Chapter 3

Status of Biological Diversity

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HIGHLIGHTS

- A general consensus exists that biological diversity is being lost or degraded in most regions of the world, but acute threats are largely localized. Despite a weak knowledge base and lack of precise measurements, enough is now known to direct activities to critical areas.
- Concern over the loss of diversity have been defined almost exclusively in terms of species extinction. Although extinction is perhaps the most dramatic aspect of the problem, it is by no means the whole problem. The consequence is a distorted definition of the problem, which fails to account for the various interests concerned and may misdirect how concerns should be addressed.
- The immediate causes of diversity loss usually relate to unsustainable resource development, but the root causes for such development are complex issues of population growth, economic and political organization, and human attitudes. The complexity of the causes implies a need for multi-faceted approaches that deal with both the immediate and the root causes of diversity loss.

INTRODUCTION

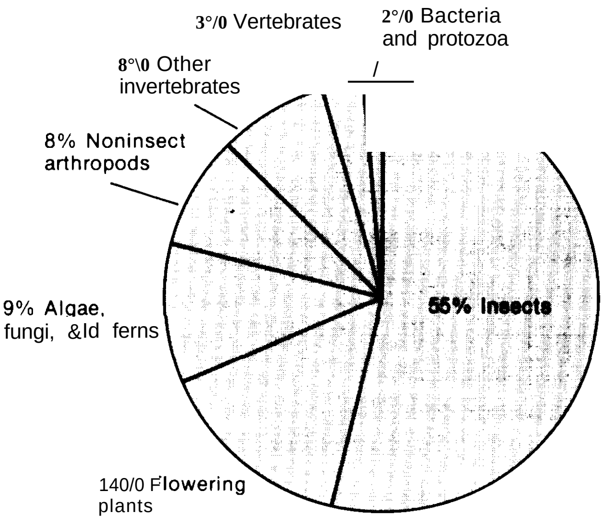
Since life began, extinction has always been a part of evolution. Mass extinctions occurred during a few periods, apparently the results of relatively abrupt geological or climatic changes. But in most periods, the rate of species formation has been greater than the rate of extinctions, and biological diversity has gradually increased. Recently in evolutionary history, the human species has derived great economic value from ecosystem, species, and genetic diversity and recognized the intrinsic values of diversity. But now that the values are being recognized, there is evidence that the world may be entering another period of massive reduction in diversity. This time, humans are the cause, and it appears that the consequence will be loss of a substantial share of the Earth's valuable resources.

Diversity is abundant at a global level. About 1.7 million species of plants and animals have been named, classified, and described (57). (Descriptions are only superficial for most of these.) The remainder are still unidentified (figure 3-I). It is estimated that the world contains 5 to 10 million species, and many of these have hundreds or even thousands of distinct genetic types. A recent inventory of insect species in the canopy of a tropical forest suggests that many more insect species may exist than previously thought, pushing the estimate for the total of all species to as high as 30 million (14).

Understanding of biological diversity issues has improved in recent years, in terms of knowing the extent of diversity and understanding the causes and consequences of changes. Enough information is available in all regions of the world to intervene in the processes that cause diversity loss.

Drastic reductions in populations of wild animals and plants are not new and have long been recognized as consequences of over-intensive hunting, fishing, and gathering. For example, great bison herds of North America were depleted in the 19th century, as were stocks of various whales and bird species (52). The now barren hills of southern China's coasts and is-

Figure 3-1 .—Currently Described Species



Of the currently described species, insects make up more than half the total. The number of flowering plants described are less than one-third of the percentage of insects.

NOTE" Percentages rounded to nearest whole number

SOURCE Office of Technology Assessment, 19S6.

lands were deforested 1,000 years ago (22). Erosion from the deforested and overgrazed Armenian hills, which eventually led to the demise of productive agriculture in Mesopotamia, apparently began over 2000 years ago (21). These kinds of changes undoubtedly caused local and regional losses of diversity,

What is new today is the *scale* on which resource degradation is occurring and thus the *rate* at which diversity is apparently being reduced. Fishing, hunting, and gathering beyond the capacity of ecosystems continues today, but the effects are being greatly exacerbated by degradation of ecosystems and significant reductions in natural areas. The decline of fisheries and sharp reduction of diversity in the Chesapeake Bay over the past two decades is an example well known to Congress, which has supported several initiatives to improve understanding of the complex syndrome of overfishing, pollution, and hydrologic changes related to the region's development.

Acceleration of resource degradation and diversity loss is partly a consequence of population growth, especially in rural areas of developing countries, where compound growth rates are often more than 1 percent per year. It is also a consequence of technologies developed over the past century that have enabled humans to devastate natural ecosystems even where population densities or growth rates are moderate. For example, modern drainage techniques and market conditions make accelerated wetland drainage possible in the United States, and veterinary drugs and modern well-drilling machinery enable African farmers to build livestock herds above the natural carrying capacity of their rangelands,

Accelerated loss of diversity is also caused by modern transportation, which reduces the effect of geographic barriers important in the evolution of diversity. Exotic species, diseases, and pests were for centuries carried across oceans, mountains, and deserts by hundreds of people traveling in ships and on foot, but now they are carried by hundreds of thousands of people traveling in trucks and airplanes.

Biologists and agriculturalists have thus become alarmed about the scale of plant and animal resource degradation during the last two to three decades. The alarm stems from observations of extensive reductions in habitat, coupled with a growing understanding of how such changes adversely affect diversity. (Key concepts that have aided this understanding are described in box 3-A.)

DIVERSITY Loss

The problem of diversity loss is broader than extinction of species because diversity occurs at each level of biological organization.

- Ecosystem diversity: A landscape interspersed with agricultural fields, grasslands, and woodlands has more diversity than the

Box 3-A.-Biological Concepts

Trends in changing biological diversity cannot be eqsured directly; so many species exist that costs of inventories would be too high. Rather, trends.~~ be inferred by applying biological concepts and by observing changes in habitats. Several biological concepts ‘are relevant:

- Species-area **relationship:** Large sites tend to have more species than smail sites. [So] When the areas of diverse natural ecosystems are reduced by land development or by degradation, diversity is reduced. From analysis of many sets of empirical data, scientists have derived a mathematical equation that can be used to predict the decrease in number of species that can be expected following a reduction in habitat area (5).
- **Provinciality effect:** Diversity of species and populations separated by geographic barriers, usually increases over time. But when species or varieties are carried across these barriers, as with the introduction of an exotic organiwn, provinciality is abruptly lost. Rapid loss of diversity can follow if native species have no defense against a exotic pathogen or pest, or if the exotic organism competes more aggressively for habitat (44) Examples include the introductions of Dutch elm disease to the United States, of cattle to California, of the paperbark tree to Florida, and of goats to many oceanic islands.
- Narrow endemism: Some species recur only within very restricted geographic ranges. This group includes many species that have evolved on islands, in mountaintop forests, in isolated lakes or other aquatic zones such as coral reefs, in areas with Mediterranean climates, including California, Western Australia, the Cape of South Africa, Chile, and the Mediterranean Basin countries. Areas with a high proportion of narrow endemic species contribute to global diversity more than other areas with similar numbers of species but less endemism. Thus, biological degradation in such areas reduces diversity more than it would elsewhere.
- **Species richness:** Some ecosystems have many more species than others. Generaily, species richness is greatest in equatorial regions, and it decreases toward the poles. It is generaliy greater in warmer or wetter places than in colder or drier places. Thus, the hot, wet tropical forests, which cover only 7 percent of the Earth’s land area may have about half of the Earth’s terrestrial plants and animals (30).
- **Species interdependence:** Interdependence can take a variety of forms. Symbiosis occurs when one or both of two species benefit from association. Mutualism occurs when neither species can survive without the other under natural **conditions.** Commensalism refers to associations in which one benefits and the other is unaffectad.
- **Natural vulnerability:** Vulnerability to extinction varies with several factors. Narrow endemics are perhaps most vulnerable. Rare-species maybe less susceptible to catastrophe if widely dispersed, but dispersion may lessen their chances for successful mating. Other species relatively vulnerable to extinction include the following: **top-level** carnivores, species with poor colonizing ability, those with colonial nesting habits; migratory species, those that depend on unreliable resources, and species with little evolutionary experience with perturbations.

same landscape after most of the woodlands are converted to grassland and cropland.

- Species diversity: A rangeland with 100 species of annual and perennial grasses and shrubs has more diversity than the same land after grazing has eliminated or greatly reduced the frequency of the perennial grass species.
- Genetic diversity: Economically useful crops are developed from wild plants by selecting valuable inheritable characteristics. Thus, the wild ancestral plants contain many genes not found in today’s crop

plants, A global agricultural environment that includes domestic varieties of a crop (such as corn) and the crop's wild ancestors has more diversity than the same environment after the wild ancestors are eliminated to make space for more domestic crops.

The quality of information used to assess the loss of biological diversity varies greatly for different ecosystems and different parts of the world. In general, both data and theories are better developed for temperate than for tropical biology; better for birds, mammals, and flowering and coniferous plants than for other classes of organisms; and better for the few major crop and livestock species used in modern agriculture than for the many species used in traditional agriculture.

Ecosystem Diversity

Natural ecosystem diversity has declined in the United States historically (26), and no evidence suggests that this long-term trend has been arrested. By comparing a nationwide evaluation of potential natural vegetation (PNV) with data on existing land uses from the 1967 Conservation Needs Inventory, scientists estimate what portion of land in the United States is still occupied by natural vegetation (26). This study estimates a percent change in area for each ecosystem type (each PNV) since presettlement times.

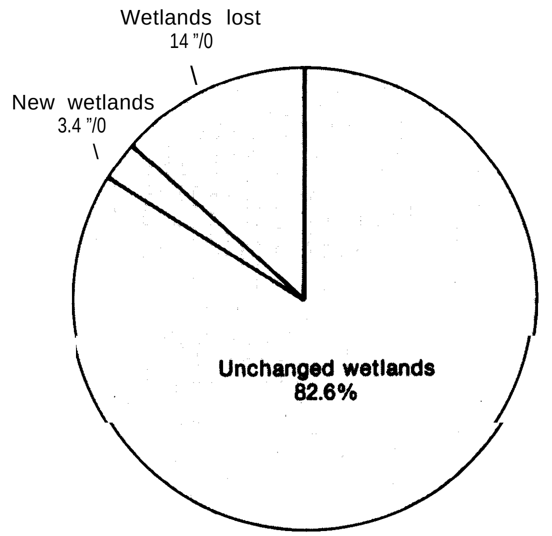
The greatest area reduction was 89 percent for the Tule Marsh PNV in California, Nevada, and Utah, mainly due to agricultural development. Twenty-three ecosystem types that once covered about half the conterminous United States now cover only about 7 percent. The agricultural States of Iowa, Illinois, and Indiana have lost the highest proportions of their natural terrestrial ecosystems (92, 89, and 82 percent, respectively),

States with the lowest losses were Nevada, Arizona, and New Hampshire (4, 7, and 12 percent, respectively), This assessment does not imply that 96 percent of Nevada is in the same condition that it was 400 years ago, The study did not assess degradation of areas still occupied by natural vegetation; rather, it indicated the areas whose uses remain unchanged. Also, the study was unable to consider some important ecosystem types, such as riparian and wetland areas, which are not included in the PNV categories (26).

Wetlands inventories are conducted by the U.S. Fish and Wildlife Service, The estimated total wetland area in the conterminous States in presettlement times was 87 million hectares. This amount was reduced to 44 million by the mid-1950s and to 40 million by the mid-1970s (figure 3-2), Thus, half the Nation's wetland area was lost in about 400 years, and another 5 percent was lost in the following two decades. Drainage for agricultural development has been the main cause of wetland ecosystem loss (48).

Riparian ecosystems are generally too small to be included as PNV types in major analyses. However, riparian areas contribute disproportionately to biological diversity, especially in the Western States, where they provide luxurious habitats compared with the adjacent uplands (9). Further, their maintenance is important to biological diversity in the streams and lakes they border. Natural riparian (mostly streamside) vegetation in the United States has

Figure 3-2.—Changes in Wetlands Since the 1950s (percentage of total)



SOURCE: Data from Fish and Wildlife Service's National Wetland Trends Study, 1982.

been reduced some 70 to 90 percent during the last two centuries (46,54). In the Sacramento Valley of California, for instance, the estimated loss of riparian vegetation areas is 98.5 percent; for Arizona, the estimate is 95 percent (45).

The diversity of agricultural ecosystems, or agroecosy stems, is also being reduced. System diversity is high in regions where agricultural land is divided into relatively small holdings and each farm uses a variety of crop and livestock species. As indicated in the preceding chapter, such landscapes support natural enemies of crop pests and are likely to contain species and varieties that can resist disease outbreaks and survive abnormal weather. However, on the fertile land of temperate-zone farming regions, where modern machinery and agricultural chemicals are used with crop varieties and where livestock are bred to maximize production, farmers can achieve substantial economies of scale on large holdings that specialize in relatively few crops or breeds. These less diverse agroecosy stems are more productive and more profitable than the older systems (36). As yet, relatively little scientific effort is being made to determine how biologically diverse farming could be made more profitable. Thus, the continuing loss of agroecosy stem diversity in the United States and throughout the world seems to be a function of both economic development and research priorities (10).

Time-series measurements of agroecosy stem diversity are lacking, as is an understanding of the advantages and disadvantages of diversity. There is also a delay between the loss of diversity and consequent increased or decreased profits. Therefore, it seems likely that agricultural system uniformity may continue to increase beyond its economic optimum. Then, a period of restoring some diversity may occur. This process may be underway in some areas of the United States, where multiple cropping, crop rotations, and restoration of shelterbelts are becoming more popular practices (51).

Attempts to increase farm profits by methods that reduce diversity may fail where severe droughts or soil erosion are common and where hot temperatures and high rainfall have resulted in soils with little capacity to hold nutrients. Where such development failures occur, restoration of more diverse farming systems can be difficult, because topsoil, water resources, germplasm, or knowledge of traditional farming methods have been lost (11,25).

Most countries do not have detailed information on changes in ecosystem diversity. The greatest concern on a global scale is for reduction of natural areas in the tropical regions, where ecosystems are least able to recover from degradation. Data on deforestation from many tropical countries indicate that the closed-canopy tropical forests are being reduced by about 11 million hectares each year. (The deforestation rates are discussed in some detail in ref. 54.)

Few data are available for the developing countries on degradation of biological diversity and other resources within the areas that remain classified as forest. Nor are data available on changes in area or quality of grasslands, wetlands, open-canopy forests, riparian and coastal zones, or aquatic ecosystems. Nevertheless, compelling anecdotal evidence indicates widespread degradation of all types of ecosystems in developing countries. In Sri Lanka, for example, removal of coral reefs for production of lime has had several consequences:

- the disappearance of lagoons important as nursery areas for fish,
- the collapse of a fishery,
- reduction of mangrove areas,
- erosion of cultivated coconut land, and
- salivation of wells and soil within half a mile of the shore (41).

Documents from development assistance agencies, such as the U.S. Agency for International Development (AID), the World Bank, the United Nations Development Programme, and the U.N, Food and Agriculture Organization abound with observations of resource degradation in developing countries. Evidence of ecosystem degradation is found in the environmental profile series that AID has been preparing since 1979, Usually the evidence is a description of problems caused by resource degradation rather than a report from careful monitoring of resource changes. At present, reports are available on about 67 developing countries, and nearly all describe ecosystem degradation. In some places the problems are the longstanding effects of unsustainable resource development; in others, the degradation has increased dramatically over the last decade and is constraining economic development (see box 3-B).

$pecies Diversity

Data to document changes in numbers and distribution of species are scarce. To document an extinction, the species must be named and described taxonomically and accurately observed at least once, then the loss must be recorded, Most documented extinctions have been of large terrestrial birds, mammals, and conspicuous flowering plants in the temperate zone and on tropical islands.

Modern taxonomic description goes back to 1753, but most recognized species were described much more recently, and the majority of species have yet to be described and named. For most of the estimated 385,000 living plant species, not much more is known than can be discerned from one or a few pressed, dried herbarium specimens. Nevertheless, personnel and financial support for the taxonomic work done in museums, herbarium, universities, and wildlife agencies around the world are being reduced (8).

Biologists estimate that at least two-thirds of all species live in the tropics. For example, a single tree in the Peruvian Amazon rain forest was found to harbor 43 species of ant belonging to 26 genera, That is a species richness about equal to the ant fauna of the entire British Isles (27). But two-thirds of the named species are in the temperate zone. This disparity reflects the historical distribution of taxonomists. In the United States, for example, about 500 plant taxonomists work with 18,000 species—a ratio of 36 species to 1 taxonomist. Tropical vascular plant species number about 190,000; about 1,500 taxonomists worldwide have expertise in tropical plants, yielding a ratio of 125 to 1 (8).

Even for conspicuous species that have been named, a considerable delay is involved in recording an extinction. For example, the U.S. Fish and Wildlife Service conducted a status review in 1985 for the ivory-billed woodpecker, whose last accepted sighting had been in the early 1950s, Had extinction been confirmed, then the lag between extinction and confirmation of loss could have been 30 years (16). The status of this species remains in doubt, however, because a sighting was reported in 1986 (2),

Indirect methods must be used to estimate changes in species diversity, because complete inventories of ecosystems would be too expensive, and because little is known of many species and the genetic attributes of populations. Methods include:

- preparing lists of species threatened with extinction and monitoring those species;
- monitoring populations of relatively well-known “indicator species” where habitats are being changed and inferring that other species in the same ecosystem are experiencing similar changes (indicator species are commonly trees, birds, large mammals, butterflies, or flowering plants); and
- using mathematical models of species-area relationships to project extinction numbers likely to result from various levels of habitat reduction.

Lists of Threatened Species

Lists of threatened animal species are prepared by the Species Conservation Monitoring Unit (SC MU) of the International Union for the Conservation of Nature and Natural Resources. For the United States, endangered animal lists are prepared by the Endangered Species Office of the U.S. Fish and Wildlife Service (FWS/ESO). For both the SCMU and the FWS/ESO, the information is better for temperate than for tropical species; better for terrestrial than for aquatic species; and better for birds and mammals than for reptiles, amphibians, fish, and invertebrates (16). Terms used in describing the status of threatened species are defined in box 3-C.

Box 3-B.—Typical Excerpts From Development Assistance Agency Reports Addressing Environmental Constraints to Development

India/Pakistan BordernLands:linRtheon (24)

The predominant natural terrestrial ingthetregion appears to be a low, open-type of dry tropical thorn forest, interspe in places with grasthe long and pervading influence of man and grazing stock, the presentgist frequently a highly degraded form of low and sparse xerophytic scrub.

The Indus delta is a critical area of high biological diversity and productivity. Mangrove zone creeks and mudflats hold crustaceans, are important to bird populations, and are a fisheries center of local and international significance. The delta appears to be subject to reduced freshwater input, increased salinity, overfishing, and environmental disturbances.

Honduras (49)

Deforestation by shifting cultivators in Yoro and Olancho is dramatic and well publicized. The human tragedy is even more serious%r the many thousands of campasino families living on degraded lands in the Choluteca Valley and the areas bordering El Salvador. The forest cover has been peeled back leaving a sparse patchwork of grazed bush fallow and cultivated plots.

By far the greatest threat to natural area functions and wildlife is the indiscriminate destruction of all natural vegetation by shifting agriculturalists and cattlemen regardless of the inappropriateness of the sites for such uses.

Mauritania (35)

Rapid desertification of much of its territory and the consequent loss of land devoted to both grazing and subsistence agriculture is the major environmental problem facing Mauritania today. This process, although severely aggravated by the drought affecting the entire Sahelian area of Africa, has been made worse by certain human practices that have upset the delicate balance of the area's ecology.

Sudan (23,56)

Increased rural population has placed pressure on land resources used for agriculture, resulting in shortened fallow periods and inadequate restitution of fertility. Crop yields have been reduced over time, and exhausted land has been totally abandoned. With loss of the more productive areas, marginal land that is prone to erosion has been cultivated, often with disastrous consequences. Between El Fasher and Nyala, removal of the stabilizing effect of trees has set ancient and once stable sand dunes in motion.

Mechanized farming adversely affected the environment through encouraging soil erosion and desertification, especially in aiareasrofalinadequate

The present lack of a resource-use policy and the unbalanced use of land results in a loss of 5 million hectares from production annually. A total of 65 million hectares are affected by some form of environmental degradation, which is equivalent to 60 percent of Sudan's potentially useful land area.

The SCMU data are gathered from an international network of correspondents identified from research papers. For example, the person compiling data on mammals has about 5,000 informants and contacts worldwide (16), The lists, organized by classes of animals in geographic regions (e.g., New World mammals), are revised on roughly a lo-year cycle, Table 3-I summarizes some of the data on threatened animals.

Since the mid-1970s, numerous lists of threatened plant species have been prepared. Because these are so new and most tropical regions do not have such lists, the data cannot yet indicate rates of extinction. For the temperate zone,

Box 3-C.-Definitions of Threatened Status

Two sets of definitions are used to classify the status of threatened species. Definitions based on the Endangered Species Act of 1973 are used in the United States. All other countries' lists of endangered species follow the definitions promulgated by the International Union for Conservation of Nature and Natural Resources (IUCN). The two sets of definitions are technically not compatible mainly because of differences in the concept of extinction and the IUCN inclusion of taxa rather than species.

Three technical definitions are used for classification of status in the United States:

1. An endangered species is in danger of extinction throughout all or a significant portion of its range.
2. A threatened species is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range.
3. Critical habitats are areas essential for the conservation of endangered or threatened species. The term may be used to designate portions of habitat areas, entire areas, or even areas outside the current range of the species.

The IUCN categories include five definitions:

1. Extinct taxa are species, or other taxa such as distinct subspecies, that are no longer known to exist in the wild after repeated search of their type localities and other locations where they were known or were likely to have occurred.
2. Endangered taxa are in danger of extinction and their survival is unlikely if the factors causing their vulnerability or decline continue operating.
3. Vulnerable taxa are declining and will become endangered if no action is taken to intervene.
4. Rare taxa are so rare that they could be eliminated easily but are under no immediate threat at present and have populations that are more or less stable.
5. Intermediate taxa belong in one of the above categories, but information is not sufficient to determine exactly which one (47).

SOURCES: M.I. Been. *The Evolution of National Wildlife Law* [New York: Praeger Publishers, 19S3): H. Synge, "Status and Trends of Wild Plant Species," OTA commissioned paper, 1985.

however, the numbers of threatened species do give some indication of the scope of the problem.

Nearly all industrial countries now have lists of threatened plant species. In Europe, all but five countries have such lists, and four of those five will have them soon (47), In the United States, many lists and reports cover both the Nation and individual States. Table 3-2 summarizes some information from the endangered plant species lists.

In North America, about 10 percent of the plant species are listed as rare or threatened. Many are plants endemic to small areas in California. A higher proportion of species are listed in Europe because of extensive threats to vegetation in the northern countries and the narrow endemism of many species in the Mediterranean countries. Data from the Soviet Union emphasize horticultural plants and are less complete than for Europe. For temperate-zone Southern Hemisphere countries, the lists are also dominated by narrow endemic plants from the Mediterranean climate regions (47).

Oceanic islands, because of geographic isolation during the millennia of evolution, typically have a very high proportion of endemic species. These areas are particularly vulnerable, because they are not adapted to animals and aggressive weeds that may be introduced by humans, Lists of threatened plants have been prepared for many such islands, Table 3-3 indicates how severe the threats are for islands with 50 to 1,000 endemic species.

Painting by George Sutton/Cornell Laboratory of Ornithology

The ivory-billed woodpecker is presumed extinct in the United States (last verified sighting occurred in 1971) and was thought to be extinct worldwide until the discovery of at least two specimens in the spring of 1986 in eastern Cuba.

Among tropical countries, Brazil has a listing project under way. Lists covering parts of India have been prepared and indicate about 900 threatened plant species. The Malayan Nature Society is preparing a database on threatened plants for the Malaysian peninsula. Listing projects are also complete or under way in some nontropical developing countries, such as Chile, Pakistan, and Nepal (47).

Monitoring Indicator Species and Habitats

Inferring trends in biological diversity from changes in the status of indicator species is a method that relies on time-series data assembled for management of economically significant species or species of special esthetic interest. For example, striped bass (known locally as rockfish) has been a highly valued species since precolonial times on the east coast of the United States, and commercial harvest data have been tabulated for areas like the Chesapeake Bay since 1924,

For 50 years, the trend in striped bass commercial harvest was upward, from around 2 million pounds landed in 1924 to 14.7 million pounds in 1973. Then, the trend reversed. B}T 1983, the catch had plummeted by 90 percent to 1.7 million pounds. The decline was believed to be due to a combination of overfishing and chemical contamination of the species' hahitat (18]. Thus, a reduction in populations of other species could be inferred from the striped bass trend.

Inference from this indicator species was confirmed in 1982 when a 7-year Environmental protection Agency study indicated the extent of the decline in the bay. Subaquatic vegetation had declined 84 percent since 1971. Areas suffering from lack of dissolved oxygen had increased fifteenfold since 1950, and in Baltimore Harbor at least 450 organic compounds, mostly toxins, were identified. Corresponding dramatic declines were documented in native animal species of the bay, including oysters, shad, and yellow perch (53).

The spotted owl is an indicator species for diversity in old-growth forests of the Pacific Northwest. The owl feeds primarily on flying squirrels and other rodents of old-growth habitat. Its decline in a region is considered a sig-

Photo credit Chesapeake Bay Founda f/on

Rockfish, once abundant in the Chesapeake, have been exploited and are now endangered in many areas of the estuary. The decline in population of this highly valued species has been attributed to overfishing and pollution.

Table 3-1.—Status of Animal Species in Selected Industrial Countries

	Mammals			Birds			Reptiles			Amphibians			Fishes		
	Species known	Threatened[a] Number	Percent	Species known	Threatened[a] Number	Percent	Species known	Threatened[a] Number	Percent	Species known	Threatened[a] Number	Percent	Species known	Threatened[a] Number	Percent
Canada	94	6	6.4	434	10	2.3	32	2	6.3	54	2	3.7	800	15	1.9
United States[b]	466	35	7.5	1,090	69	6.3	368	25	6.8	222	8	3.6	2,640	44	1 7
Japan	186	4	2.2	632	35	5.5	85	3	3.5	58	1	1.7	3,144	4	0 1
Australia	320	43	13.4	700	23	3.3	550	9	1.6	150	6	4.0	3,200	X	X
New Zealand	68	14	20.6	282	16	5.7	37	7	18.9	6	X	X	777	3	0.4
Austria[c]	83	38	45.8	201	121	60.2	X	X	X	X	X	X	92	54	58.7
Denmark	49	14	28.6	190	41	21.6	5	0	0.0	14	3	21.4	166	17	10.2
Finland	62	21	33.9	232	15	6.5	5	1	20.0	6	0	0.0	58	4	6.9
France[d]	107	34	31.8	264	79	29.9	32	4	12.5	30	6	20.0	70	13	18.6
Italy	97	13	13.4	419	60	14.3	46	24	52.2	28	13	46.4	503	70	13.9
Netherlands[e]	60	29	48.3	257	85	33.1	7	6	85.7	15	10	66.7	49	11	22.4
Norway	71	10	14.1	280	28	10.0	5	1	20.0	5	1	20.0	X	X	X
Portugal	79	X	X	337	X	X	4	X	X	17	X	X	X	X	X
Spain[f]	100	53	53.0	389	142	36.5	9	20	40.8	23	8	78.3	17	12	8.8
Sweden	63	11	17.5	250	34	13.6	6	0	0.0	11	5	45.5	X	X	X
Switzerland	86	X	X	190	74	38.9	5	X	X	20	X	X	10	X	X
Turkey	31	11	35.5	217	36	16.6	X	X	X	X	X	X	X	X	X
United Kingdom[g]	51	12	23.5	200	24	12.0	6	2	33.3	6	2	33.3	37	8	21 6
West Germany[c e]	94	44	46.8	455	98	21.5	2	9	75.0	19	1	57.9	73	40	23 1

X = Not available.
[a]Threatened refers to the sum of the number of species in the endangered and vulnerable categories.
[b]Including Pacific and Caribbean Islands.
[c]Data for threatened animals include extinct and/or vanished species.
[d]Data for known freshwater fish species only
[e]The number of bird species known includes occasional visitors.
[f]Peninsular Spain and the Baleares only.
[g]Data refer only to terrestrial mammals.

SOURCE: Organisation for Economic Cooperation and Development, *OECD Environmental Data Compendium 1985* (Paris: 1985).

Table 3-2.—Summary of Data From Endangered Plant Species Lists

Country/region	Species	Rare and threatened species	Extinct taxa	Endangered taxa
Australia	25,000	1,716	117	215
Europe[a]	11,300	1,927	20	117
New Zealand	2,000	186	4	42
South Africa	23,000	2,122	39	107
U.S.S.R.	21,100	653	=20	=160
United States[b]	20,000	2,050	90	7

[a]Exclydes European U.SSR , Azores, Canary islands, and Madeira
[b]Excludes Hawall, Alaska and puerto RICO

SOURCE S Davis et al Plants in Danger What Do We Know~(forthcomlng) as clted in H Synge, "Status and Trends of Wild Plants " OTA commissioned paper 1985

Table 3-3.— Data on Threatened Plant Species of Selected Oceanic islands

Island	Number of endemic speciesa	Number listed as rare or threatened
Azores	55	30 (55"/0)
Canary Islands	569	383 (670/o)
Galapagos	229	150 (66"/0)
Juan Fernandez	118	95 (81 '/0)
Lord Howe Island	75	73 (97"/0)
Madeira	131	86 (66"/0)
Mauritius	280	172 (61 '/0)
Seychelles	90	73 (81 0/,)
Socotra.	215	132 (61 '/0)

aEndemic meansthe species occurs only On the island

SOURCE S Davis, et al *Plants* In Danger *What Do We Know?* (forthcoming), as cited In H Synge 'Status and Trends of Wild Plant s," OTA commissioned paper, 1985

nal that its prey and other species associated with the habitat are also in decline (3).

Diversity losses due to pollution may be indicated by animals' food chains, such as the bald eagle and other fish-eating birds. Plants susceptible to air pollution, such as lichens, may also be useful indicators. Extensive records of observations on smaller animals of long-standing interest to professional and amateur biologists can also gauge diversity change, The decline of Bay Checkerspot butterflies, for example, is taken as an indication of decline of many associated organisms in the San Francisco Peninsula area (13).

Models of Species-Area Relationships

The scale of diversity reduction can be estimated for most tropical countries only by inferences from the reduction of habitat. Nearly all attempts to estimate global extinction rates focus on the tropical moist forests, These ecosystems are exceedingly species-rich, contain areas of narrow endemism, and are undergoing extensive and rapid conversion to other uses, Because they typically have erosion-prone soils incapable of holding many plant nutrients and occur where rain and heat are especially intense, these forest ecosystems are highly susceptible to degradation. In fact, the undeveloped forests are so diverse, and the deforested, degraded landscapes to which they are often converted support so few species, that the models used to estimate extinction rates generally treat the diversity of deforested landscapes in the moist tropics as negligible (43).

A recent projection of bird and flowering-plant extinctions that could be caused by continued deforestation in tropical America is based on a mathematical model of the species-area relationship (see box 3-A). About 92,000 flowering plant species have been described for regions where the forested area for recent human-caused deforestation was about 6.9 million square kilometers (43). Over the next 15 to 20 years, the forested area will be reduced to about 3,6 million square kilometers if the rate of deforestation remains at the level of the 1970s. The mathematical relationship between area and species numbers, derived by analysis of some 100 empirical data sets (5), indicates that this reduced forest could be expected to support about 79,000 species. Thus, a 15-percent reduction in numbers of species is projected for the near future.

Deforestation is expected to continue for more than 20 years, however, and it seems likely that it will accelerate as the rapidly growing human populations of tropical American coun-

Photo credit: U S Fish and Wildlife Service

Northern spotted owl requires large tracts of Pacific Northwest old-growth forest as habitat. If harvesting of old-growth continues at current rate, the habitat for this species could disappear within the next two decades.

tries need more rapid resource development. A "worst-case" calculation indicates that if the forests were reduced until they covered only National Parks and their equivalents that had been established by 1979 (about 97,000 square kilometers), then the final effect could be as high as a 66-percent reduction (43).

About 704 species of land birds have been described in the Amazon region of tropical America. Using the same mathematical relationship as used for plants, a 60-percent reduction of the original forest area over the next 15 to 20 years could be expected to cause eventual extinctions of 86 bird species. The worst-case calculation, with reduction of the Amazon forest to the area of already established national parks, projected that 487 types of birds, or about 70 percent of the species, could become extinct (43).

Several assumptions tend to underestimate extinction rates. For example, extinctions resulting from reduced provinciality are ignored in the calculations, as are effects of the narrow endemism that occurs in several parts of tropical American forests. On the other hand, the assumption that none of the plant and bird species will find habitats they need after deforestation seems an exaggeration. Such projections may be helpful in stimulating institutional responses to prevent the worst cases from occurring. Many nations' governments have begun to take steps in the past decade to protect endangered habitats. The worst-case calculations are thus not predictions, but indications of the direction and scale of the projected trend.

Distracting Numbers Game

Projections of alarming losses in species diversity have attracted attention to this issue, But discrepancies among the estimated extinction rates have called into question the credibility of all such estimates. In one sense, the numbers themselves have become an issue, confusing policy makers and the general public and possibly detracting from efforts to deal with the causes and consequences of diversity loss (28), This numbers game also has defined the problem of loss mainly in terms of species extinction, which may be the most dramatic aspect of the diversity question, but it is only part of the problem. Further, global and national data and projections may mask the localized nature of resource degradation, diversity loss, and the consequences of both. Large inaccessible areas of forest, for example, may make the global deforestation rate seem moderate, but destruction of especially diverse forests in local areas of Australia, Bangladesh, India, the Philippines, Brazil, Colombia, Madagascar, Tanzania, and West Africa proceeds at catastrophic rates (32).

Genetic Diversity

Ideally, concern about loss of biological diversity should be focused on genetically distinct populations, rather than on species (13,16,34). But with so little information available about the majority of wild species, this seems impractical.

For agricultural species, on the other hand, the concern is mainly about genetic diversity. The species do not seem to be in danger of extinction, but the variety of genes in many crops and livestock breeds is being reduced (39). Many distinct types are being eliminated as improved breeds and varieties that are genetically similar are gaining more widespread use. Ironically, success in exploiting genetic resources for agriculture threatens the genetic diversity on which future achievements depend.

With livestock, the principal diversity loss involves developing-countries' breeds being replaced by imported ones, The threat seems greatest for those species in which artificial insemination is widely used, and it is particularly a problem with cattle, for which over 270 distinct breeds exist. For farmers with only a few cows, artificial insemination is cheaper than keeping a bull. But developing countries lack facilities to collect and freeze semen from locally adapted breeds, so semen is usually imported from commercial studs in industrial countries. Threatened breeds include the criollo of Latin America and the Sahiwal and several others from Africa (see table 3-4) (15).

Llama and alpaca—as well as vicuna and guanaco, their wild relatives—are South American species used for meat, as beasts of burden, and for their hair and pelts. Numbers of all four species have declined sharply since the Spanish conquest of the Incan empire, and loss of genetic diversity has almost surely occurred, though it is unmeasured (15).

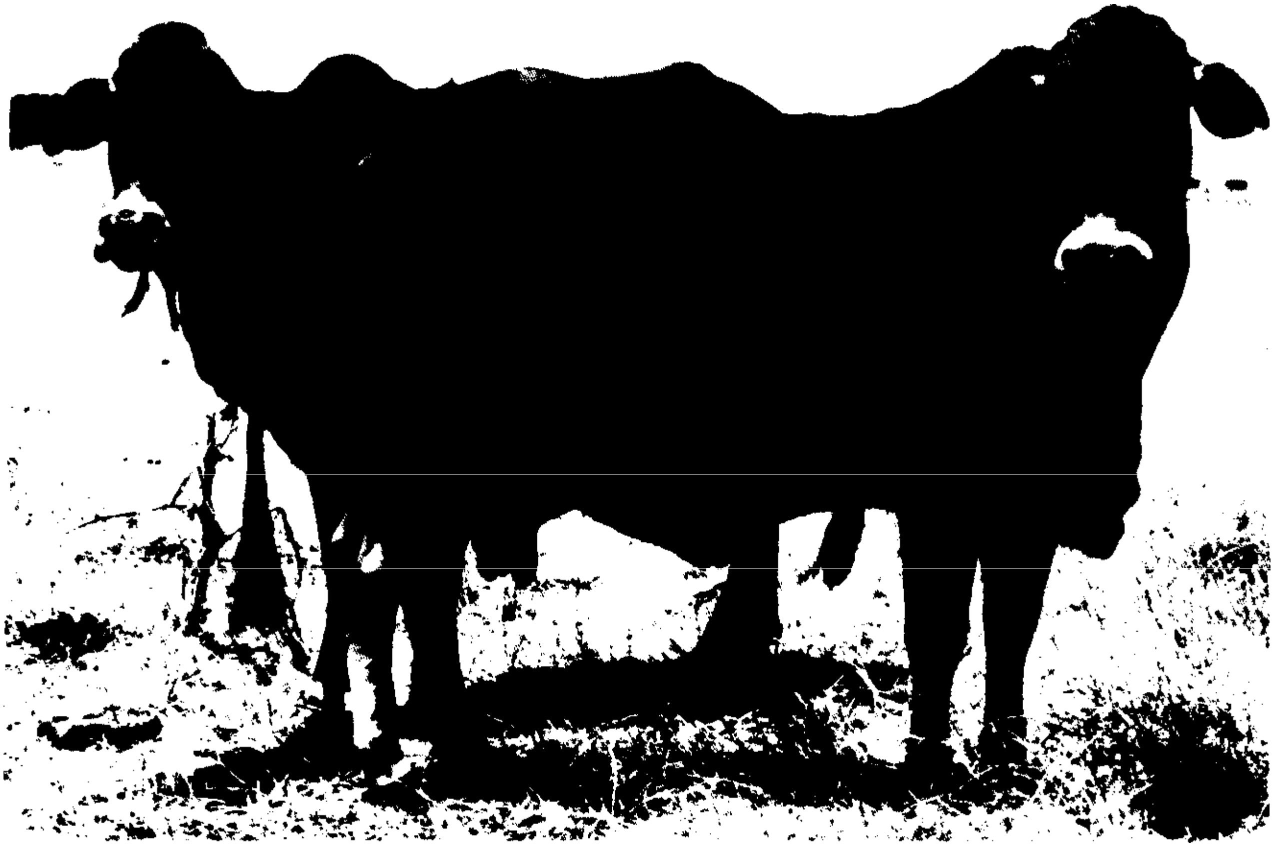
Poultry and swine breeds are also moving toward genetic homogeneity, because controlled breeding has been rapid and intensive to produce varieties suitable for modern commercial production. Poultry breeding has been

Table 3-4.—Endangered African Cattle Breeds

Breed	Location	Purpose	Reasons for decline in number	Advantages
Mutura	Nigeria	Meat, draft	Civil war, crossbreeding, lack of interest by farmers as tractors become available	Trypanotolerant,[a] hardy, good draft animal, low mortality
Lagune	Benin, Ivory Coast	Meat	Crossbreeding, lack of interest by farmers because of small mature size (125 kg) and low milk yields	Trypanotolerant, adapted to humid environment
Brunede l'Atlas	Morocco, Algeria, Tunisia	Meat	Crossbreeding to imported breeds	Adapted to arid zones
Mpwapwa	Tanzania	Milk	Lack of sustained effort to develop and maintain new breed	Adapted, dual-purpose
Baria	Madagascar	Milk, meat	Crossbreeding	Adapted, dual-purpose
Creole	Mauritius	Milk, meat, draft	Crossbreeding	Adapted, multiple-purpose
Kuri	Chad	Milk, meat	Political instability, numbers reduced by rinderpest and drought	High milk production, ability to float and swim in Lake Chad, tolerant of heat and humidity
Kenana	Sudan	Milk	Crossbreeding (artificial insemination) to imported dairy breeds, loss of major habitat to development scheme	High milk potential; adapted to hot, dry environment
Butana	Sudan	Milk	Crossbreeding	High milk potential; adapted to hot, semiarid environment

[a]Ability to survive Trypanosome infection (spread by tsetse fly), which normally causes African sleeping sickness in cattle

SOURCE: Adapted from K.O. Adeniji, "Prospects and Plans for Data Banks on Animal Genetic Resources," *Animal Genetic Resources Conservation* (Rome: Food and Agriculture Organization, 1984) as cited in H. Fitzhugh et al., "Status and Trends of Domesticated Animals," OTA commissioned paper, 1985.



dominated by a few companies (probably fewer than 20 worldwide) (15). These firms typically retain a number of breeds from which to make selections and crosses, but they do not find it cost-effective to retain stocks that might prove useful more than 10 years in the future (7). Meanwhile, breeds adapted to traditional farm conditions are becoming rare in industrial countries, because fewer farmers want them and the number of small hatcheries producing them has declined sharply. Poultry breeds from industrial countries are being exported to urban markets in many developing countries, but no evidence exists that these have affected the genetic diversity of poultry in rural areas of developing countries.

Hundreds of plant species have been domesticated, and traditional farming systems continue to use many species. But modern agriculture produces most human sustenance, plant-derived fibers, and industrial materials from only a few species, Three-quarters of human nutrition is provided by just seven species: wheat, rice, maize, potato, barley, sweet potato, and cassava (31). Within the United States, the top 30 crops account for $57.7 billion in farm sales and imports annually, which is 60 percent of the combined value of all U.S. agricultural plant resources (see table 3-5) (39).

Within these 30 crops, modern varieties have replaced traditional ones, reducing diversity between and within agricultural sites and genetic populations. The narrow species and genetic base of modern agriculture generates two distinct concerns: 1) the extinction of genes, which reduces opportunities to produce new

Table 3-5.—Crops Grown or reported by the United States With a Combined Annual Value of $100 Million or More (average 1976 to 1980)

Average annual value (U.S. $ millions)	Crop
11,278	Soybean
10,412	Corn
6,475	Wheat
4,233	Cotton
3,925	Coffee
2,851	Tobacco
1,723	Sugarcane
1,525	Grape
1,206	Potato
1,163	Rice
1,150	Sweet orange
1,147	Sorghum
1,054	Alfalfa
1,051	Tomato
1,016	Cacao
815	Apple
760	Beet crops
747	Peanut
706	Rubber
672	Barley
527	Lettuce
517	Common bean
393	Sunflower
368	Banana
365	Cole crops
355	Almond
349	Peach
314	Coconut
304	Oats
287	Onion
252	Strawberry
219	Grapefruit
198	Chrysanthemum
192	Cucumber
189	Melon
186	Pineapple
179	Roses
167	Celery
164	Walnut
158	Peppers/c hilis
156	Jute
155	Plum/prune
148	Sweet cherrylsour cherry
146	Pear
144	Olive
143	Oil palm
142	Carrot
142	Pea
136	Lemon
130	Bermudagrass
128	Tea
116	Watermelon
116	Cashew
110	Sweet potato
102	Pecan
100	Azalea/rhododendron

SOURCE C Prescott-Allen and A Prescott-Allen, *The First Resources Wild Species in the North American* Economy (New Haven, CT, and London Yale University Press, 1986)

varieties better suited for production at particular sites; and 2) the increased uniformity of crops, which makes them more vulnerable to pests and pathogens. Of these two, extinction of genes is the greater problem. For annual crops, uniform genetic vulnerability can be quickly corrected as long as a high degree of genetic diversity is maintained for the crop somewhere. Gene extinction, however, cannot be reversed.

Published information on status and trends of crop diversity usually consists of impressions by plant breeders and others on the loss of cultivated varieties or threats to wild relatives of crops, such as: "it may not be long before landraces are irretrievably lost" or "many locally adapted varieties have been replaced by modern varieties" (39). Such reports have been collected and evaluated by the International Board on Plant Genetic Resources (IBPGR). IBPGR's information has stimulated conservation action and has helped to determine general collecting priorities for protection of genetic resources.

Plant breeders and germplasm collectors generally concur that crop genes have been lost and that losses are still occurring rapidly and widely in many crops (39), in spite of progress with collection and offsite maintenance programs (see ch. 6). Three problem areas include:

1, crops that have low priority for IBPGR but are of major economic importance to the United States (e.g., grape, alfalfa, lettuce, sunflower, oats, and tobacco);
2. crops that despite being a high international priority still lack adequate provision for long-term conservation (including those maintained as living collections rather than as seeds, such as cacao, rubber, coconut, coffee, sugarcane, citrus, banana); and
3. wild relatives of major crops, which, except for sugarcane and tomato, are represented in collections by extremely small samples.

Detailed assessments of the status and trends of genetic diversity are lacking, even for crops whose collection is well advanced, such as rice, maize, potato, tomato, and bean. Such assessments are needed to understand the dynamics of crop genetic change and its relationship to social and economic change (39).

The status of diversity conservation for economically important timber trees lies between that of wild plants gathered for economic use and that of agricultural plants. Some commercial tree species are protected by parks and other protected natural areas, and the diversity of some is at least partially captured in offsite seed collections. In many extensively managed forests, commercial tree species regenerate naturally after logging, fire, or other disturbances, and local genetic diversity is maintained. However, replanting with stock propagated from selected parents and from tree-breeding programs is a common practice with some trees, such as Douglas fir, and gene pools for these species are being gradually altered (19).

The genetic resources of commercial trees and other economic plants and animals in developing countries are being eroded by conversion of forest areas to agriculture or grazing use. An international panel recently identified some 300 tree species or important tree populations (presumably with unique genetic characteristics) that are endangered (17), Thus, in the United States and developing countries where U.S. agencies provide assistance, protection of natural gene pools of commercial trees and other nondomesticated economic species could become an objective in development planning (see ch. 11). At present, economic species not used in agriculture or horticulture are poorly represented in genetic conservation programs.

CAUSES OF DIVERSITY LOSS

Forces that contribute to the worldwide loss of biological diversity are varied and complex, and stem from both direct and indirect pressures. Historically, concern has focused on the commercial exploitation of specific threatened or endangered species. But now attention is also being focused on indirect threats more sweeping in scope (30).

Development and Degradation

Economic development usually entails making sites more favorable for a manageable number of economic activities. Consequently, the changed landscape has fewer habitats and supports fewer species. Habitats may be affected by offsite development too—by pollution, for example, or changed hydrology. Some development, such as logging in a mosaic pattern through a large forested area, mimics natural processes and may result in a temporary increase in diversity.

But poorly planned or badly implemented development, such as agricultural expansion without investment in soil conservation, can severely disrupt biological productivity, and it can start a self-reinforcing cycle of degradation, For example, soil erosion reduces soil fertility, which in turn can reduce growth of plants for cover, leading to more soil erosion and to rapid depletion of diversity as the site becomes suitable, for fewer and fewer species (51). Other causes of site degradation include grazing pressures, unnatural frequency or severity of fires, and excessive populations of herbivores (such as rabbits) where predators are eliminated. Arid and semiarid sites are especially susceptible to degradation from such pressures. Species may be reduced by one-half to two-thirds without outright conversion of the land use (33).

Modernization of farming systems is also a cause of diversity loss. Such systems often include many species of crops and livestock; genetic diversity is typically high, because cultivars and breeds adapted to the vagaries of site-specific conditions are used. To achieve productivity gains, however, traditional systems are being replaced with modern methods. Capital inputs, such as manufactured fertilizers and feeds, are used to compensate for site-specific differences, Thus, it is possible to replace traditional crops and livestock with fewer varieties

Photo credff U N Phofo 152 843'/(Muldoon

Overgrazing In Burkina Faso—one major cause of diversity loss.

bred to give high yields under more artificial conditions.

The loss of traditional agroecosystems is not restricted to developing countries. Native American farming systems that interplant corn with squash, numerous types of beans, sunflowers, and many semidomesticated species are reduced to isolated areas now and continue to be abandoned. These systems and crop varieties have been described in anthropological literature, but they are lost before being scrutinized by agricultural scientists.

Agricultural development may cause abrupt disappearance of traditional varieties, as with the replacement of traditional wheat in the Punjab region of India, or it may be gradual, as with fruit and vegetable varieties in the united States and livestock breeds in Europe, Locally adapted varieties may become extinct in a single year if germplasm for a traditional variety is lost because of a catastrophe or is destroyed to control a disease. Examples include traditional grain varieties that were replaced with modern ones in Africa when seed was eaten during the recent famine, and local swine populations that were exterminated in Haiti and the Dominican Republic to control a disease and then replaced with modern breeds (15).

Exploitation of Species

As noted earlier, concern with loss of biological diversity historically focused on extinctions or population losses that resulted from excessive hunting and gathering. whales, cheetahs, passenger pigeons, bison, the North Atlantic herring, the dodo, and various orchids are all examples of organisms hunted or gathered in excess (30).

Today the direct threat to wildlife remains. Numerous monkeys and apes are endangered by overhunting, mainly to supply the demand

Photo credit: D. Ehrenfeld

The green turtle is an example of a species threatened by direct factors, such as exploitation of adults and eggs, and by indirect factors, including nesting beach destruction, ocean pollution, and incidental catch in shrimp trawls.

from medical research institutions. Some 108 primate species are hunted for an international trade worth about $4 million annually (30). For many, perhaps most of these, the capturing process is very destructive. Apes such as the gibbon are captured by shooting mother animals from the treetops and taking any infants that survive the fall. Many of the infants die while passing through the market system. Thus, the 30,000 primates sold in 1982 (30) actually compose a much higher number killed to support the trade.

The rhinoceros has declined more rapidly over the past 15 years than any other large mammal. From 1970 to 1985 there was an almost 80-percent decrease in the numbers of rhinos, from 71,000 to only about 13,500 today. The most spectacular decline has been that of the black rhino–from 65,000 to 7,000 in the past 15 years. Whole populations of black rhino have been almost totally eliminated over the past 10 years in Mozambique, Chad, Central African Republic, Sudan, Somalia, Ethiopia, and Angola. In the past 2 years, Mozambique has lost the white rhinoceros for the second time in this century—a dubious achievement indeed (29),

The main reason for this catastrophic decline since 1975 is due to the illegal killing of the animal, mostly for its horn. In the early 1980s about one-half of the horn put onto the world market went to North Yemen where it is used for the making of attractive dagger handles, while the remaining half went to eastern Asia where it is used mostly to lower fever, not—as often supposed—as an aphrodisiac (6).

Plant species are also subject to overharvest. A cycad plant species was reported eliminated in Mexico during just one year when 1,200 specimens were exported to the United States (55).

Vulnerability of Isolated Species

If the range of species is restricted to a relatively small area, such as an island or a mountaintop forest, a single development project or the introduction of competing or exotic species can lead to loss of diversity. Many recorded extinctions have been animals and plants from oceanic islands (see table 3-6) (52). Some of these areas, such as Haiti, are infamous for deforestation and rapid rates of soil erosion. It may be inferred that diversity loss has been and probably continues to be especially severe on such islands.

Complex Causes

Most losses of diversity are unintended consequences of human activity, and the species and population affected are usually not even recognized (30). Air and water pollution, for example, can cause diversity loss far from the pollution's source, Substantial gains in reducing these pressures have been achieved in industrial countries, particularly in the United

Table 3.6.—Oceanic Islands[a] With More Than 50 Endemic Plant Species

Island	Endemics	Percentage endemism
Madagascar	=9,000	
Cuba	2,700	46
New Caledonia	2,474	76
Hispaniola[b]. ..., . . .	1,800	36
New Zealand ..., ...	1,618	81
Sti Lanka.	=900	
Taiwan.	=900[c]	
Hawaii . . ..., ..., ..., .	883	91
Jamaica. . . ..., ..., ..., .	735	23
Figi	=700	
Canary Islands .,.....,..	383	
Puerto Rico	332	12
Caroline Islands. ,...,.. .,	293[c]	
Trinidad and Tobago, ...,,	215	
Galapagos. . ..., ...	175	25
Mauritius. . . ..., ..., ...,	172	
Ogasawara-Gunto ...,	151[c]	
Reunion. ..., ..., ..., .	=150	
Vanuatu. . . . ., . . .	=150	
Tubuai ..., ..., ..., ..., . .	S140	
Comoro Islands ..., ...,	136	
Socotra ..., ..., ..., .	132	
Bahamas, ...	121	
Sao Tome	108	
Marquesas Islands	103	
Samoa	>100	
Juan Fernandez ..., ...,	95	
Cape Verde.	92	
Madeira. . ..., ..., ..., .	86	
Mariana Islands ..., . .	81[c]	
Lord How Island . . ..., ,.	73	
Seychelles	73	

[a]Excludes Australia, New Zealand, Borneo, New Guinea, and Aldabra
[b]Hispaniola comprises the nations of Haiti and the Dominican Republic
[c]Omits monocoyledons

SOURCE Adapted from A H Gentry, 'Endemism in Tropical Versus Temperate Plant Communltles;' Conservation *Biology*, M. Soulé (ed) (Sunderland, MA Sinauer Associates, Inc 1988), and H Synge, "Status and Trends of Wild Plants," OTA commissioned paper, 1985

States, since passage of the National Environmental Policy Act,

Yet pollution remains a major threat to bioIogical diversity, because abatement is often expensive and is sometimes a very complex organizational task, especially when it depends on international cooperation. Acid rain is an example. In Scandinavia, several fish species have declined in numbers because of acidification of lakes; in eastern Canada, a trout species has been placed in the severely threatened category (37), International pollution by acid rain has recently been reported to extend far from industrial regions into Zambia, Malaysia, and Venezuela, for example.

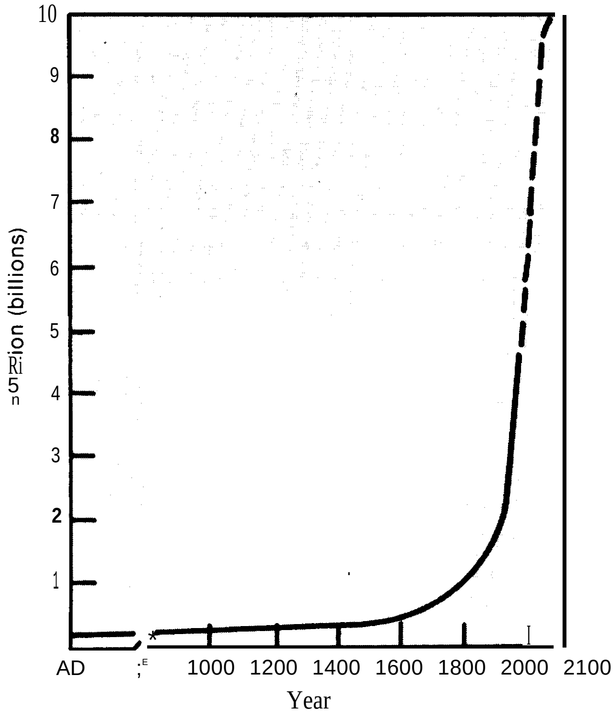
Climate change is apparently being caused by increased carbon dioxide and atmospheric dust, which result from fossil-fuel burning and from the release of carbon stored in vegetation when extensive areas are converted from forest to cropland or sparsely vegetated grassland. The expected consequences include significant changes in temperature and rainfall patterns, Temperature rises seem likely to occur rapidly, at least in evolutionary terms, so diversity will probably incur a net loss during the next century (38).

In both industrial and developing countries, diversity is lost as land is converted from forest, grasslands, and savanna to cropland or pasture. If the land being converted will support permanent agriculture with relatively high yields, the effect on diversity is contained, Moderate areas of such land can support substantial populations. But much of the newly cleared land is marginal or totally unsuitable for the cultivation or grazing practices being applied. As a result, extensive areas must be cleared, especially where the land is so poor that it degrades to wasteland and is abandoned after a few years, which is typical in the moist tropical forest regions and in semiarid areas of both the temperate and tropical zones (30).

The underlying causes of inappropriate land clearing are many and exceedingly complex. Population growth, poverty, inappropriate agricultural technologies, and lack of alternative employment opportunities are all problems far too complex for biologists and conservationists alone to resolve.

Population growth in itself may not seem intrinsically threatening to biological diversity. In some industrial countries, such as the United States and Japan, disruption of ecosystems has been mitigated by urbanization, establishment of parks, and land use regulation (30). But the connections between affluent populations and their impacts on biological diversity are obscured by the complexity of commerce. The Japanese, for example, carefully protect the diversity of their own remaining forests, but they use large quantities of timber from forests in other countries where controls are lax. Much has been written about the "hamburger con-

Figure 3-3.— Past and Projected World Population



If the current growth in population continues, by the year 2000 more than 6 billion people will inhabit the world. With this growth, irreversible environmental degradation and loss of biological diversity can be expected.

SOURCE World Resources Institute and International Institute for Environment and Development, *World Resources 1986 (New* York: Basic Books, 1986)

nection" by which U.S. and European beef consumers are said to be causing loss of diversity in tropical countries where forests are converted to pasture. The very difficult task of identifying, measuring, and mitigating such negative economic-ecologic links between nations is increasingly important as the world economy becomes more and more international (30).

The causal link between human population size and diversity loss is clearer in developing countries where population growth in rural areas continues to be rapid, and land-use regulations do not exist or are poorly enforced. Between 1980 and 2000, rural populations are expected to increase by 500 million in the developing world (57) (figure 3-3). where these people continue to rely on extensive agriculture, resource degradation and diversity loss can be expected to accelerate. The harmful impacts of population growth are also likely to be exacerbated by development programs that encourage large resettlements of landless people into deserts or tropical lowlands without providing the means to sustain agricultural productivity in such difficult sites (42).

CONCLUSION

Circumstantial Evidence

Biological diversity is abundant for the world as a whole. More than 10 million species may exist, but after more than 2oo years of study, scientists have only named and described some 1.7 million. Many of these species contain numerous genetically distinct populations, each with a different potential for survival and utility.

The abundance and complexity of ecosystems, species, and genetic types have defied complete inventory or direct assessment of changes. But from events and circumstances that can be measured, it can be inferred that the rate of diversity loss is now far greater than the rate at which diversity is created.

The circumstantial case is based on the knowledge that each wild species and population depends on the habitat to which it is adapted. Diverse natural habitats are being converted to less diverse and degraded landscapes. On those sites, diversity has been reduced. The sites that remain in a natural or nearly natural condition are often fragmented patches that will not support the diversity of larger areas.

For domesticated agricultural plants and anireals, the concern is genetic diversity, which must be maintained by active husbandry. Farming systems with high genetic diversity are being replaced by new systems with much lower diversity, so husbandry of many genetic types is abandoned. Thus, gene combinations that reproduce particular characteristics and took decades to develop may be lost in a single year. The rapid rate and large scale of agricultural modernization imply that genetic diversity losses are great, though quantitative estimates have not been made.

Data for Decisionmaking

In recent decades, inventories and monitoring of ecosystems, species, and genetic types have improved, and the knowledge of what exists has greatly enhanced abilities to maintain diversity. Biologists, resource managers, and conservationists concur that information available now is adequate in virtually every country to guide programs to maintain diversity.

The circumstantial case for diversity loss in the United States and other industrial countries is bolstered by abundant site-specific data as well as by regional survey data on ecosystems and species. This information has moved public and private organizations to allocate substantial resources to the establishment and management of nature reserves, abatement of pollution, and other programs that sustain biological diversity. Opportunities to improve the use of these data are discussed in chapter 5.

The situation is quite different in developing countries. Circumstantial evidence of diversity loss is compelling, and many countries have designated parks and natural areas in recent years. But the available data are not adequate to support policy decisions to allocate enough funds and other resources to maintain diversity. Both money and trained personnel are needed to develop the necessary information.

Public and private funds that might be used for conservation are extremely scarce. Therefore, a great need exists for good data and comprehensive planning, so that whatever funds can be allocated will be used effectively. Organizations such as The Nature Conservancy and the IUCN are working to develop the data and local planning expertise needed to adequately assess the status of biological diversity and prospects for its conservation. More concerted support from public institutions is needed, however, both in the United States and abroad.

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