access.

The applicable management systems and technologies also depend largely on economic factors. Costs of alternative management systems and the value of resources to be conserved may be relatively clear in the case of genetic diversity. For example, the benefits of breeding programs compared with the cost of seed

maintenance easily justify germplasm storage technologies (see ch. 7). However, cost-benefit analysis is more difficult when benefits are diffuse and accrue over a long period (7). This problem is particularly acute for onsite maintenance programs where competition for land exists. Current threats to biologically rich tropical forests by land seeking peasant agriculturalists illustrate these conflicting interests,

## COMPLEMENTARINESS OF MANAGEMENT SYSTEMS

Each of the four management systems serves different objectives. Historically, the two off-site approaches have developed independently from onsite approaches. However, some links have developed between the different management programs (see figure 4-1). Improvement of such links will contribute substantially to the cost-effectiveness of each management system and will help to achieve the overall goal of maintaining biological diversity.

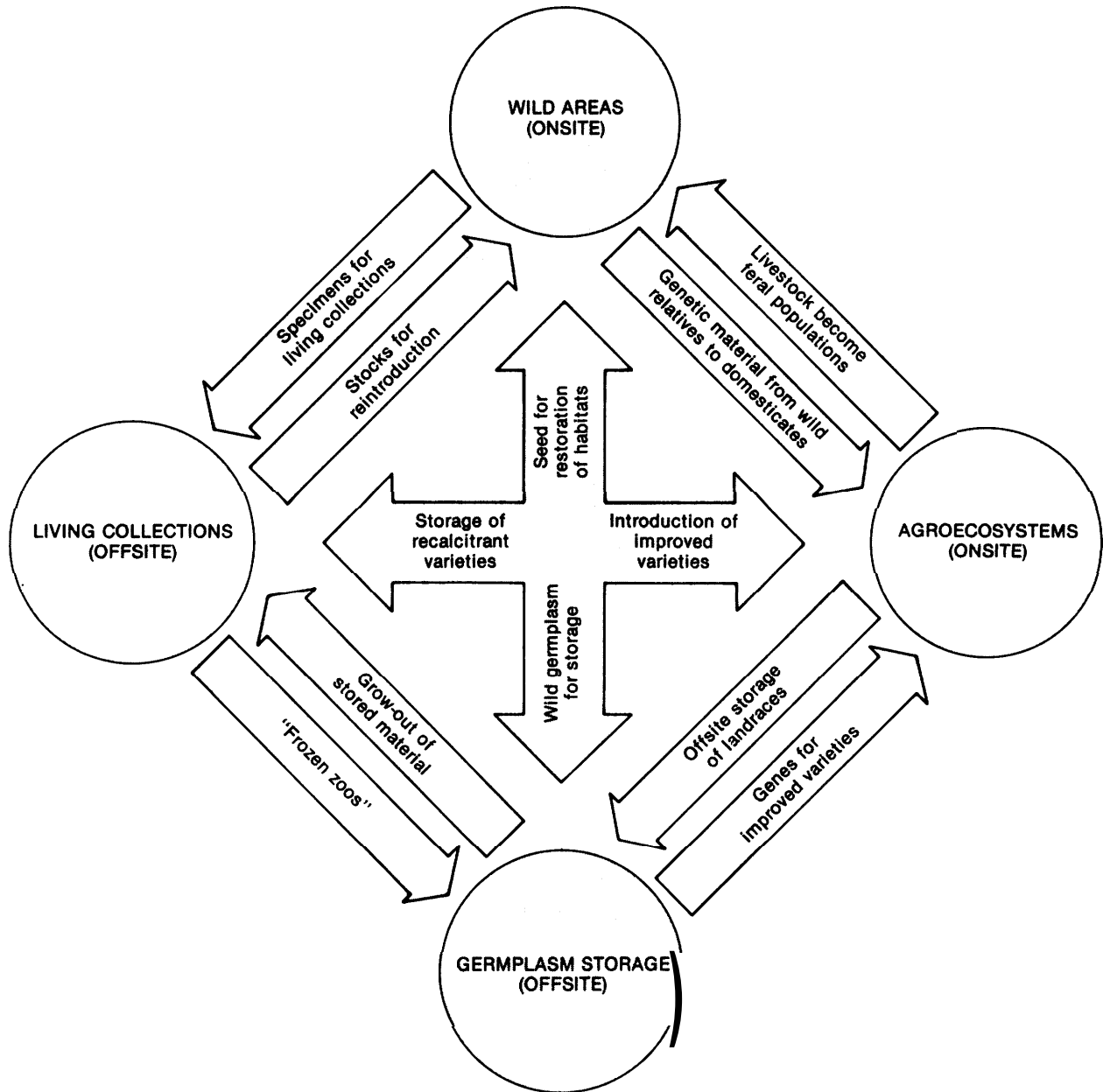
### Biological Linkages

Transfers of biotic material among the four management systems can enhance diversity.

Exchanges between onsite systems occur, for example, when genetic material from wild plants becomes incorporated into locally cultivated varieties. Exchanges between offsite systems occur, for example, when seeds and clones of agricultural varieties are taken from storage and grown out in living collections for use in breeding programs. Similarly, a zoo may collect animal semen from its living collection and place it in cryogenic storage to expand the number of individuals it can maintain—in a sense creating a “frozen zoo.”

Exchanges of species or germplasm between wild areas and living collections are most evident when wild specimens are taken for zoos,

Figure 4-1.—Transfers of Biotic Material Between Management Systems



SOURCE: Office of Technology Assessment, 1986

botanic gardens, or private collections. Taking wild specimens for living collections may provide material for research and public education, may prevent captive populations from inbreeding, and may even enhance wild populations through later reintroduction. However, these activities can—and have—threatened wild populations of a number of species.

It is often possible to take only germplasm—seeds, cuttings, and semen—rather than entire organisms. This approach has the advantage of being less destructive to rare or endangered populations (6). In the interest of preserving endangered populations, mammal germplasm collection is increasingly being attempted. Semen has been collected from wild populations of

cheetahs, rhinoceroses, and elephants (10). But collecting mammal germplasm, without keeping the animal in captivity, is more difficult and costly. And many of the wildlife specimens maintained in zoos are the survivors of destructive capturing procedures.

Efforts increasingly are being made through captive breeding to produce stocks for reintroduction into the wild. The golden lion tamarin program in Brazil (11) has been successful for example. Less attention has been focused on reintroducing threatened plant species, but the recent reintroduction of a wild olive tree species on the island of St. Helena suggests that this approach is possible (6).

Perhaps the most important transfer of genetic material occurs between agroecosystems and germplasm storage: Landraces produced in traditional farmers' fields are the result of thousands of years of natural and human selection from thousands of different crop varieties. Many varieties can no longer be maintained by the farmers, who abandon them to plant higher yielding crop varieties. But the genetic diversity of traditional varieties is needed to create improved varieties. Thus, collecting expeditions to transfer these varieties into offsite storage are critically important to maintenance of the world's agriculture. Germplasm flows from storage back to agroecosystems, via research and breeding programs, as new varieties are introduced into agricultural systems.

Transfers are not always beneficial, however. Livestock that escape captivity can become feral animals with populations so high that they threaten native wild plants and animals. Feral goats on Pacific islands and feral horses on some rangelands of the United States are well-known examples. Similarly, exotic plants introduced as ornamental or agricultural crops sometimes escape to become weeds that crowd out native species. Efforts to capture specimens for living collections can also be destructive. The challenge is to manage the transfers among sites and programs to enhance the positive contributions to diversity maintenance and minimize the negatives ones,

## Technological Linkages

Research and technology transfers between diversity management programs can increase the efficiency, effectiveness, and capacity for maintaining biological diversity. Some technologies developed for domesticated species can be adapted for use with wild species. For example, technologies for offsite maintenance of wild species—particularly germplasm storage and captive breeding—have benefited substantially from the research and experience in agriculture. Perhaps the most dramatic linkage is embryo transfer technologies developed for livestock that are now being adapted to endangered species (ch. 6). Similarly, storage technologies developed for agricultural varieties, such as cryogenics and tissue culture, may become valuable tools for maintaining collections of rare or threatened wild plant species.

Like biological linkages, technological linkages work both ways. For example, research on living collections has provided information that can be applied to maintaining populations in the wild (2). Likewise, research on wild populations supplied information on a number of species' special reproduction requirements, which led to successful results with breeding in captivity.

Technological linkages among institutions engaged in researching, developing, and applying technologies have been limited. Researchers and resource managers in this area have historically worked in relative isolation, dealing almost exclusively with others in their fields of activity. The few interactions that have occurred have had a positive impact. Thus, the potential for benefits from increased cooperative work seems apparent, but institutions are slow to make such changes.

## Institutional Linkages

Exchanges of organisms and technologies have occurred because they have been considered necessary for success of the different programs. However, most programs focus on relatively narrow subsets of diversity. Some groups



devote their attention exclusively to maintaining certain agricultural crops, while others focus on specific wild species—e. g., whales or migratory waterfowl. The result is that much of the work is done in isolation, and the scope and effectiveness of overall diversity maintenance effort becomes difficult to monitor. And while particular concerns may be well-addressed, other concerns receive little or no attention.

Institutional problems that impede overall maintenance of biological diversity include:

- overlap and inter institutional or intra-institutional competition,
- c gaps between goals and the human and financial resources available to achieve them, and
- lack of complementariness or cooperation between initiatives (4).

Institutional links can identify common interests, strengths, and weaknesses of various organizations as well as gaps and opportunities to address overall concerns. Not all activities should be operationally linked, however. A diversity of approaches in conservation activities is beneficial, and interaction should occur principally with those programs closest in purpose and approach (4).

Useful technologies emerge through a series of steps. Basic research provides an understanding of the nature of biological systems. Drawing on this knowledge, researchers define requirements and develop techniques to manage ecosystems, species, or genetic resources. Once the techniques are developed, however, researchers must synthesize techniques into technologies, then transfer and apply the technologies to site-specific circumstances.

In practice, the process of technology development is impeded by institutional constraints. Research is undertaken by scientists in many institutions, including universities, botanic gardens, zoological institutions, and government agencies responsible for natural resources. These scientists commonly emphasize the theoretical. At the other end of the spectrum are resource managers who apply particular techniques. Although the transfer of basic

research to applied research is a problem in developing useful technologies, the principal weakness seems to be the failure of institutions to support synthesis of scientific information into useful management tools.

The problem of technology development is more pronounced for onsite than for offsite maintenance. This difference perhaps reflects the more pragmatic nature of offsite maintenance, where institutions (most with agricultural interests) emphasize research *and* development. Focus on technology development is commonly lacking in onsite maintenance. Institutions may deter scientists from translating research into practical techniques (8). To apply ecological studies to onsite maintenance, greater emphasis needs to be placed on comparative and predictive science, which implies less emphasis on descriptive studies (4).

Forces working against diversity are largely social and economic. Therefore, human dimensions need to be included in the scientific investigations, and natural and social sciences must be involved in conservation initiatives. There is, however, a paucity of social science research for the development of technologies to conserve biological diversity. This lack is partly because of the complexity and difficulty of such work, and partly because the potential for social science to make important contributions has been overlooked.

Greater support is needed for inventory and monitoring of diversity in natural systems and in agricultural systems. Some of this information is already available, but most of it has not been assimilated or made available to decision-makers,

Finally, science needs to be applied to provide policy makers and the general public with better information on the scope and ramifications of diversity loss. Such information needs to be accurate, compelling, and digestible by a lay audience. To produce such information, scientists and scientific institutions need to become more directly involved and accommodating within the public policymaking process (9). At the same time, the information they provide

should meet the four criteria for effective public policy:

1. Adequacy—meets the accepted standards of objectivity, completeness, reproducibility, and accuracy, and is appropriate to the subject and the application.
2. Value—addresses a worthwhile problem; neither too narrow nor too broad.
3. Effectiveness—able to influence policy in a constructive way and linked with the network of decisionmakers responsible for the issue,
4. Legitimacy—carries a widely-accepted presumption of correctness and authority (3),

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