Part III
Institutions

Chapter 9
Maintaining Biological Diversity in the United States

CONTENTS

Tables

Figures

Chapter 9

Maintaining Biological Diversity in the United States

HIGHLIGHTS

- Many U.S. public laws and programs addressing the use of natural resources and the activities of private groups contribute significantly to the conservation of biological diversity. However, diversity is seldom an explicit objective, and where it is mentioned, it is not well-defined. The resulting ad hoc coverage is too disjunct to address the full range of concerns over the loss of diversity.
- Existing laws and programs focus on either onsite or offsite conservation, which impedes establishment of effective linkages between the two general approaches to maintaining diversity. Links help define common interests and areas of potential cooperation between various institutions—important steps in defining areas of redundancy, neglect, and opportunity.
- Personnel of federally mandated programs that deal directly with maintenance of biological diversity, such as the National Plant Germplasm System and the Endangered Species program, have stretched budgets to meet their mandated responsibilities. It appears, however, that these programs will be unable to continue to meet their mandates without significant increases in funding and staffing.

OVERVIEW

Federal legislation authorizes onsite conservation of species and communities and offsite collection and development of plant and animal species of economic importance. The Federal Government consequently supports programs for agricultural plant and animal conservation and for onsite conservation of selected species, but little consideration is given to a myriad of other diversity maintenance objectives. The numerous Federal onsite programs are not well-coordinated to promote a comprehensive approach. State and private efforts fill some gaps, but in many cases, maintaining diversity is not a specific objective, merely a result.

Many organizations or programs discussed in this chapter focus on one aspect of diversity maintenance: plant seeds, rare animal breeds, or onsite conservation of endangered species. This chapter considers Federal mandates related to diversity conservation, onsite conservation, offsite plant and animal conservation, and microbial conservation. In each case, Federal, State, and private activities are assessed, although these categories are arbitrary and, in fact, biological diversity maintenance programs frequently fall into more than one category,

FEDERAL MANDATES AFFECTING BIOLOGICAL DIVERSITY CONSERVATION

No Federal law specifically mandates the maintenance of biological diversity, either offsite or onsite, as a national goal. The term itself is used only in Title VII of the Foreign Assistance Act of 1983 (discussed in ch. 11). A number of Federal laws require the conservation of resources on Federal lands, however, or require that consideration be given to resources in Federal agency activities. Offsite maintenance of agricultural plant germplasm diversity is mandated indirectly through legislation authorizing the National Plant Germplasm System (discussed later in this chapter). But offsite maintenance of wild plants, wild animals, and microbial resources is not explicitly mandated by Federal legislation.

The lack of a comprehensive Federal onsite policy leads to uncoordinated programs, frequently leaving important gaps in conservation. Generally, Federal agencies coordinate conservation activities onsite for species that are specifically mentioned in Federal protection laws, but this coordination frequently does not extend to nonlegislated species. For example, onsite conservation can be coordinated among Federal agencies for threatened and endangered species under the Endangered Species Act of 1973 (Public Law 93-205). But no formal institutional mechanism exists to coordinate conservation of thousands of plant, animal, and microbial species not recognized as threatened or endangered.

offsite germplasm conservation mandates are equally vague. For example, the Agricultural Marketing Act of 1946 is intended to "promote the efficient production and utilization of products of the soil" (7 U. S.C.A. 427), but it is interpreted narrowly by the Agricultural Research Service to mean domesticated plant species and varieties. Little consideration has been given to conservation of wild plant species,

Federal mandates give even less attention to offsite conservation of domesticated and wild animals. Legislative authority is vague and provides little direction to the Agricultural Research Service.

Table 9-1 lists the major Federal mandates pertinent to diversity maintenance. Species protection laws authorize Federal agencies to manage specific animal populations and their habitats onsite. Legislation on the protection of natural areas authorizes the acquisition or designation of habitats and communities that help maintain a diversity of natural areas under Federal stewardship, Federal laws for offsite maintenance of plants authorize conservation and development (or enhancement) primarily of plant species that demonstrate potential economic value, Offsite maintenance of domestic animal germplasm is authorized indirectly by the Agricultural Marketing Act of 1946. The Endangered Species Act of 1973 is in both categories of table 9-1 because it authorizes wild plant and animal species protection, habitat protection, and offsite conservation for those species considered threatened or endangered in the United States,

Although the National Forest Management Act of 1976 (Public Law 94-588) is the only Federal legislation that includes in its mandate the onsite conservation of a "diversity of plant and animal communities, " it offers no explicit congressional direction on the meaning and scope of onsite maintenance of biological diversity. Interpretation of this provision has been a difficult process and has involved lengthy consultation with scientists and managers around the country (50). The U.S. Forest Service ultimately decided the law gave them a mandate to maintain terrestrial vertebrate species diversity and the structural timber stands on all Forest Service lands in conjunction with planning and management processes (44 F.R. 53967-53779), Whether this interpretation fulfills the congressional intent on conserving diversity has not been challenged.

Such terms as *biological resources, wildlife, animals,* and *natural resources* can and have been interpreted differently by Federal agen-

Table 9-1 .—Federal Laws Relating to Biological Diversity Maintenance

Common name -	Resource affected	US Code
Onsite ***diversity mandates:***		
Lacey Act of 1900	wtld animals	16 U.S.C 667, 701
Migratory Bird Treaty Act of 1918 . . . , . ,	wtld birds	16 U S.C 703 et seq.
Migratory B!rd Conservation Act of 1929, ..., ...	wild birds	16 U.S.C 715 et seq.
Wildlife Restoration Act of 1937 (Plttman-Robertson Act) .,	wild animals	16 U. SC. 669 et seq.
Bald Eagle Protection Act of 1940	wild birds	16 U.S.C. 668 et seq.
Whaling Convention Act of 1949, ...	wild animals	16 U SC 916 et seq.
Fmh Restoration and Management Act of 1950 (Dingell-Johnson Act) , . . , , . , ,	flshenes	16 U.S. C. 777 et seq
Anadromous Fish Conservation Act of 1965 (Publlc Law 89-304)	flshenes	16 U S.C 757a-f
Fur Seal Act of 1966 (Public Law 89-702)	wild animals	16 U SC 1151 et seq.
Marine Mammal Protection Act of 1972, ,, ...,.,.,, ,, .,.,, ,,.	wild animals	16 U SC 1361 et seq.
Endangered Species Act of 1973 (Public Law 93-205),, ...	wild plants and animals	7 U S C. 136 16 USC, 460, 668, 715, 1362, 1371, 1372, 1402, 1531 et seq
Magnuson Fishery Conservation and Management Act of 1977 (Public Law 94-532). ... .., .., .., .,, ...,,.,.,,	flsherles	16 U,S.C. 971, 1362, 1801 et seq.
Whale Conservation and Protection Study Act of 1976 (Public Law 94-532) ... .,, . .	wild animals	16 USC 915 et seq
Fish and Wildllfe Conservation Act of 1980 (Publtc Law W-366). .	wild animals	16 U S.C 2901 et seq
Salmon and Steelhead Conservation and Enhancement Act of 1980 (Publlc Law 96-561).. ., ..,	ftsherles	16 U.S.C 1823 et seq
Fish and Wlldllfe Coordination Act of 1934 . .	terrestrial/aquatic habitats	16 US.C 694
Flshand Game Sanctuary Act of 1934	sanctuaries	16 USC 694
Hlstorlc Sites, Buildings, and Antlqultles Act of 1935	natural landmarks	16 U.S.C. 461-467
Fish and Wildlife Act of 1956	wildlife sanctuaries	15 U.S.C. 713 et seq. 16 U.S.C. 742 et seq.
Wilderness Act of 1964 (Publlc Law 88-577) ., ., ., .,	wilderness areas	16 U S C. 1131 et seq
National Wildlife Refuge System Administration Act of 1966 (Public Law 91-135) . . . . . ,, ...	refuges	16 U S C, 668dd et seq
Wild and Scenic Rivers Act of 1968 (Public Law 90-542) ,,, . .	river segments	16 U S.C. 1271-1287
Marine Protection, Research and Sanctuaries Act of 1972 (Public Law 92-532)	coastal areas	16 U.S.C. 1431-1434 33 U.S.C. 1401, 1402, 1411-1421, 1441-1444
Federal Land Policy and Management Act of 1976 (Publlc Law 94-579)	public domain lands	7 USC. 1010-1012 16 U.S.C. 5, 79, 420, 460, 478, 522, 523, 551, 1339 30 U.s.c. 50, 51, 191 40 U.s.c. 319 43 U.S.C. 315, 661, 664, 665, 687, 869, 931, 934-939, 942-944, 946-959, 961-970, 1701, 1702, 1711-1722, 1731-1748, 1753, 1761-1771, 1781, 1782
National Forest Management Act of 1976 (Publlc Law 94-588)	national forest lands	16 U.S.C. 472, 500, 513, 515, 516, 518, 521, 576, 581, 1600, 1601-1614
Public Rangelands Improvement Act of 1978 (Publlc Law 95-514)	public domain lands	16 U.S.C 1332, 1333 43 U SC 1739, 1751- 1753, 1901-1908
Of fsite diversity mandates:		
Agricultural Markettng Act of 1946 (Research and Marketing Act)	agricultural plants and animals	5 U.s.c, 5315 7 U.S C, 1006, 1010, 1011. 1924-1927, 1929, 1939-1933, 1941-1943, 1947, 1981, 1983, 1985, 1991, 1992, 2201, 2204, 2212, 2651-2654, 2661-2668 16 U,S.C. 590, 1001-1005 42 U.S.C. 3122
Endangered Species Act of 1973 (Public Law 93-205)	wild plants and animals	7 U.S.C. 136 16 U.S.C, 460, 668, 715, 1362, 1371, 1372, 1402, 1531 et seq.
Forest and Rangeland Renewable Resources Research Act of 1978 (Publlc Law 95-307), . . ., ...	tree germplasm	16 USC, 1641-1647

NOTE Laws enacted prior to 1957 are cited by Chapter and not"Publlc Law number

SOURCE Off Ice of Technology Assessment, 1986

cies. *Wildlife*, for example, has been defined in a number of ways, including the following:

- mammals that are hunted or trapped (game);
  all mammals—the word *animal* is sometimes used interchangeably with mammal;
- all animals, both vertebrates and invertebrates, excluding fish; and
  all animals, both vertebrates and invertebrates, including fish (65).

These definitional differences are further evidence of the lack of a comprehensive Federal approach to these issues.

ONSITE BIOLOGICAL DIVERSITY MAINTENANCE PROGRAMS

U.S. onsite programs seem to have one of three main objectives: 1) maintenance of diverse habitats or ecosystems, 2) preservation of individual species through habitats' protection, and 3) restoration of habitats to their natural condition. These objectives are not necessarily exclusive. Safeguarding communities and ecosystems could help protect rare species. Protecting the habitat of a species may conserve an ecosystem or community. And restoring habitats could enhance the diversity of species within an ecosystem.

Ecosystem Diversity Maintenance

Maintaining ecosystems is the only way to ensure the continued viability and evolutionary processes of the organisms within these areas (see ch. 5). Numerous mechanisms exist at the Federal, State, and local level to manage land and water areas for their maintenance. The net result is the continued existence of a diversity of ecosystems in the United States.

Ecosystem diversity maintenance within Federal, State, and private holdings depends on the degree of protection given to the area, its size, and the impact of external influences. Protection of ecosystem diversity within land and water designations ranges from scant to strict. The use of land and waters in the National Wilderness Preservation System is greatly restricted—generally, motorized vehicles and long-term human activities are prohibited. Some wilderness areas are regularly patrolled and violators cited. Others receive little regulatory attention. At the other extreme, estuarine sanctuaries are not required to have any Federal protection; jurisdiction over any use is determined exclusively by the States. One preliminary assessment concluded that privately owned, legally secured, single-purpose nature reserves offer the greatest protection to biological diversity (10),

The size of a designated area and proximity to other land designations also influence its contribution to onsite diversity (10). Some Research Natural Areas (RNAs), for example, are well-protected but may be very small (the smallest is only 2 acres), Numerous vertebrates and larger plants would not be able to survive and reproduce successfully in a small "island" habitat; therefore, small RNAs contribute little to community diversity maintenance.

Natural areas are influenced by human activities on surrounding land that reduce the area's ability to sustain natural biological communities. The National Park Service has reported that 55 percent of the threats to park natural resources come from influences outside park boundaries (64). The National Wildlife Refuge System also noted that influences from adjacent areas were harming the fish and wildlife within refuges (63). Concern over such threats has prompted introduction of legislation to minimize negative effects of activities conducted in adjacent areas,

Table 9-2 provides a summary of the Federal ecosystem conservation programs in which designated areas are maintained in a relatively natural condition, The land designations included are only some of more than 100 categories used by Federal agencies, Some programs involve more than one agency, such as the Re-

Table 9-2.—Examples of Federal Ecosystem Conservation Programs

Program title and responsible Federal agency or agencies	Number of units	Acres (millions)
Nationa/ Natural Landmarks		
National Park Service	10	0.95
U.S. Forest Service	48	0.69
Bureau of Land Management.	45	1056
Fish and Wildlife Service	3.15	
Federal Aviation Administration	1	0.003
Department of Energy	1	0.13
Department of Defense.	16	0.19
Department of Transportation	3	0.014
Bureau of Reclamation	1	0.032
Research Natural Areas		
National Park Service ...	66	2,3
U.S. Forest Service	151	0.184
Department of Energy	2	0.75
Fish and Wildlife Service	194	1,94
Bureau of Land Management.	18	0.048
Department of Defense.	4	0.006
Tennessee Valley Authority	4	0.0001
Bureau of Indian Affairs	1	00009
Wild and Scenic Rivers		
National Park Service	23	1,927 miles
Bureau of Land Management.	15	1,367 miles
U.S. Forest Service	23	2,098 miles
Fish and Wildlife Service ...	7	1,043 miles
Biosphere Reserves[a] (Man and the Biosphere)		
National Park Service	25	25.09
U.S. Forest Service	18	1.63
Fish and Wildlife Service	4	2.81
Bureau of Land Management,	1	0034
Agriculture Research Service	2	0.209
National Oceanic and Atmospheric Administration	3	0.633
Wilderness Areas		
U.S. Forest Service ...	332	31,84
Bureau of Land Management.	22	0.37
National Park Service	38	36.78
Fish and Wildlife Service	65	19,33
Nat\onal Parks		
National Park Service	337	79,44
National Monuments		
National Park Service	**77**	4.72
National Preserves		
National Park Service	**12**	21.10
Nat/onal Rivers		
National Park Service	**4**	0.359
National Forests		
U.S. Forest Service	**152**	190,4
Experimental Forests, Ranges, and Watersheds		
U.S. Forest Service	**88**	0.240
Experimental Ecological Reserves		
U.S. Forest Service	**27**	0.219
Fish and Wildlife Service	**2**	0.057
Bureau of Land Management.	**2**	0.022
National Oceanic and Atmospheric Administration	1	0.006
Agriculture Research Servtce	**4**	0.100
National Park Service	1	0.093
Tennessee Valley Authority	1	0.069
Smithsonian Institution	1	0,001
National Wildlife Refuges		
Fish and Wildlife Service	**424**	89.9
Outstanding Natural Areas Management		
Bureau of Land Management.	**37**	0.377
Areas of Critica/ Environmental Concern		
Bureau of Land Management.	**236**	1.94
Marine Sanctuaries		
National Oceanic and Atmospheric Administration	**7**	2,322 (sq. nautical miles)
Estuarine Sanctuaries		
National Oceanic and Atmospheric Administration	**17**	268,762 (sq. nautical miles)
National Environmental Research Parks		
Department of Energy	**5**	1.15

NOTE When more than one aaency has res~onslblity for an area acreaqe has been dlwded eWJall Y and each a9enc Y receives credit for an area
[a]Because biosphere reserves ;re managed by severa~ agencies slmul tan eously the total number (53) in the table exceeds [he actual n u m ber of reserves (43)

SOURCE Adapted from W D Crumpacker Status and Trends of U S Natural Ecosystems OTA commissioned paper. 1985, M Bean. 'Federal Laws and Policies Pertaining to the Maintenance of Biological Diversity on Federal and Private Lands, OTA commissioned paper. 1985

search Natural Area Program. Other programs are under the jurisdiction of just one agency, such as the National Forest System.

Few programs are designed specifically to maintain biological diversity, even though some programs may indirectly have this as one of their objectives. One exception is the Man and the Biosphere Program, coordinated through the United Nations Educational, Scientific, and Cultural Organization (UNESCO), which considers the onsite maintenance of biological diversity a major goal (17). The U.S. network of 43 biosphere reserves provides a framework for linking complementary protected areas in particular biogeographical regions and for conducting research on strategies for managing ecosystems to conserve diversity (22). The U.S.

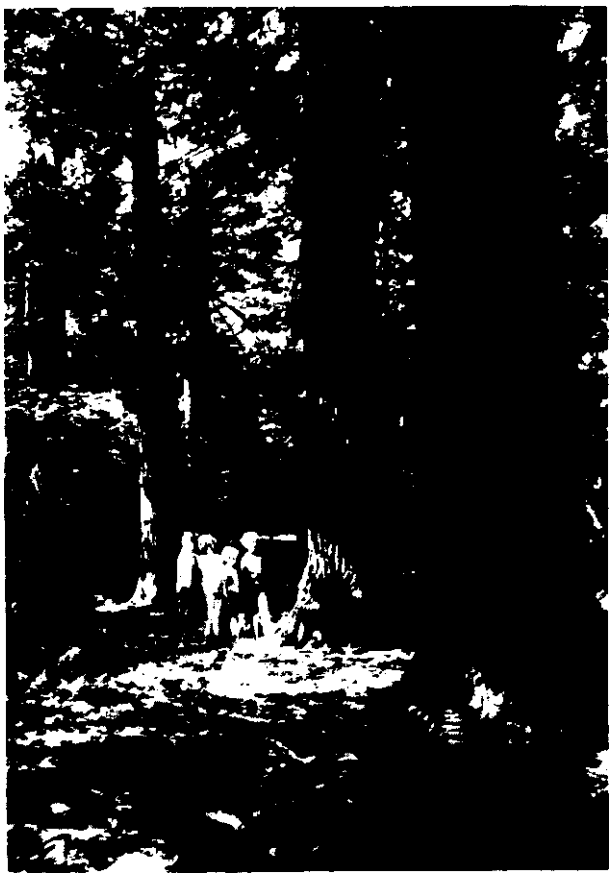
M

program, unlike programs in other countries, is strictly voluntary; designation is used mainly to encourage cooperation and increase use for scientific and educational purposes,

Research Natural Areas and Experimental Ecological Areas are designated by appropriate Federal agencies and the National Science Foundation, respectively, to conserve natural ecological communities for research in natural community manipulation. A Federal Committee on Ecological Reserves was established in 1974 to coordinate designation of these sites, in part to ensure that each community type was included in the system (4). The coordinating committee still exists nominally, but it no longer provides an advisory function. Designations of Research Natural Areas are currently determined independently by each Federal agency.

A variety of management options exist within programs that consider diversity an objective, For example, national forests are directed by law (National Forest Management Act) to be managed in a way that sustains plant and animal diversity, At the individual forest level, supervisors have flexibility in determining how and to what extent vertebrate species diversity will be considered in forest operations.

Similarly, National Wildlife Refuges and National Parks consider maintaining diversity an objective, although this attitude is not supported by specific mandate. National Wildlife Refuge managers may try to maintain a diversity of species with the existing habitat or may manipulate areas to create a diversity of habitats, In some cases, refuges are managed exclusively for a single species. National Parks have to bal-



m
m h
fl m g g h g
G N P

Contributions of these Federal programs to maintaining diversity depends on the degree of protection offered for each designation (10). For example, National Natural Landmarks are designated to identify and conserve unique, rare, or representative communities in the United States. Designation of these sites does not, however, include protecting the site from human alteration. Approximately half the National Natural Landmarks exist on private lands, where conservation depends on the good will of the individual landowner. National Natural Landmarks on Federal- or State-controlled lands require the cooperation of the authorized agency to ensure that protection is considered in the area's management.

An attempt has been made to identify the amount of potential ecosystem diversity that is protected in Federal landholdings. Potential ecosystem diversity is that which would be expected to develop on a site under natural conditions. According to an assessment that considered areas of approximatey 23,000 acres or larger, lands of four agencies failed to include 22 percent of the recognized ecosystem types (i.e., 69 out of 315), These four agencies were the National Park Service, Forest Service, Fish and Wildlife Service, and Bureau of Land Management. Another 29 percent of these ecosystem types were only minimally included (9). Since this analysis assessed only potential diversity, it probably underestimates existing ecosystem diversity in the landholdings (9). The largest number of unrepresented types were in Texas and Oklahoma, which have relatively large amounts of ecosystem diversity but relatively few Federal lands.

Another analysis of the same Federal holdings, using a different classification scheme for potential ecosystem diversity, obtained similar results (12). These two studies indicate that any attempt to include all ecosystem types within Federal programs would require considerable expansion of existing holdings. For the national wilderness preservation system, however, almost half the unrepresented types in that system could be added from existing Federal agency holdings (12).

Natural area management programs also occur at the State level. State parks, forests, and protected sites may be managed for one or a few resources, but they help preserve some remnants of diversity, particularly when they are managed in conjunction with private or Federal reserves. State designations could also be wildlife areas, fishing areas, university research stations, botanic sites, school and other public lands, or special districts (e. g., a water management district) (10).

Private holdings also contribute to maintaining diversity, especially through the protection of remnant areas. Many of the remaining tall grass prairies in the Midwest, for example, are privately owned by individuals or as railroad right-of-ways. private land trusts lease parcels of land for biological or historical significance, which may contribute to onsite diversity maintenance. (For further details, see ref. 55.) Many of the land parcels are small and isolated, with little attention given expressly to diversity maintenance, but they do contribute to the patchwork of natural areas in the United States. An assessment of the protection associated with all these Federal, State, local, and private land designations is under way (11).

One private institution with an explicit goal of natural area preservation is The Nature Conservancy (TNC), TNC is a nonprofit organization with chapters in most States. Its objectives are to identify species and community diversity onsite, purchase areas or work with landholders to protect the species or community, and manage areas to ensure the continued existence of the species or community.

TNC, through State Natural Heritage Programs (discussed in ch, 5 and in the next section), conducts field investigations of rare, threatened, or endangered organisms and communities across the Nation. The information generated from these surveys helps identify organisms that should be given Federal or State protected status, as well as habitats and communities where special attention is necessary.

TNC, one of the largest private landholders in the United States, owns 895 preserves (39). In addition, it works with Federal, State, and local governments to designate protected areas. Thus, the organization, through a grassroots approach, is effectively identifying and maintaining a diversity of rare species or community types in the United States.

Species Habitat Prosection

The most comprehensive national program for the protection of species diversity and their habitats is the Endangered Species Program, authorized under the Endangered Species Act of 1973, The program authorizes the Secretary of the Interior, through the U.S. Fish and Wildlife Service (FWS), and the Secretary of Commerce, through the National Marine Fisheries Service (NMFS), to protect endangered and threatened species of plants and animals in the United States and elsewhere.

The program, administered by the Office of Endangered Species, has several phases: listing species, developing recovery plans, and managing species' habitats. Species are listed as threatened or endangered when sufficient information on the status and distribution of the species suggests significant declines in population or range or both and when an extensive public review has been completed. In general, a species is considered a candidate between the time a petition to propose a species is received and the listing process is completed. In addition, many candidate lists are put together through expert review by the regional and Washington offices of the FWS,

Lists of candidates are published periodically in the Federal *Register.* (The most recent lists were published in September 1985 for vertebrates and plants and in May 1984 for invertebrates.) To date, approximately 3,9oo species and subspecies of plants, vertebrates, and invertebrates are candidates compared with approximately 385 species already listed (18).

When a species is listed, the next step is development of a formal recovery plan outlining the responsibilities of all parties with jurisdiction over the species' habitat and their management roles. Recovery plans are advisory documents to the Secretary of the Interior, not binding agreements. Recovery plans are approved or awaiting approval for approximately two-thirds of the species listed (see table 9-3), Implementation of recovery activities, however, has been slow (13).

The thrust of the Endangered Species Program is protection through proper management of a species' habitat. Most management activities are carried out by Federal and State agencies with jurisdiction over the habitats, not by FWS (unless the species occur on National

Table 9-3.— Number of U.S. Species at Various Stages of Listing and Recovery as of 1985

Species Identified as candidates for listing	3,908
Candidates with completed status research	964
Species IIsted as threatened or endangered .	383
Species with approved recovery plans . . .	223
Species recovering ...	22

SOURCE J Fttzgeralc-and G M Meese Sawng *Endangered Spec/es* (Wash, n g (on DC Defenders of WIldl!fe 1986I

Wildlife Refuges]. These habitats, often called critical habitats—because the species depend on these areas for survi~ral or reproduction—are designated either in conjunction with, or subsequent to, the listing of a species. To date, critical-habitat designations have been made for only about 70 listed species (13),

A federally listed threatened or endangered species is protected from any federally authorized activity that may jeopardize its continued existence, even when the activity occurs entirely on private land (4), Any Federal agency undertaking or authorizing a project in the range of an endangered species must consult with FWS or NMFS to ensure that the impacts on a listed species tvill be minimal. The consultation requirement is one of the most effective parts of the program in protecting threatened or endangered species (4). It is one of the least well-funded areas of the Endangered Species Program, however.

To a limited degree, efforts to manage a threatened or endangered species involve offsite techniques, such as artificial propagation of plants and captive breeding programs for animals. Efforts to recover several species of large birds (e.g., the peregrine falcon and whooping crane) demonstrate the success of such techniques, In some cases, captive breeding programs provided the opportunity for species to be reintroduced into their historic range.

In addition to Federal activities, State agencies may receive Federal funding to implement species-specific recovery and management efforts. To date, 41 States have approved programs for animals, and 17 have programs for plants (4).

Overall, the Endangered Species Program effectively maintains species already listed and protected under the law, but it provides insufficient protection for those that are candidates, The program is criticized for the slow pace of candidate review in the listing process. Some animals and plants may have become extinct between the time they were proposed as candidates and their review by FWS (4,18). The Texas Henslow's sparrow and the Schweinitz's Waterweed are two such examples (31). This delay underscores the need to list species or take other action in time to prevent their loss,

By publishing lists of candidates in the *Federal Register,* the Endangered Species Office has succeeded in bringing public attention to these candidates. Now the office is working with other Federal agencies to promote consideration of candidate species in agency planning. However, no legislative authority currently protects candidates from adverse impacts of Federal agency actions.

Underfunding and understaffing of the Office of Endangered Species hampers its ability to implement listing, recovery, and consultation objectives *(18).* With an increased budget, resources would be applied initially to develop recovery plans for all listed species. Consultation among agencies is also severely underfunded. Any funding increase to the Endangered Species Program could be gradual, over 5 years perhaps, so the office could expand existing program efforts. Program growth might involve annual increases of **$2** million for State grant programs, **$500,000** for species listing, $1.5 million for consultation, and $4 million for recovery plans **(54).**

Other programs identify and protect selected species, sometimes known as public trust resources, designated in Federal mandates, Examples include migratory bird management and anadromous fish hatchery programs, The programs provide little protection for overall species diversity. The Fish and Wildlife Service, the major Federal agency with authority to manage biological resources, is currently focusing its limited personnel and budget al locat ions primarily on publIc trust resources.

One Federal program focusing on public trust resources is the National Wildlife Refuge Sys-

tern, administered by FWS (3). Many of the refuges have been created by revenues from annual waterfowl hunting permits. Consequently, most refuges are purchased to protect habitats for migratory birds. Refuges may also protect habitats of threatened or endangered species (e.g., Atwater Prairie Chicken National Wildlife Refuge in Texas) or large mammals (National Bison Range in Montana), with funding from the Land and Water Conservation Fund, a land trust funded by the sales of grazing leases, offshore oil, mineral rights, and other sources on Federal lands. The Land and Water Conservation Fund is the principal source of money for land purchases by Federal agencies.

Refuges may provide habitats for a diversity of species, but the designation of the refuge is to benefit one or a few species of special interest, Woodland habitats along some east coast refuges, for example, have been converted to grassland-wetland habitats to enhance waterfowl at the expense of overall diversity.

State programs also tend to focus on selected species of fish, wildlife, and plants, although the emphasis differs somewhat from Federal programs. States generally receive revenues from hunters, fishermen, and Federal grants, for management and conservation of harvested species. Interest in nongame species is increasing, however. State agencies, through referendums, are expanding their fish and wildlife programs to a wider array of species' conservation efforts. Public pressure to conserve and manage nongame populations and increased budgets to implement programs (62) are increasing State efforts. However, State nongame programs are funded by add-on monies from tax checkoffs, which hampers the ability of most States to adequately fund or maintain personnel for their nongame programs. In addition, this type of funding severely hampers long-range planning and implementation of nongame projects. An alternative to this type of funding is to provide monies from the State's general fund, as is being done by the Florida Fresh Water Game and Fish Commission (31).

Another State activity is the Natural Heritage program, a set of public and private programs to protect diversity in each State (46), Each program develops an inventory of the State's rare species and ecosystems and identifies priority actions. The Nature Conservancy establishes and initially supports the programs. In some instances, States will take over the program devised by TNC and incorporate activities into the State government. In other instances, States and TNC share responsibilities.

State Natural Heritage Programs and databases are designed to be compatible so national information on species diversity can be collated, As of February 1986,44 States had contracted for the program and 26 of these had assumed administration of the program from TNC (30), The Conservancy also maintains four noncontracted programs and has separate contracts with the Tennessee Valley Authority, the Navaho Nation, and Puerto Rico,

Programs' abilities to protect diversity are limited by their resources and the degree of influence they have in the State governments. The Rhode Island program, for instance, although part of the State government, receives its funding from the Federal Fish and Wildlife Service, Thus, its inventory is primarily limited to species identified by the Endangered Species Act, A lack of resources and influence hamper this program's ability to comment on State and Federal developments and State land-acquisitions. The South Carolina program, also part of the State government, is supported by a $400,000 State grant fund and income-tax checkoff (21). with these resources, the program maintains a larger inventory, buys and manages land, and comments on all relevant State and Federal developments.

programs that are not part of a State government have fewer resources and opportunities to affect Federal and State decisions. Two further constraints are the limited information that programs are able to collect and the lack of a national classification system for natural ecosystems.

Nevertheless, State Natural Heritage Programs perform a function unfulfilled by existing institutions. The continuing inventory of rare species and ecosystems enables the pro-

tection of the most important biologically diverse lands and the early identification and modification of potentially destructive development plans.

A variety of private conservation organizations work to protect species of particular interest. The National Audubon Society, for example, maintains some 60 refuges to protect the habitat of endangered species. Many of the first refuges were designated to protect marine and coastal waterbird colonies (I 5). More recently, sanctuaries are being acquired to protect inland habitats and to restrict development. These areas provide refuge for an array of species, in addition to the key species for which the sanctuary was purchased.

Conservation organizations such as Izaak Walton League of America help maintain diversity through an advocacy role. These groups work with the U.S. Congress and Federal and State agencies to develop laws and programs that reflect the importance of maintaining species. Like Federal programs, diversity conservation is not a stated objective of most nonprofit organizations (except TNC), but their efforts aid in maintaining species and habitat diversity on site.

Additional groups working for species preservation include single-species organizations or foundations, such as the Carolina Bird Club, Desert Fishes Council, or Trout Unlimited (47). These offices work to promote habitat protection for these organisms, manage habitats for particular species, and advocate survival of these species through Federal and State agencies. The net result is species maintenance and conservation of particular components of biological diversity.

A multitude of nonprofit organizations also function at the local and State level. These groups tend to be small, poorly financed, and focused on a particular area or species of concern. (For further discussion, see ref. 59.) Such organizations generally do not have biological diversity as an exclusive objective, but they contribute to the maintenance of biological diversity through their achievernents of preserving a specific species o f concern or its habitat.

Onsite Restoration

Another facet of maintaining biological diversity is the restoration of degraded sites. The field is relatively new, few institutions have well-developed programs, and complete restoration has been difficult to achieve. (See ch. 5 for discussion of restoration technologies.)

A key Federal legislation that directly provides for revegetation after a disturbance is the Surface Mining Control and Reclamation Act of 1977, also known as S MC RA (Public Law 95-87). Section 515(b)(19) states that mining operations shall:

> . . . establish . . . a diverse, effective, permanent vegetation cover of the same seasonal variety native to the area of land to be affected.

The number and composition of species is often suggested by past management practices. The Bureau of Land Management (BLM), Forest Service, and Soil Conservation Service have each developed vegetative mixtures for various types of disturbances that can be economically managed and are likely to succeed. There is a problem, however, with the definition of "native." BLM, for instance, interprets native to include introduced exotics that have been established within the area before the project was assessed.

Section 515(b)(2) states that the mine operation shall:

> . . . restore the land affected to a condition capable of supporting the use which it was capable of supporting prior to any mining, or higher or better uses.

Thus, SMCRA provides an incentive to develop techniques for establishing native plant species. The natural diversity aspect of SMCRA could be strengthened at the State level by requiring the use of native species in revegetat ion mixtures.

A few Federal agencies are initiating restoration efforts. The Forest Service is mandated by the National Forest Management Act of 1976 to replant all lands in the National Forest System that do not regenerate naturally after timber harvesting. Tree monoculture are most 1ikely to be planted, thus reducing diversity in-

stead of restoring the area's original diversity. The National Park Service (NPS) has instituted small-scale restoration projects, mainly for areas affected by past tourist use or other disturbances (32). An exception to the typical small-scale NPS restoration project is the legislatively mandated (Public Law 95-250) Redwood Creek rehabilitation project in Redwood National Park. The project is developing rehabilitation techniques for 36,000 acres of previously logged and seriously eroded slopes in the redwood-mixed conifer ecosystem.

The Fish and Wildlife Service and Environmental Protection Agency identify water bodies polluted by chemicals or acid rain that are suitable for restoration. In lakes damaged by acid rain in the Northeast, for example, FWS has spent $5 million in a liming effort to reduce lake acidity and restore aquatic life (32). The U.S. Army Corps of Engineers is researching wetland restoration techniques to mitigate development projects in wetlands,

One future opportunity to restore diversity is by the U.S. Department of Agriculture's (USDA) implementation of the conservation reserve provision of the Food Security Act of 1985 (Public Law 99-198). The conservation reserve:

> . . . authorizes USDA to contract with farmers to remove 40 million acres of erodible land from row crop production. . . , The retired acres would be planted to grasses, legumes, and trees to reduce erosion and enhance wildlife (66).

This provision could be strengthened if restoration of vegetation in riparian areas were included in the legislation, The reconstruction of debt portion of this bill may be more beneficial to diversity. It allows the farmer to offer up land for not less than 50 years to be used to lower the debt.

Private efforts may be the leading contributors to restoring biological diversity. Although much reclamation is being carried out by industries and consulting firms in compliance with regulations, work is also being done by small organizations and individuals motivated by esthetic and environmental interests. Universities also are conducting research to develop techniques for restoring different ecosystems, Recently, restoration has been identified as a focus of research at the Cary Arboretum in New York and at the Center for Restoration Ecology at the University of Wisconsin (32),

OFFSITE DIVERSITY MAINTENANCE PROGRAMS

Federal programs to maintain diversity offsite generally involve germplasm of agriculturally or economically important plants and animals, Less attention is given to wild plants and animals at the Federal level than at the State or private level. State efforts to conserve a diversity of plants, animals, or micro-organisms offsite are poorly documented and tend to be widely dispersed. Private institutions conduct numerous activities directly related to the maintenance of biological diversity offsite. Consequently, offsite conservation of many biological resources occurs only as a result of private efforts. For ease in discussion, offsite maintenance of biological diversity is divided into plant, animal, and micro-organism programs, although programs overlap considerably.

Plans Programs

Historically, responsibilities for maintaining plant resources at the Federal level included only domesticated plants under the jurisdiction of USDA. Although recent legislation has included some wild plant species (e. g., Forest and Rangeland Renewable Resources Research Act, Rural Development Act), the focus of USDA is still reflected in programs to maintain crop-related germplasm,

Agricultural Plants

The most significant program is the National Plant Germplasm System (NPGS)—a diffuse network of USDA, State, and private institutions, private industry, and individuals. NPGS

activities include acquiring, maintaining, and improving plant germplasm. Various components of the system also conduct research that supports preservation of genetic diversity, acquisition of new materials, and use of stored germplasm (see figure 9-l).

Work done by NPGS is in response to specific national needs. Agricultural plant exploration and development of new crop species led to a formal Federal program (Section of Seed and Plant Introduction) in 1898 within USDA (28). Recognizing that germplasm resources were being lost due to inadequate maintenance facilities, Congress enacted the Agricultural Marketing Act in 1946, authorizing regional centers to maintain and develop plant germplasm (27).

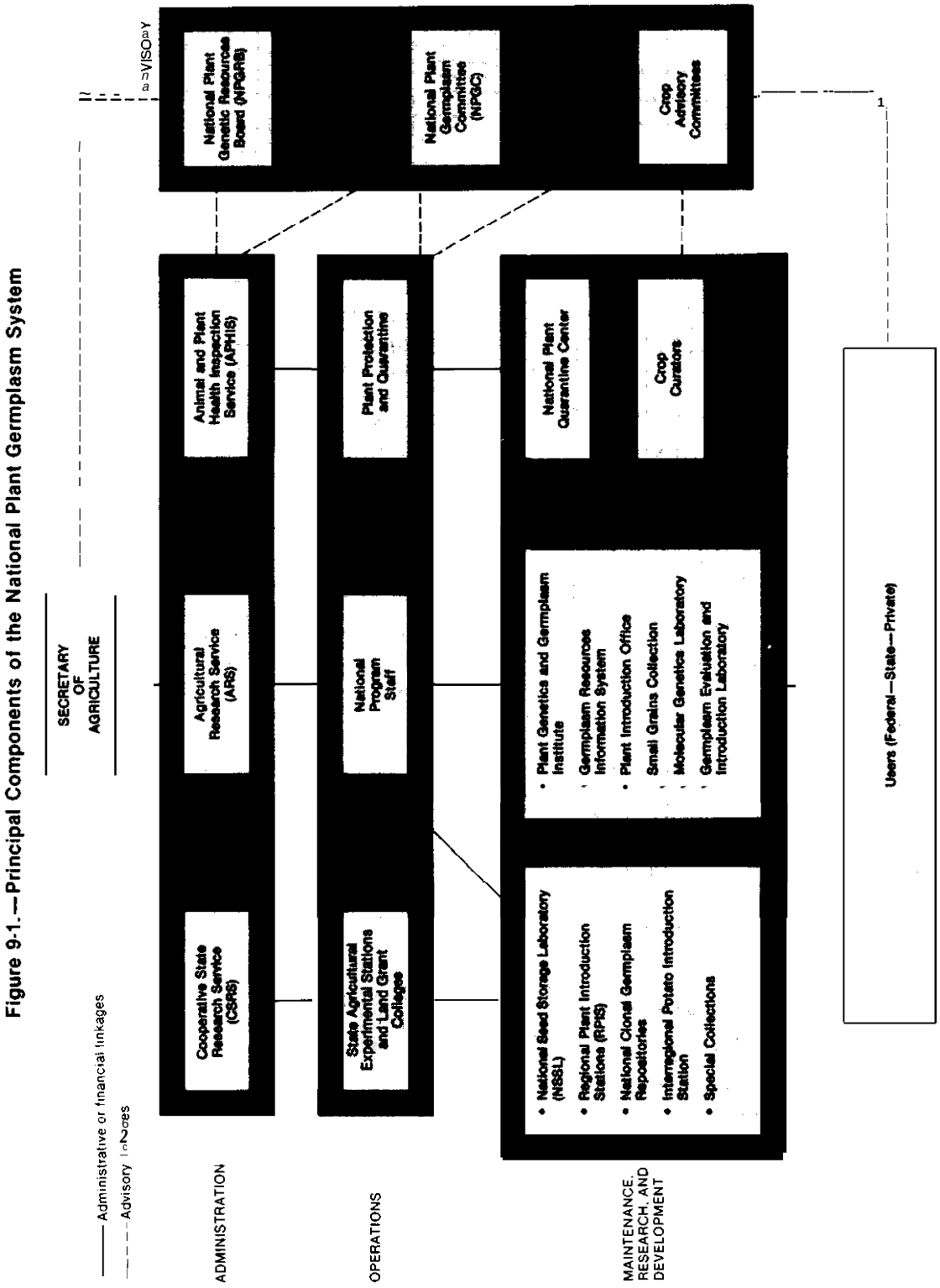
Federal contributions to NPGS currently are administered through the Agricultural Research Service (ARS) and the Cooperative State Research Service (CSRS). The ARS National Program Staff in Beltsville, MD, coordinates these various activities and facilities:

- *Advisory Committees:* The National Plant Germplasm Committee and individual crop advisory committees provide both policy and technical advice to administrators and curators of NPGS. The National Plant Genetic Resources Board advises the Secretary of Agriculture on resource issues and serves as liaison between NPGS and the International Board for Plant Genetic Resources.
- *Plant Genetics and Germplasm Institute:* This USDA/ARS facility includes the following:
  - —the Plant Introduction Office that coordinates the acquisition of new materials, assignment of introduction numbers, and distribution to appropriate facilities;
  - —the Plant Molecular Genetics Laboratory, devoted to developing methods for using germplasm to improve crops;
  - —the Germplasm Resources Information Network (GRIN) Database Management Unit, responsible for developing and maintaining the computer-based system that is intended to contain passport, evaluation, and inventory information on NPGS germplasm; and
  - —the National Small Grains Collection.
- *National Seed Storage Laborator~:* The National Seed Storage Laboratory (NSSL) in Ft. Collins, CO, is designed to be the principal storage facility for agricultural crop seeds in the NPGS, Ideally, all plant varieties are stored at NSSL as base collections. NSSL is responsible for monitoring the viability of seeds within its collections as well as seeds stored in active collections. The laboratory does not evaluate its samples, however, and depends on other facilities in the network to regenerate samples when germination declines,
- *Germplasm Collections:* National responsibility for maintaining major crops is divided among four Regional Plant Introduction Stations (RPISS). Many important collections are not associated with an RPIS, such as those for soybeans, cotton, sugar crops, and small grains. Germplasm that must be clonally maintained is the responsibility of the five newly established and four developing national clonal repositories. Several collections of genetic or mutant stocks that possess specific traits exist, Although not generally used in breeding, such stocks have been important resources for research on cytogenetics, physiology, biochemistry, and molecular genetics of crops.

The mission of NPGS is to acquire, maintain, evaluate, and make accessible as wide a range of genetic diversity as possible in the form of seed and clonal materials to crop breeders and plant scientists (60), The scientific expertise on germplasm maintenance is among the best available,

Assessments of NPGS during the past 5 years have highlighted shortcomings in coordination, communication, storage facilities, maintenance of seed viability, and staffing levels (7,56,57,60). Facilities such as NSSL, for example, have been criticized for inadequately maintaining seed stocks and for storage limitations. A 1981 study by the General Accounting Office (GAO) found that NPGS curators sent only half the seeds

Figure 9-1.—Principal Components of the National Plant Germplasm System



SOURCE: Office of Technology Assessment.

from active collections to the NSSL (56). And the study determined that approximately 63 percent of the active germplasm collections were stored in inadequate containers or in undesirable climates, The result, GAO concluded, may be the loss of at least one-fourth of the germplasm resources held by NPGS.

Efforts have been made to address some of these deficiencies through reallocation of resources, construction of new facilities, and centralization of responsibilities, but the need to improve germplasm maintenance remains, Recommendations to improve NPGS have been hampered by the diffuse nature of the network and by inadequate resources.

The system has been cited as needing a clearer division of responsibility y for maintaining and evaluating germplasm collections (7), Because it is a cooperative network, lines of authority are frequently unclear, and there may be too many levels of authority to adequately administer a national program on germplasm (60). The result is a general lack of understanding of how decisions concerning NPGS are made by ARS. Such decisions can be further complicated by the competing interests and concerns of other cooperative Federal (i. e., CSRS] or State agencies that may provide program support.

The ARS staff has recently increased its input into budget allocations for Federal facilities and has attempted to centralize program responsibilities into one office (42). Further centralization could provide increased coordination of the system's collections, improved communication on available germplasm diversity (especially through the GRIN database), and more effective identification of funding priorities.

One area that has received insufficient funds is regeneration of seeds with reduced viability. Although NSSL monitors seed viability, it sends seeds that germinate poorly to another facility for growing-out. If viability is found to be low, it may be difficult to obtain a regenerated sample. If NPGS does not have specific responsibility for a sample, NSSL must locate a willing donor, but it does not have funds to pay for grow-outs. A comprehensive system to support regeneration of stored seed has been hampered by competing interests for available resources.

The crop advisory committees {CACS) in NPGS were developed to improve communication about crop-specific needs (see table 9-4). CACS are comprised of scientists from NPGS, private industry, and the academic community. They provide technical expertise to the NationaI Plant Genetic Resources Board, the National Plant Germplasm Committee, ARS staff, and NPGS curators. In some cases, such as the pear collection at the national clonal repository in Corvallis, OR, CACS advise the facility in charge of a particular crop **(7].**

CACS are growing in importance and influence within NPGS (45). Committees have been

Table 9.4.—Existing and Proposed Crop Advisory Committees of the National Plant Germplasm System

Existing committees	Proposed committees
Alfalfa	Asparagus
Barley	Florist crops
Carya	Leafy vegetables
Citrus	Tropical fruit and nuts
Clover	Woody ornaments
Cotton	
Crucifer	
Grass	
Juglans	
Maize	
Malus	
Oats	
Pea	
Peanut	
Phaseolus	
Potato	
Prunus	
Pyrus	
Rice	
Root and bulb	
Small fruits	
Sorghum	
Soybean	
Sugar beet	
Sugarcane	
Sunflower	
Sweet potato	
Tomato	
Vigna	
Vine crops	
Vitis	
Wheat	

SOURCE U S Department of Agriculture, Agricultural Research Service Plant Genetics and Germplasm Institute Germplasm Resources Information Network, Progress Update, February 1986

asked to identify gaps in the diversity of crop species, coordinate collection and maintenance needs, develop priorities for crops, and assess the data available on accessions. However, no provision exists within NPGS to ensure that the necessary meetings of a CAC will be held or reports developed. To date, NPGS has relied on the dedication and commitment of the scientists involved to accomplish these tasks, Although some CACS have achieved a great deal, others have been slow to organize and develop their activities. ARS has argued that funding or other support for CACS is unnecessary, but OTA has found the committees feel they would be more effective if funds for frequent and regular meetings were available.

The diverse nature of NPGS can also be seen in its different roles of providing service functions of maintaining germplasm and undertaking research programs. Functions such as growing out seeds, evaluating accessions, assessing viability, and managing information are service-oriented, Many Federal and State scientists within NPGS, however, are evaluated on a system that can provide disincentives for such activities. The problem can become acute when decreased funding means that research staff must handle service functions.

The need for more personnel and funding has increased with the amount of germplasm held by NPGS facilities, Concern about characterization and evaluation of accessions has created additional burdens for many facilities. Therefore, proposed changes should consider improved support of the basic operations along with plans for new construction.

The National Seed Storage Laboratory continues to need improvement (7,56,57,58,60). Within 2 years, the existing facility will exceed its storage capacity. Collections at the RPISS and other facilities are witholding some accessions from NSSL. But keeping them creates an additional burden for facilities not equipped for long-term storage. Without expanded space, NSSL cannot provide the necessary backup storage for NPGS germplasm collections.

In addition, NSSL storage rooms were built before the use of subfreezing and cryogenic storage. OTA found that the NSSL collections require upgraded facilities with access to modern storage technologies and backup refrigeration systems. One proposed NSSL facility would quadruple present storage capacity and enable use of modern technologies. Funds for construction, however, are not available in the Administration's current budget (4.5).

Although many long-standing deficiencies have been addressed by administrative changes such as creation of the crop advisory committees, future improvements of NPGS will require additional funds for facilities, as well as personnel, equipment, and supplies to support basic operations.

Most States do not formally fund offsite germplasm maintenance activities independent of NPGS, California, an exception, began a program in 1980 to conserve the genetic diversity of important plant and animal species within the State (33). The California Gene Resources Conservation Program, which is currently inactive, raised awareness of the need to conserve germplasm resources, A program at the University of California at Davis will conduct research on germplasm resources in the State and provide funds for orphan collections, those that may be vulnerable due to the death or retirement of principal curators (49).

Private individuals and grassroots organizations are preserving a significant amount of agricultural crop diversity not found in governmental collections (20,44,59), The Seed Savers Exchange, for example, helps preserve heirloom vegetable varieties and other vegetable seeds not available from the Federal Government or commercial producers. The exchange of seeds among its 450 members helps ensure the survival of some 3,500 plant varieties, most of which can be found only within the organization. (For further discussion of Seed Savers Exchange and other grassroots efforts to preserve agricultural plant germplasm, see ref. 59.)

Private industry also maintains plant germplasm in conjunction with developmental programs for new crop varieties or as marketed seed varieties, United Brands, for instance, maintains the most extensive collection of

W

banana germplasm (23). Although the objective in most *cases* is not the maintenance of genetic diversity, industries could maintain germplasm resources that contribute to the overall plant diversity in the United States.

Support can be provided by private industry by granting funds, equipment, facilities, or land. The Rhododendron Species Foundation, for example, maintains an extensive collection of wild rhododendrons at a facility donated by the Weyerhaeuser Co. (59), A grant to NPGS by Pioneer Hi-Bred International, Inc., of $1.5 million over 5 years will support the evaluation of Latin American corn varieties (2)—work not possible under present NPGS budgets.

Wild Plants

No Federal equivalent to NPGS exists for wild plant species. Although NPGS maintains some wild plant germplasm, this is clearly a secondary function and generally involves relatives of cultivated crops or species economically valuable, such as ornamental or florist crops. Most wild plant diversity is stored in living collections such as botanic gardens and arboretums.

Federal programs that make some contribution to maintaining wild plant diversity do not cover the majority of plant diversity, USDA's Soil Conservation Service (SCS) maintains some wild species (those with known or suspected value to soil or water conservation) in its Plant Materials Centers. Species not being used in plant development programs are sent to NSSL (52).

The Forest Service maintains germplasm of tree species with known or potential commercial value (5). The Smithsonian Institution maintains an extensive collection of North American wild plant species. The Office of Endangered Species provides some funding for offsite maintenance and propagation of threatened or endangered plant species.

The contributions of current State efforts are unclear. Generally, State programs are coordinated through the State Department of Agriculture and focus on species with some economic importance to the State—e. g., timber varieties, shrubs, and grasses useful in land reclamation, along with important wildlife foods.

The most significant offsite programs for germplasm are financed and managed in the private sector (59). One such effort, the Center for Plant Conservation (CPC), is beginning a network of botanic gardens and arboretums to conserve all threatened and endangered wild plant species. CPC, located at the Arnold Arboretum in Massachusetts, has solicited the participation of 14 major botanic institutions across the country to act as regional *centers* for wild plant diversity. By establishing a data network, CPC hopes to identify plant species

Photo credit L McMahan

Greenhouses of the Berry Botanic Garden, Portland, OR, Botanic gardens are becoming increasingly important to the effort to conserve diversity.

for inclusion into the national program (16). CPC also has agreements with NSSL for long-term storage of selected wild species (40).

Arboretums and botanic gardens historically have not considered the maintenance of wild plant diversity a goal (37). They have generally provided display gardens—areas where showy flowers or unique plants are presented–with a secondary objective of preserving wild plant species. Interest in maintaining diversity is increasing, however (37,59). In some cases, reproductive individuals of rare plant species may be found only in arboretums or botanic gardens. Yet, aquatic plants are underrepresented in botanic institutions, and few aquatic gardens exist to conserve such species.

Regardless of their objectives, these botanic institutions and the individuals who run them contribute to the maintenance of plant diversity. However, no coordination exists for information exchange or evaluation of contributions, Although it is too early to assess results, the Center for Plant Conservation may provide significant coordination of such efforts.

One possible way to improve offsite wild plant maintenance is to expand NPGS to include nonagricultural varieties. The objective is to take advantage of existing Federal, State, and private cooperation. Crop advisory committees could be established for species that are important but have little market value. NSSL could be expanded to serve as a repository for wild species' seeds that may have future economic or ecological significance. Existing plant centers and scientists could play a larger role in propagation and reintroduction programs for wild plant species, particularly threatened or endangered species.

The underlying responsibilities of NPGS would need to be changed to accommodate nonagricultural species. Biological differences between agricultural and wild species, such as dormancy and seed production barriers, would increase the need for research to prepare plans for storage, germination, and regeneration.

Expanding the role of the system to include wild plant species could reduce already insufficient funding for existing programs, however. The Agricultural Research Service budgeted nearly $16 million (gross) for germplasm work in 1986, but one report has estimated that by the 1990s, annual allocations of almost $40 million (1981 dollars) will be needed to support programs (43,60). Adding approximately 20,000 new plant species (perhaps millions of accessions to represent the diversity of each species) would severely strain an already underfunded program,

Animal Programs

The United States has no organized program for maintaining diversity in agricultural animals (6). Federal activities to conserve genetic

resources are minimal, and private efforts, though more substantial, are so disperse that it is difficult to assess gaps or overlaps.

Neither the Federal Government nor State governments have programs designed to maintain wild animal diversity offsite, It is minimally supported by Federal contributions to private sector programs, but no overall Federal plan exists and funding is erratic, Thus, the private sector is currently making the most significant contributions to maintaining domestic and wild animal diversity.

Domestic Animals

USDA was authorized to collect, maintain, and develop animal genetic resources under the same legislation that provides authority for the National Plant Germplasm System's components (Agricultural Marketing Act of 1946). However, USDA contributions to domestic animals did not evolve along with its agricultural plant activities.

The department has concentrated on identifying foreign germplasm of potential importance in U.S. livestock production. Beginning in the mid-1960s, a substantial number of foreign breeds were introduced into the United States (6). The importation of cattle was emphasized, but several breeds of sheep and swine were also introduced. Breeds were chosen for their likely contribution to U.S. agriculture and without particular attention to the degree of endangerment in their country of origin. Several of these stocks have since become firmly established within the United States.

USDA evaluated the breeds and in some cases (especially for sheep and swine) initiated their importation. A key group in this effort was the Germplasm Evaluation Program of the Roman L. Hruska U.S. Meat Animal Research Center (MARC) in Nebraska, which compared more than 20 foreign and domestic cattle breeds (61). Current efforts at MARC deal with development of composite gene-pool stocks for new and more productive breeds of sheep and swine.

Within the private sector, breed associations —loose unions of individuals who produce a particular livestock breed—have been formed for common species (e.g., cattle, pigs, sheep, goats, and horses) to record pedigrees and production of individuals within livestock breeds available in the United States (see table 9-5). These groups do not consider maintenance of biological diversity as a goal, although they may contribute to maintenance of animal genetic resources (25,59). A diversity of livestock breeds will be maintained only if an association exists for each breed.

Most programs that deal with germplasm conservation as such (i. e., separate from efforts to use that diversity within the livestock industry) are undertaken and funded by the private sector, Many minor livestock breeds in the United States are maintained by one person or a few individuals, working relatively independently (25,59).

The American Minor Breeds Conservancie (AMBC), a nonprofit organization, is currently seeking to identify these people and open lines of communication among them, (For further discussion of AMBC and the contributions of individuals and breed associations to domestic animal genetic diversity, see ref. 59.) AMBC recently completed a census of North American livestock that identifies some 80 breeds, including cattle, pigs, sheep, donkeys and

Table 9-5.—Active Breed Associations in the United States

Species	Number of associations	Number of registrations[a] Minimum	Maximum	Average
Beef cattle	18	297	195,267	43,976
Dairy cattle	6	4,085	425,385	89,382
Sheep	8	4<568	58,994	18,675
Swine	10	382	245,423	61,050
Horses	15	631	68,346	22.260

[a]For fiscal year 1983

SOURCE National Society of Livestock Record Associations 1983

mules, and goats, needing special attention to ensure their survival (26).

private companies also make significant contributions to animal germplasm maintenance. For example, the majority of poultry germplasm is maintained by firms that operate both domestically and internationally (6). Several maintain unselected, random-bred control lines that serve as reservoirs of genetic diversity. These lines, however, are vulnerable to changes in economic conditions, and their maintenance does not currently represent public or industry policy.

Artificial insemination (A. I.) firms control and distribute the majority of U.S. dairy cattle germplasm. These companies have formed pools of individual breeders involved in planned matings, testing progeny of specific germplasm strains, and development of improved breeding lines (6). Companies focus almost entirely on Holstein cattle because the market is so large. Increased emphases on planned matings among superior individuals have been required to maximize genetic improvement within the dairy industry because of intense competition among A.I. organizations,

As a result, new bulls for use in artificial insemination often represent the offspring of a small sample of bulls from the previous generation. For example, of the 6 to 7 million dairy cows bred each year in the United States, about 65 percent are impregnated by only 400 to 500 A.I. sires, In addition, of the approximately 1,000 performance-tested dairy bulls in a given year, nearly half are sons of the 10 best bulls of the previous generation (67). This process tends to maximize rates of genetic improvement and almost certainly will result in an excessive narrowing of the genetic base.

Researchers affiliated with universities and Agricultural Experiment Stations help identify genetic resources or help maintain and develop germplasm resources, although not as much as breed associations or private industries do, For example, one researcher at the University of Connecticut has produced an international registry of poultry genetic stocks that is annually updated and acts as an important catalog of existing poultry resources (53). University animal or veterinary science departments may maintain small breeding populations of livestock for experimental and educational purposes (26).

U.S. universities with programs for domestic animal research and utilization also play a role at the international level. The International Sheep and Goat Institute associated with Utah State University, for example, works with researchers and livestock operators in other countries to identify and propagate genotypes of sheep and goats. Although the focus of the institute is to assist countries in the production of sheep and goats best-suited to local environments, its members are also involved in training international institutions in the storage and management of sheep and goat genetic resources (29).

Even with these various efforts, the overall diversity within many domestic animal breeds is declining (6). In summary:

- Storage facilities do not exist for in *vitro* maintenance of sheep, swine, or poultry genetic stocks.
- Breed associations report that although a few breeds of sheep in the United States have declined to very small numbers, global diversity of sheep germplasm remains adequate.
- Genetic diversity in dairy and meat goats does not appear to be changing significantly.
- Because relatively few competitive strains of highly specialized egg and meat chickens, turkeys, and waterfowl account for much of the world poultry populations, there is concern about maintaining adequate genetic diversity for future needs.
- The increasing emphasis on whole-milk production dairy cattle favors the adoption of Holstein breeds among milk producers, causing the decline of other minor dairy breeds,
- Genetic diversity appears to be stabilized or increasing slightly in beef cattle in the United States.

Public awareness of the potential problems associated with loss of genetic diversity and institutional concern about the issue are not as evident for domestic animal species as they are for agricultural crop species. Concern about loss of agricultural animal diversity is increasing, however, at the international level, where a perception exists that a significant amount of genetic diversity is disappearing (see ch. 10). Insufficient information exists on the status and trends of domestic animal breeds at the global level to substantiate this belief (19), But it is the unregistered and unrecognized breeds that are in the greatest danger of becoming extinct.

Wild Animals

Federal efforts to maintain wild animals offsite occur only through the captive breeding programs of the U.S. Fish and Wildlife Service, individual specimens of critically endangered species may be selected for captive breeding programs at the Patuxent Wildlife Research Center in Patuxent, MD. The center has been responsible for the captive breeding and reintroduction of more than 60 species of birds, mammals, and reptiles native to the United States (37).

Endangered fish species have been propagated at the Fish and Wildlife Service's National Fish Hatchery in Dexter, NH, Additionally, FWS provides nominal funding for captive breeding and reintroduction programs for endangered animal species to the private sector, and in one case, to the State of Wyoming to recover the black-footed ferret. Overall, however, programs for the offsite maintenance of diversit y in wild animals are controlled and financed primarily by universities and institutions in the private sector ***(37).***

zoos are well-known storehouses for wild animal species, although historically they made few contributions to maintaining biological diversity. But their role in this area is becoming significant, especially in terms of public education. More institutions are identifying the need for expanded activity in research and technology development to maintain genetic diversit}r of zoo animals.

In one case, zoos are working together to maintain viable populations of wild animals bred in captivity. The American Association of Zoological Parks and Aquariums coordinates breeding programs for selected endangered wild species. These programs, known as Species Survival Plans (SSPS), are being implemented for some 30 species that are critically endangered in the wild, that have sufficient numbers at various zoos to ensure genetic viability within a captive breeding program, and that have a sufficient nucleus of professionals at the cooperating institutions to carry out the plan (l). (For a discussion of captive breeding techniques, see ch, 6.)

Breeding programs are designed by experts with knowledge of the species and carried out by scientists within the zoological community (l). Since more animal species meet the SSP criteria than zoos realistically have resources to implement, further criteria exist for determining which species to include:

1, a high probability' of successful implementation of the plan,
2. a high relative degree of endangerment, and
3, a high relative degree of uniqueness within the animal kingdom.

Species Survival Plans are designed to overcome the space and population limitations of most zoos. For many institutions, adequate facilities to maintain a viable breeding population of at least ***250*** animals simply do not exist. The SSP outlines agreements between participants in the program for the translocation of breeding adults or their reproductive products (e.g., eggs, sperm, or embryos) among zoos to simulate a much larger breeding population than could exist at and one facility, Information on the breeding programs must be carefully recorded and entered into a master database, the International Species inventory System (ISIS). These programs are too new to assess their effectiveness in maintaining genetic diversity.

ISIS was developed at the Minnesota Zoo to catalog information about the genetic makeup of individual animals from more than 200 zoo-

logical institutions worldwide. One goal in the database development was to address the problem of inbreeding among species within zoos. ISIS acts as a computerized matching service, helping zoos around the world identify other institutions that have distinct bloodlines in breeding populations of a particular wild animal (14), Other goals include identifying captive management problems, monitoring the captive status of some 2,500 species, and providing information to managers. It appears that ISIS is widely used by zoological institutions and therefore makes important contributions to maintaining genetic diversity.

A large number of zoos are not involved with the SSP or ISIS, yet still provide offsite maintenance of selected wild animal species. These institutions may support populations of locally endemic wild animals or include individuals of internationally rare species. Maintenance of a diversity of species or of individuals within a species is generally not an objective at these institutions, however.

Much of the work undertaken by zoos to preserve species involves internationally endangered ones, with less attention given to threatened and endangered species found in the United States. The focus on species from elsewhere in the world or exotic animals is due, in part, to the degree of endangerment of these animals. Those that are critically endangered in the United States, such as the California condor or the black-footed ferret, are also the focus of active captive breeding programs at U.S. zoos (8,36). Compared with zoos, most aquariums accord the maintenance of aquatic species diversity a low priority. Almost no work has been done at U.S. aquariums to maintain the diversity of species found in U.S. waters (38). When they need specimens, they generally collect them from the wild (37).

Fairly large collections of breeding wild animals are maintained by individuals, In many cases, these people establish societies around a particular species or group of species to exchange information and breeding stock among society members. Their efforts range from the small-scale activities of individuals that breed exotic birds or reptiles to the management of large herds of Asian and African antelope species by Texas game ranchers. (For further discussion, see ref. 59.)

Microbial Resource Programs

No U.S. institution or institutional mechanism addresses the preservation of microbial diversity. Numerous collections of micro-organisms exist in the United States in both the public and private sectors. Most were established to study a particular taxonomic group of micro-organisms, and they represent detailed sampling within that group. Several hundred specialized working collections of microbial germplasm are part of the basic and applied research programs of scientists working in both the public and private sectors (7).

Federal Institutions

The largest public microbial culture collection in the United States is the Northern Regional Research Laboratory (NRRL) collection held by USDA's Agricultural Research Service. It is an archival collection with a taxonomically broad range of micro-organisms stored for long-term preservation, NRRL does not publish a catalog of its holdings and does not encourage general distribution of the germplasm it holds, in part because of the high cost of distribution. No moderately sized collections (3,000 to 10,000 accessions) of micro-organisms function as national repositories or resource collections for a range of microbial classes (24).

Several collections supported by the U.S. Government are devoted to assembling microbial strains within a particular taxonomic group. The largest of these is held by the Neisseria Reference Laboratory of the U.S. Public Health Service. Similar taxonomically specific collections supported by USDA, such as the cereal rust collections at the Universities of Minnesota and Kansas, distribute microbial germplasm on request, but they generally do not catalog their holdings (24).

Like many scientific institutions, organizations holding culture collections are currently

suffering from financial cutbacks (24). Funding from USDA has been reduced or redirected to other areas at the expense of the network of archival collections (table 9-6). The result is a diminished capacity to maintain the record-keeping, authentication, and taxonomic characterization necessary for a collection. Expansion of existing collections is restricted by such financial constraints.

State Collections

No organized State efforts to collect and maintain microbial diversity, apart from specialized collections, seem to exist. The many specialized collections that exist at State universities and colleges are typically the responsibility of individual scientists. Some have gained institutional support and achieved national significance. Pennsylvania State University supports the major U.S. collection of *Fusarium* species, a plant fungus of major interest to breeders (7). Such efforts commonly depend on the continued interests and abilities of individuals who initiated them.

Unless sources of support and personnel are available, institutional commitments to microbial collections, where they exist, may not continue after key individuals leave, retire, or die—a problem noted earlier with regard to agricultural plant germplasm collections, When the curator of an extensive collection of *Rhizobium* germplasm died in 1975, his university was unable to provide future management for the extensive collection—at that time considered the richest collection in the world of soil bacteria in this group (24), It would have been lost had it not been acquired by the University of Hawaii as part of a U.S. Agency for International Development (USAID) research project in 1976.

It was not until 1981 that the university agreed to accept responsibility to maintain the collection in perpetuity as part of an international

Table 9-6.—Microbial Culture Collections in the United States With More Than 1,000 Accessions

Collection	Sponsor	Number of cultures
Living re;ource:		
American type culture collection (Rockville, MD)	Private	27,630
Reference and archival:		
Northern Regional Research Center. (Peoria, IL)	Government	63,000
USDA Rhizobium Culture Center (Beltsville, MD)	Government	1,200
Neisseria Repository, School of Public Health (Berkeley, CA)	Government	1,700
Neisseria Reference Laboratory (Seattle, WA)	Government	30,000
NiFTAL Rhizobium Germplasm Resource (Paia, Hi)	Government and university	2,000
Plasmid Reference Center (Stanford, CA)	Government and university	2,000
Education and research:		
Fungal Genetics Stock Center (Arcata, CA)	Government	7,755
L.L. Collection Waksman Institute of Microbiology. (Piscataway, NJ)	University	3,070
Industry:		
Microbial and Fermentation Products Research (Indianapolis, IN)	Industry	66,060
Upjohn Culture Collection (Kalamazoo, Ml)	Industry	7,755

SOURCE V F McGowen and V B D Skerman, *World Directory of Collections of Cultures of Microorganisms* (Brisbane Australia World Data Center, 1982)

agreement designating them as an international Microbiological Resource Center, under the auspices of UNESCO and the United Nations Environment Programme / International Cell Research Organization Panel on Microbiology (see ch. 10). Such an agreement would not have been possible if the University of Hawaii had not obtained USAID funding.

Private Collections

The best microbial resource reference collection in the United States is maintained by the American Type Culture Collection (ATCC). ATCC is a national nonprofit repository for medical, industrial, and agricultural microbial germplasm, as well as a national and international repository for patented microbes. Its collection of approximately 36,000 strains includes bacteria, fungi, clamydiae, rickettsiae, protozoans, algae, cell lines, and viruses. Although its holdings are smaller and it charges for each culture sent, actual distributions from ATCC far exceed those of the government-sponsored NRRL (24). Of the U.S. collections of more than 30,000 accessions, only ATCC distributes a catalog.

Many collections are also held for specific purposes by U.S. corporations or universities. These are usually personal collections of individual scientists and may receive little or no direct financial support. Private specialized microbial collections, like their counterparts in universities, usually begin as personal collections accumulated and maintained over a career. Although typically holding a limited number of microbial genera, they are unequaled for taxonomic detail and are an important facet of the total microbial diversity conservation effort.

The *Frankia* culture collection, for example, held at the Battelle-Kettering Laboratory in Yellow Springs, OH, began as a personal commitment by one scientist to isolate and culture frankiae, the symbiotic actinomycetes of some nitrogen-fixing plants (24). This internationally respected collection is not supported by an institutional commitment or extramural funding and thus depends on the dedication and resourcefulness of its curator. When a curator leaves a company, or when business considerations force redirection of that person's efforts, a specialized collection like this can be lost.

The costs of maintaining a collection pose significant constraints for commercial collections, In fact, recordkeeping and distribution expenses are important factors in many corporate decisions not to make materials from their collections generally available (24). Specialized collections are vulnerable to deterioration if funding cannot be obtained for their upkeep. For commercial collections such as ATCC, cultures must be maintained on a no-loss basis. Accessions that are not requested or used frequently and have no current intrinsic value may be discarded.

Quarantine

Maintaining biological diversity frequently involves the importation of foreign materials to increase the available genetic base for crop and livestock species or for offsite maintenance in zoos, botanic gardens, or arboretums. Quarantine regulations are designed to prevent accidental introduction by imports of exotic pests and diseases that could be harmful to U.S. agriculture, For both plants and animals, quarantine procedures are a combination of regulatory requirements controlling importation and distribution of germplasm and inspection or testing procedures designed to detect pests and diseases (for specific testing methods, see chs. 6 and 7). Regulations, administered by the Animal and Plant Health Inspection Service (APHIS) of USDA, have been viewed by some as restrictive with regard to importation of new genetic diversity (34,45).

Quarantine regulations classify both plant and animal germplasm ranging from materials considered to be of low risk of carrying disease organisms to those prohibited entry due to the extreme hazard they pose of introducing disease. Rice is prohibited from all countries and sorghum from many countries—except for germplasm that may enter under a USDA permit specifying the safeguard conditions, which often result in extensive delays.

Likewise, limited numbers of cloven-footed animals can be imported with heavy restrictions from areas known to harbor foot-and-mouth disease (41). For most materials, some degree of restriction is required and the plants or animals must enter through a designated port of entry for inspection. Most plants, for example, must enter the United States through one of 14 APHIS Plant Inspection Stations, where they are inspected, treated if necessary, and released within 1 to 3 days (35).

Some materials enter under conditions of post-entry quarantine, whereby they are inspected at an appropriate facility and released to the importer under an agreement that regulates their maintenance and release. Such agreements exist for some zoo animals, including most ungulates, Animals subject to post-entry quarantine are permanently consigned to the designated facilities, and only their offspring can be distributed or moved to other institutions. Plant materials are generally exempt from restriction if no pests or diseases are detected during the normal detention period of 2 years (35),

Importation of wild animal species posing threats to agricultural livestock can be length}, expensive, and difficult. For example, most bird species are very difficult to import due to APHIS concerns over the introduction of Newcastle's disease, a serious threat to domestic poultry stocks.

State programs regulating movement of plants and animals vary and are most stringent for States with economies based heavily on agricultural crops (e.g., California and Florida). Efforts to prevent the spread of pests and diseases can include restrictions on the carrying of fruits and vegetables into a State or requirements for treatment of potentially infected materials before entry, For importation of germplasm from outside the country, States cannot place restrictions on materials that are greater than those imposed by the Federal Government (35).

Biological diversity maintenance has not been a concern in the establishment of quarantine regulations. Although such regulations and procedures can be important to protecting agricultural diversity, they also, paradoxically, inhibit the development of new \arieties by restricting or slowing the flow of new materials into the country.

NEEDS AND OPPORTUNITIES

A variety of activities in the United States address the maintenance of some aspect of biological diversity. These efforts are carried out by both government and the private sector. Benefits from maintaining diversity, such as improvements in agriculture and the ecological processes that support life, accrue to all individuals though they seldom pay for them. The public nature of these benefits makes it the major responsibility of the public sector to maintain.

Private sector activities, nonetheless, complement government efforts in important ways. Activities of some groups and individuals may back up national programs. In other cases, private actii'ities maintain diversity in ways that the public sector does not, cannot, or will not. A number of private groups supplement the National Plant Germplasm System by maintaining heirloom and endangered commercial varieties of vegetables, for example, including many that are not contained in existing national collections, Private crop breeders have been influential in elevating the issue of genetic diversity loss to a national concern and have been providing increasing input in public germplasm maintenance activities. To date, these private activities have received little recognition, and minimal effort has been made to encourage and support private initiatives. Increased cooperation between public and private efforts could not only strengthen the latter but also improve maintenance of diversity.

The various laws and programs of Federal, State, and private organizations provide an elaborate framework on which a concerted biological diversity effort could be built. But because few of these activities cite the maintenance of biological diversity as an explicit objective, the goal is not considered in a comprehensive or coherent manner. Duplication of effort, conflicts in goals, and gaps in geographic and taxonomic coverage consequently exist.

One means of addressing biological diversity maintenance in a comprehensive way is to develop a national strategy, The process of developing a plan would help pinpoint areas where activities overlap or are lacking. At the least, such a process would initiate coordination of Federal agencies' activities. Those administering programs related to biological diversity would have to provide detailed reports on how programs are being implemented to conserve diversity. In particular, they would need to identify measures being undertaken to reduce program overlap, minimize jurisdictional problems, and identify areas for new initiatives. The latter is most evident in the lack of a national animal genetic resources program and of a system of protected representative ecosystems in the United States.

Any strategy, no matter how good it appears on paper, cannot be effectively implemented without adequate resources. Sustained long-term funding, in turn, requires consistent commitment to the process, The inconsistent funding and staffing of many existing programs illustrate the complexity and accompanying uncertainty of the political process.

An examination of trends in Federal budget allocations for natural resource conservation—including pollution control, water resources, public lands, recreation, and soil conservation—reveals a considerable decline over the last decade. This decline stands in contrast with real spending increases between 1978 and 1986 for defense (50 percent), payments to individuals—e. g., social security, Medicare, veterans' benefits, food stamps, and so on–and a tripling of interest payments on the national debt (51). The proportion of U.S. Government research and development (R&D) expenditures devoted to environmental R&D has also declined in recent years and assumes a smaller proportion of total government R&D funding compared with other industrial countries (48),

Programs of particular relevance to biological diversity maintenance, namely the Endangered Species Program and the National Plant Germplasm System, have been stretched to the point of being unable to adequately meet their objectives. These programs are able to prevail, in light of the constraints, mainly because of the dedication and ingenuity of the individuals working in them. The National Plant Germplasm System, for instance, has been underfunded for years. Within 2 years, the National Seed Storage Laboratory's storage facilities will be full, and aging equipment and buildings at NSSL and other facilities require major repair, upgrading, or replacement. Similarly, the effectiveness of the Endangered Species Program in preventing extinctions has been hindered by a shortage of resources.

CHAPTER 9 REFERENCES

1. American Association of Zoological Parks and Aquariums, Species *Survival Plan* (Wheeling, WV: undated).
2. Anonymous, "Block Announces Pioneer Grant," *Diversity* 7:9-10, fall 1985.
3. Bean, M. J., *The Evolution of' National Wildlife Law (New* York: Praeger Publishers, 1983).
4. Bean, M., "Federal Laws and Policies Pertaining to the Maintenance of Biological Diversity on Federal and Private Lands," OTA commissioned paper, 1985.
5. Bonner, F., "Technologies To Maintain Tree Germplasm Divers ity," OTA commissioned paper, 1985.
6. Council for Agricultural Science and Technology, *Animal Germplasm Preservation and Uti-*

lization in Agriculture, Report No. 101 (Ames, 1A: 1984).
7. Council for Agricultural Science and Technology, *Plant Germplasm Preservation and Utilization in U.S. Agriculture,* Report No. 106 (Ames, 1A: *1985).*
8. Crawford, M., "Condor Recovery Effect Hurt by Strategy Debate," *Science 23* 1:2 13-214, Jan. 17, 1986.
9. Crumpacker, W. D., *Potential Diversity and Current Protection Status of Major Natural Ecosystems in the United States: A Preliminary Report to the Heritage Conservation and Recreation Service* (Washington, DC: U.S. Department of the Interior, Heritage Conservation and Recreation Service, 1979).
10. Crumpacker, W. D., "Stat us and Trends of U.S. Natural Ecosystems, " OTA commissioned paper, *1985.*
11 Crumpacker, W. D., University of Colorado, personal communication, June *1986.*
12 Davis, G. D., "Natural Diversity for Future Generations: The Role of Wilderness," *Proceedings Natural Diversity in Forest Ecosystems Workshop,* J. L. Cooley and J. H. Cooley (eds.) (Athens, GA: University of Georgia, *1984). In:* Crumpacker, *1985.*
13 Drabelle, D., "The Endangered Species Program, " *Audubon Wildlife Report, 1985* (New York: National Audubon Society, 1985).
14. Dresser, B., and Leibo, S., "Technologies To Maintain Animal Germplasm, " OTA commissioned paper, 1986.
15. Dunstan, F., assistant director, Sanctuary Program, National Audubon Society, personal communication, May 18, 1984.
16. Falk, D., and Walker, K., "Networking To Save Imperiled Plants, " *Garden,* January-February *1986,* pp. *2-6.*
17. Fernald, E. A., et al., *Guidelines for Identification, Evaluation, and Selection of Biosphere Reserves in the United States,* OES/ENR, U.S. Man and the Biosphere Report No. 1 (Washington, DC: U.S. Department of State, *1983). In:* Crumpacker, *1985.*
18. Fitzgerald, J., and Meese, G. M., *Saving Endangered Species* (Washington, DC: Defenders of Wildlife, *1986).*
19. Fitzhugh, H., Getz, W., and Baker, F., "Status and Trends of Domesticated Animals, " OTA commissioned paper, 1985.
20. Fowler, C., *"Report on Grassroots Genetic Conservation Efforts, ' OTA commissioned paper, *1985.*
21. Greeter, S., South Carolina State Heritage Trust, personal communication, Apr. 7, *1985.*
22. Gregg, W. P., and Fretz, P. R., "Biosphere Reserves: A Background Paper for the Task Force on Conserving Gene Pools, " unpublished U.S. National Park Service report, *1986.*
23. Gulick, P., and van Sloten, D. H., *Directory of Germplasm Collections: Tropical and Subtropical Fruits and Tree Nuts (Rome:* International Board for Plant Genetic Resources, 1984).
24, Halliday, J., and Baker, D., "Technologies To Maintain Microbial Diversity," OTA commissioned paper, *1985.*
25, Henson, E., "An Assessment of the Conservation of Animal Genetic Diversity at the Grassroots Level, " OTA commissioned paper, 1985.
26. Henson, E., *1985 North American Livestock Census* (Pittsboro, NC: American Minor Breeds Conservancy, *1985).*
27, Hougas, R. W., "Plant Germplasm Policy, " *Plant Genetic Resources: A Conservation Imperative,* C.W. Yeatman, D. Kafton, and G. Wilkes (eds.), AAAS Selected Symposium *87:15-30* (Washington, DC: American Association for the Advancement of Science, 1984).
28 Hyland, H. L., "History of Plant Introduction in the United States, " C.W. Yeatman, D. Kafton, and G. Wilkes (eds.), AAAS Selected Symposium 87: 5-14 (Washington, DC: American Association for the Advancement of Science, *1984).*
29. International Sheep and Goat Institute, untitled pamphlet (Logan: Utah State University, undated).
30. Jenkins, R., science director, The Nature Conservancy's State Natural Conservancy Program, personal communication, Feb. *6, 1987.*
31. Jones, B., Office of Endangered Species, Fish and Wildlife Service, U.S. Department of the Interior, Washington, DC, personal communications, August *1986.*
32. Jordan, W., Peters, R., and Allen, E., "Ecological Restoration as a Strategy for Conserving B iodiversity, " OTA commissioned paper, 1986.
33. Kafton, D., "The California Gene Resource Conservation Program, " C.W. Yeatman, D. Kafton, and G. Wilkes (eds.) AAAS Selected Symposium 87:55-62 (Washington, DC: American Association for the Advancement of Science, 1984).
34 Kahn, R, P., "Plant Quarantine: Principles, Methodology, and Suggested Approaches, " *Plant Health and Quarantine in International Transfer of Plant Genetic Resources,* W.B. Hewitt and L. Chiarappa (eds.) (Cleveland, OH: CRC Press, 1977).

35, Kahn, R. P., "Technologies To Maintain Biological Diversity: Assessment of Plant Quarantine Practices, " OTA commissioned paper, 1985.
36. Kline, L., Office of Endangered Species, Fish and Wildlife Service, U.S. Department of the Interior, personal communication, 1986.
37. Lucas, G., and Oldfield, S., "Living Collections (Plants and Animals)," OTA commissioned paper, 1985.
38. Lynch, M. P., and Ray, C., "Preserving the Diversity of Marine and Coastal Ecosystems, " OTA commissioned paper, 1985.
39. Matia, W, T., director of stewardship, "Public Information Flyer on Stewardship Program, " The Nature Conservancy, 1986.
40. McMahan, L., "Participating Gardens Vital to Center's Work, " *The Center for Plant Conservation 1:1,* summer 1986.
41. Moulton, W. M., "Constraints to International Exchange of Animal Germplasm, " OTA commissioned paper, 1985,
42. Murphy, C., National Germplasm Program Coordinator (acting), Agricultural Research Service, U.S. Department of Agriculture, personal communication, Dec. 16, 1985,
43 Murphy, C., National Program Staff, Agricultural Research Service, U.S. Department of Agriculture, personal communication, Aug. 11, 1986.
44. Nabhan, G., and Dahl, K., "Role of Grassroots Activities in the Maintenance of Biological Diversity: Living Plants Collection of North American Genetic Resources, " OTA commissioned paper, 1985,
45. National Plant Genetic Resources Board, Minutes of the Meeting of the National Plant Genetic Resources Board, Washington, DC, May 14-15, 1986.
46. The Nature Conservancy, *Preserving Our Natural Heritage* (Washington, DC: U.S. Government Printing Office, *1977).*
47. Norse, E. A., "Grassroots Groups Concerned With *In-Situ* Preservation of Biological Diversity in the United States, " OTA commissioned paper, 1985.
48. Organization for Economic Cooperation and Development, *The State of the Environment 1985* (Paris: 1985).
49. Qualset, C., Agriculture Department, University of California at Davis, personal communication, 1986.
50. Salwasser, H., Thomas, J. W., and Samson, F., "Applying the Diversity Concept to National Forest Management. " *In:* J.L. Cooley, J.H. Cooley (eds), *Natural Diversity in Forest Ecosystems: Proceedings of the Workshop, Nov.* 29-Dec. 1, 1982, Institute of Ecology, Athens, GA, 1984.
51, Sampson, N., "Natural Resources Get the Axe, " *American Forests* 92:10-1 *1, 58-59,* 1986.
52. Sharp, C., National Plant Materials Specialist, Soil Conservation Service, U.S. Department of Agriculture, personal communications, Jan. 7, 1986.
53. Somes, R. G., Jr., *International Registry of Poultry Genetic Stocks,* Bulletin 469, Storrs Agricultural Experiment Station (Storrs, CT: University of Connecticut, 1984). *In:* Henson (OTA commissioned paper), 1985.
54. Spinks, J., Office of Endangered Species, U.S. Fish and Wildlife Service, U.S. Department of the Interior, personal communication, January 1986.
55. Stone, P., 1985-1986 *National Directory of Local and Regional Land Conservation Organizations* (Bar Harbor, ME: Land Trust Exchange, 1985),
56 U.S. Congress, General Accounting Office, *Better Collection and Maintenance Procedures Needed To Help Protect Agriculture's Germplasm Resources* (Washington, DC: U.S. Government Printing Office, 1981),
57. U.S. Congress, General Accounting Office, Comptroller General, *The Department of Agriculture Can Minimize the Risk of Potential Crop Failures* (Washington, DC: U.S. Government Printing Office, 1981).
58. U.S. Congress, National Seed Protection Act of 1985, H.R. 3973, Dec. 17, 1985.
59. U.S. Congress, Office of Technology Assessment, *Grassroots Conservation of Biological Diversity in the United States—Background Paper #l,* OTA-BP-F-38 (Washington, DC: U.S. Government Printing Office, March 1986).
60. U.S. Department of Agriculture, "The National Plant Germplasm System—Current Status, Strengths and Weaknesses, Long-Range Plans" (Washington, DC: 1981).
61. U.S. Department of Agriculture, "Germplasm Evaluation Program, " Progress Report No. 11, USDA/ARS-1, 1984.
62. U.S. Department of the Interior, Fish and Wildlife Service, 1980 *National Survey of Fishing, Hunting and Wildlife Associated Recreation* (Washington, DC: U.S. Government Printing Office, 1982).
63. U.S. Department of the Interior, Fish and Wildlife Service, Division of Refuge Management,

"Preliminary Survey of Contaminant Issues of Concern on National Wildlife Refuges," (Washington, DC: 1986).

64 U.S. Department of the Interior, National Park Service, Office of Science and Technology, *State of the Parks 1980: A Report to the Congress* [Washington, DC: U.S. Government Printing Office, 1980).

65 U.S. Library of Congress, Congressional Research Service, ".Mandates To Federal Agencies To Conduct Biological Inventories," OTA commissioned paper, 1985.

66. Williamson, 1,.1,. (cd.), *'Senate Approves Farm Bill," *Outdoor News Bulletin 39(29):1,* Nov. *29, 1985.*

67. Young, C. W., "Inbreeding and the Gene Pool," *Journal of Dairy Science 67:472-477, 1984.*