ENDANGERED ECOSYSTEMS

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GLOSSARY

biological diversity The variety of genes, species, and ecosystems in the living world.
biome Group of ecosystems with similar characteristics, usually a major vegetation type such as tropical rain forest or grassland.
community All of the populations of different organisms that live within a given area.
conservation status Relative likelihood of extinction of a species or community.
deforestation Physical removal of trees and consequent reduction in forest cover.
ecoregion Geographic region of similar ecological processes and ecosystems.
ecosystem A dynamic complex of plant, animal, and microorganism communities and their nonliving environment interacting as a functional unit.
endangered Very likely to become extinct within the near future.
endemism Degree to which species are unique to a specific location.

THE SCALE OF HUMAN IMPACT on the natural environment has resulted in the decline and loss of many ecosystems. All of the world's major biomes are to some degree adversely affected by human activities, with forests, scrub and grasslands, and freshwater and coastal ecosystems being the most threatened. Specific ecosystems at high risk include dry tropical forests, especially on islands, temperate forests, Mediterranean shrublands, temperate grasslands, and most coastal marine systems. Overall, the large marine and oceanic ecosystems, polar regions, and dry deserts are generally less threatened, although the potential impacts of climate change on these ecosystems are only just beginning to be understood.

I. INTRODUCTION

A. Definition of an Endangered Ecosystem

The Convention on Biological Diversity (CBD) 1992, defines an ecosystem as "a dynamic complex of plant, animal and micro-organism communities and their nonliving environment interacting as a functional unit." By itself, however, the term "ecosystem" does not define any specific dimensions and the boundaries of ecosystems are often indistinct. Even in aquatic ecosystems, where the presence of water helps to identify the boundaries of lakes and rivers, the extent of an aquatic ecosystem fluctuates with changing water levels, floods, and tides. In the marine environment, ecosystems may be defined by particular attributes of water temperature or chemistry, or by the characteristics of the substrate, in addition to specific plant communities, such as sea grass beds or kelp forests. Other ecosystems may be defined by specific geographic or special physical characteristics, such as caves or seamounts.

Encyclopedia of Biodiversity

The concept of an endangered ecosystem is relatively new as compared with the widely accepted concept of an endangered species. The World Conservation Union (IUCN) has maintained an internationally recognized system of Red Data Books for defining and listing threatened species for many years, but no universally applied system has been developed for ecosystems so far. Similarly, there is no recognized system for measuring the relative conservation status of an ecosystem and it is often not clear in what sense the whole of the ecosystem can be seen to be threatened. While it is clear in most cases at what point a species has become extinct, it is much less clear at what point a specific ecosystem ceases to exist.

The uncertainty in defining the exact extent of an ecosystem has hampered attempts to quantify their conservation status, and there is an ongoing debate as to the appropriate scale for organizing and prioritizing conservation efforts. At the broadest level, ecosystems cross international boundaries and are subject to a wide range of threats and human influences. These major ecosystem types can be subdivided, as they vary enormously in their biological composition, environment, and functioning, often as a result of major geographic features such as mountain ranges, bays, and river catchments. At a finer level, an ecosystem may comprise a small group of underwater cave systems, sand dunes, an isolated island and fringing coral reef, or a mossy high-altitude swamp that covers no more than a few hectares.

B. Global Reviews of Endangered Ecosystems

The paucity of information on many ecosystems, as well as the lack of a standard approach, has hampered past attempts at national or global assessments of conservation status. However, recent progress in determining the conservation status of ecosystems at a global level has been made in response to the identified need for an international ecosystem assessment by a number of international agencies. Organizations that have been involved in global reviews of threatened ecosystems include the United Nations Environment Programme, and nongovernmental organizations such as Conservation International (biodiversity hotspots) and WWF (Global 200 ecoregions). The most significant of these have been published by the United Nations Environment Programme in the form of the Global Environment Outlook series and The World Resource Institute's Millennium Ecosystem Assessment (Reid *et al.*, 2005).

The purpose of the Millennium Ecosystem Assessment (MA) as stated in the foreword to the Biodiversity Synthesis report was to "assess the consequences of ecosystem change for human well-being and to establish the scientific basis for actions needed to enhance the conservation and sustainable use of ecosystems and their contributions to human well-being." The report includes global overviews of major ecosystem types including marine systems, coastal systems, inland water systems, forest systems, dryland systems, island systems, mountain systems, and polar systems. In addition to these overviews, 18 subglobal assessments were commissioned as part of the overall project.

The conclusions of the MA are graphic in their portrayal of ecosystem loss and state that "virtually all of Earth's ecosystems have now been dramatically transformed through human actions." In summary, over half of the 14 biomes that the MA assessed have experienced a 20–50% conversion to human use, with temperate and Mediterranean forests and temperate grasslands being the most affected.

At the national level, both the United States and Australia have undertaken recent reviews of threatened ecosystems. In Australia, some 2859 threatened ecosystems were identified in 2002, the majority of these being ecosystems associated with eucalypt forest and woodlands.

II. MAJOR ECOSYSTEMS AT RISK

A. Forests and Woodlands

The net reduction in global forest and woodland cover is estimated to be 5.3 million ha/yr, with more than one-third converted globally since 1700, mostly as a result of expanding human populations and agriculture. Trends in deforestation and net changes in forest area vary across regions, although there are many commonalities within major biomes across regions. In densely populated subregions, such as western Europe and southern China, this level of conversion has been much greater, with $<30\%$ of original vegetation cover now remaining.

The large-scale loss of ecosystems resulting from human influence has been most apparent in the conversion of fertile temperate forests into cropland and pasture. Considerable decline in forest area had already taken place by 1700, especially in the Mediterranean Basin and the Indus Valley and in northern and northwestern China. Large declines also occurred in northwestern Europe during the Middle Ages.

Primary or old growth forest (more than 200 years old) is now only a small part of the world's total forest area.

In contrast to the Mediterranean region, development in North America did not lead to the almost complete loss of forest. Over some 150 years, an initial rapid conversion of forested land was followed by a slowing down in clearance rates, and eventually by stabilization. In Australia, some 47% of all forests were cleared over the last 200 years, mostly during the period of rapid economic expansion and mechanized clearing of native woodlands for agriculture in the mid-twentieth century.

The major areas of rapid deforestation currently are in the tropics. Africa accounts for over 50% of recent net global deforestation, although the continent hosts only 17% of the world's forests. Ten tropical countries (six of them in Africa) had net annual change in forest areas of more than 3%, and four countries (three in Africa plus Nicaragua) had change rates of 2.5–3.0% between 1990 and 2000.

A similar pattern of forest loss is now occurring in the developing (mostly tropical) world. These patterns are again fueled by expanding human populations and agriculture, with the added impetus of industrial crops such as rubber and oil palm. It is clear that deforestation, particularly in the tropics, is having extremely negative impacts on forested ecosystems. Fifteen of the world's 25 biodiversity "hotspots" originally identified by Norman Myers in 1997 contain tropical forests (Myers, 1997). These areas once covered nearly 12% of Earth's land surface, but their remaining natural habitat has now been reduced to only 1.4% of that surface.

1. Clearing in Tropical Forests

All of the world's major tropical forest ecosystems are being rapidly cleared, the only exception at this point being the relatively intact forests of the island of New Guinea. The remaining forests in humid West Africa, for example, are disappearing at the rate of about 2% a year, and exceeding 5% in the extreme case of Côte d'Ivoire. The relic blocks of forests left at Gola in Sierra Leone, at Sapo in Liberia, and at Tai in Côte d'Ivoire are now of global importance as the last significant remains of the structurally complex and species-rich forests of the upper Guinea zone. Some areas, such as Fouta Djallon, Mount Nimba, and Loma at the head of major watersheds in western Africa (the Niger, Senegal, and Gambia Rivers), harbor exceptional biodiversity. The major cause of deforestation is clearance for agriculture (particularly commercial farming and to some extent shifting cultivation) and the harvesting of fuelwood. Commercial logging is limited, but settlement and agriculture around roads built to transport timber have resulted in additional clearing of forest areas.

In South America, deforestation is also mainly due to the expansion of agriculture. This process is driven by a number of factors, the most important being the displacement of peasant farmers from traditional farming areas, large-scale settlement programs such as in Rondônia in Brazil, and the deliberate promotion of livestock-raising activities in the Amazon through financial incentives. In addition, commercial logging, collection of firewood for household use, and road construction have all led to the unsustainable exploitation of the region's forests. Deforestation has been most severe on the Pacific coast of Central America, where $<2\%$ of the original 550,000 km^2 remains, and within the Atlantic forests of Brazil, which is left with only 4% of its original 1 million km^2 as pristine forests. The rapid loss of highly diverse native forests is of particular concern, because they are often replaced by species-poor pastures or by monocultures of exotic timber species. Most of the endangered tropical plants in Brazil (65%) are found in this highly endangered tropical forest ecosystem.

In the Asia and Pacific region deforestation has increased from 2 million ha/yr during 1976–1981 to 3.9 million ha/yr in 1981–1990, with Bangladesh, Pakistan, the Philippines, and Thailand experiencing the fastest rate of forest clearance. The Pacific subregion has the lowest rate of deforestation (around 130,000 ha/yr), most of which occurs in Papua New Guinea. Rapid population growth has contributed to depletion of forests not only through land clearing for cultivation but also through overharvesting of forests for fuelwood, roundwood, and fodder. At the current rate of harvesting, the remaining timber reserves in Asia may not last for more than 40 years.

Although the extent of forest cover in Europe may be significant and stable, or even increasing in parts, many of the elements of the forest ecosystem have been severely modified or lost and for this reason are considered to be threatened. Mature natural forest ecosystems are very rare. In northern and Central Europe this rarity has been caused primarily by intensive logging, resulting in a significant decrease in the integrity and natural condition of forests. Forests have been modified significantly to increase their commercial value at the expense of natural ecosystem complexity and structure. They are more likely to contain uniform, relatively even-aged stands, with little dead timber, and with a significantly reduced complement of animal species. In addition, there has been extensive

use of nonnative species such as Sitka spruce (*Picea sitchensis*) in the north and eucalyptus (*Eucalyptus* spp.) in the south.

Only the United States and Western European countries currently harvest less wood from available forest land than they regrow annually. Canada, Russia, Central and eastern Europe, and most developing countries harvest above replacement rates in their available forest areas.

Table I shows examples of some of the most endangered and biologically diverse forest ecoregions in the world. It is clear from this table that many tropical moist forests are endangered, particularly forests in western Africa, the lowland forests of Southeast Asia, and forests on islands such as Madagascar and the Philippines. Twenty-nine of a total of 53 tropical and subtropical moist forest ecoregions are endangered. Although rapid development of these regions for agriculture and large-scale commercial logging have been primarily responsible for this extensive forest loss, large-scale fire now poses a major problem in some of the previously contiguous forests of Indonesia and Malaysia, especially during periods of prolonged drought.

2. Mediterranean Forests

The Mediterranean forests have lost much of their natural condition as a result of excessive logging, fire, and overgrazing by livestock, especially goats. Forests are especially threatened at the boundaries of their natural distribution, such as the forest–steppe regions of southern Ukraine and Russia or in the Mediterranean Basin. Most of the Central Europe's alluvial forests along all major river courses have virtually disappeared. Airborne pollution (mostly in the form of acid deposition and photochemical smog) is also a major cause of damage to forest ecosystems in Europe, particularly in Central and eastern Europe. First reported in the Black and Bavarian forests of Germany in the early 1970s, damage from air pollution may now be detected in a quarter of all European trees.

3. Dry Tropical Forests

Similar problems face the seasonally dry forests, especially the monsoonal forests and conifer forests in the tropical and subtropical regions of the world, because these are often more restricted in their original distribution. The biologically rich dry forests of Madagascar and Central and South America are now much reduced. The remaining dry forests of Madagascar represent some of the richest dry forest ecosystems in the world in terms of their natural diversity. Around 165 Ma, Madagascar drifted away from Africa, which allowed its native species to evolve in isolation from the mainland continent. Among the many unique species are the lemurs—members of the primate family found only in Madagascar and the neighboring Comoros Islands—including the recently discovered mouse lemur (*Microcebes myoxinus*) and golden-crowned sifaka (*Propithecus tattersalli*), both of which appear to be restricted to this ecosystem.

4. Temperate Forests of the Caucasus

Temperate forests have also been extensively cleared for hundreds of years and few large examples remain intact. Forest loss has been most severe in western Europe, and most examples of this forest type are now restricted to Central and eastern Europe. The Caucasus ecoregion harbors some of the most diverse and distinctive temperate conifer and broad-leaved forests in Eurasia, as well as rich woodlands, steppe, and grasslands. One of the world's seven temperate rain forests formerly occurred here, but this habitat has been virtually destroyed. Lowland forests are dominated by oak, chestnut, and lime, while higher regions are covered by beech, fir, and spruce. Although the ecoregion covers a relatively small area, its varied range of landscapes and climates, and its geographic position at the edge of Europe and Asia, which represent many of their respective species, has given the ecoregion a high level of biological diversity. In the Caucasus Mountains alone, more than 6400 species of vascular plants have been recorded (of which 23% are endemic), as well as 7000 species of ferns, lichens, and mosses.

5. Temperate Forests of China

The temperate forests of southern China are among the world's most biodiverse and endangered temperate forest ecosystems. Subtropical evergreen broad-leaved forest is the dominant vegetation of this ecoregion, which also includes alpine ecosystems, steppe grasslands, and wetlands. Alpine vegetation of the Qiinghai–Tibet plateau predominates in the west and the higher regions in the southwest of the Hengduan Mountains. Deciduous broad-leaved forests of the warm temperate zone occur north of the province. Though the biological richness of China and Sichuan is well recognized, international attention has largely focused on a single species that has become a symbol for conservation efforts worldwide—the giant panda (*Ailuropoda melanoleuca*). Sichuan province is home to the vast majority of the world's wild pandas. Loss of vegetation cover is one of the main threats to wildlife

TABLE I

Some endangered forest ecosystems

Region	Tropical and subtropical moist broad-leaved forests	Tropical and subtropical dry and monsoon broad-leaved forests	Conifer and temperate broad-leaved forests
Africa	Madagascar moist forests Guinean moist forests (West Africa) Eastern Arc montane forests East African coastal forests Albertine Rift highland forests (central Africa) Seychelles and Mascarene Islands forests Gulf of Guinea island forests Macronesian (Atlantic islands) forests Congolian coastal forests (West Africa)	Madagascar dry forests Maputaland–Pondoland dry forests	
Asia	Western Ghats moist forests (India) Sri Lankan moist forests Peninsular Malaysia lowland and montane forests Sumatran–Nicobar Islands forests Northern Borneo–Palawan moist forests Philippines moist forests Southeast China subtropical forests Hainan Island forests (China) Nansei Shoto Archipelago forests (Japan)		Western Himalayan temperate forests Central China temperate forests Eastern Himalayan broad-leaved and conifer forests
Australasia and Pacific	New Caledonia moist forests New Zealand subtropical forests Lord Howe and Norfolk Island forests (Australia) Hawaiian moist forests South Pacific island forests	New Caledonia dry forests Hawaiian dry forests	
Europe and Russia			Southern European montane forests
Latin America and Caribbean	Brazilian Atlantic forests Northern Andean montane forests Coastal Venezuela montane forests Greater Antilles moist forests Varzea flooded forests	Bolivian lowland dry forests Tumbesian and North Inter-Andean Valleys dry forests Southern Mexican dry forests	Mexican pine–oak forests Greater Antilles pine forests Valdivian temperate rain forests (Chile)
North America			Klamath–Siskiyou coniferous forests Appalachian and mixed mesophytic forests Pacific temperate rain forests (United States and Canada) Sierra Nevada conifer forests Southeastern conifer and broad-leaved forests

in the province and half of the panda's habitat ($10{,}000\,km^2$) was lost between 1974 and 1989 alone. Logging and small-scale agriculture are the main reasons for this decline. Hunting in wildlife reserves and human disturbance from people collecting medicinal plants are additional concerns.

B. Scrub, Heath, and Grassland Ecosystems

Despite their often uniform appearance, low-stature vegetation communities of the type referred to as scrubs, heaths, and grasslands are complex and varied, with many regional variations and subtle differences

resulting from soil type and climate. They are usually present where soil nutrients, water availability, or climate are not conducive to the growth of forests. They are well suited, however, to grazing by domestic animals and for conversion to cultivation, especially cereal crops. As a result of their suitability for agricultural development, temperate scrubs, heaths, and grasslands are among the most modified of the world's major ecosystems.

Large areas of current and former temperate scrub and grasslands occur throughout continental Europe and Asia and North America. In northern polar regions, these communities extend into the Arctic Circle, forming a vast patchwork of semifrozen and permanently frozen swamps and low vegetation. This latter region appears to be relatively intact, although the future impacts of global warming might considerably alter the distribution and extent of these ecosystems.

European communities of this type range from the Arctic tundra to the Mediterranean shrublands, including many different types of woody shrub communities (including maquis and dwarf shrub heath), tall herb stands, and many types of grassland. They occur at all altitudes and can range from very sparse to very dense cover, and from a few centimeters to 2 or 3 m in height. Human activities have modified most European scrub and grassland plant communities other than those found on mountaintops or on very poor soils. In some cases, particularly where wetland drainage or forest clearance for timber and farming has taken place, new scrub and grassland ecosystems have been created.

Given their suitability for grazing animals and agriculture, it is not surprising that large areas of grasslands have been converted from their natural state. In eastern Europe, the steppe ecosystems have become extremely rare and large areas of undisturbed steppes are now found only in the south, where they border semidesert regions (north and west of the Caspian Sea, i.e., the Volga Delta and Terek region). The principal cause for the loss of scrub and grassland habitats over the last 50 years has been the advent of widespread agricultural mechanization, which has resulted in the cultivation of large areas of natural and seminatural grassland. Remaining grasslands are isolated and highly fragmented, and usually restricted to steep slopes and ground with thin soils. Increased use of fertilizers and biocides has further threatened many species. The grassy plains of North America have been drastically reduced. The tallgrass prairies of the American Midwest and Great Plains are a unique set of plant communities that once covered vast areas of the continent and supported huge herds of grazing animals such as the bison. Originally thought to be poor agricultural lands, because of the scarcity of trees, the prairie ecosystem was discovered to be immensely fertile, and during the period from the early 1800s to 1930, about 90% of this ecosystem was converted to farmland.

Closer to the tropics, large areas of tropical savannas and grasslands can still be found in Africa, Australia, and South America. Most of these savannas are used for pastoralism, and the impact of large numbers of grazing animals, often poor soils, changed fire regimes, and human settlements have modified and degraded many areas. As native vegetation cover declines, soil erosion proceeds and turns these semiarid ecosystems into deserts.

Table II shows some of the most endangered and biologically diverse ecoregions of this type in the world. Many temperate ecosystems have been lost, or so extensively modified that it is difficult to determine their original nature. In Australia, for example, $<1\%$ of the original temperate lowland grasslands remain, much of this restricted to roadsides, railway lines, cemeteries, and lightly grazed unimproved pastures. Some of the world's most floristically diverse regions, such as the mixed shrublands of the Mediterranean, South Africa, and southwestern Australia are now highly fragmented and suffer from impacts such as dryland salinity and more frequent or intense fires.

1. South African Fynbos Ecosystem

One of the most biologically diverse and endangered of all the world's ecosystems is the fynbos shrublands of the southwestern and southern Cape of South Africa. Although relatively small in extent, the 470 km^2 of the Cape Peninsula, including Table Mountain, are home to 2285 different plant species, including one of the highest concentrations of endangered plant species. The fynbos is under serious threat from increasing urban expansion (especially in the Cape Flats area) and invasion by exotic weed species, including a number of Australian acacias. Similar shrubland communities can be found along the coastlines of the Mediterranean, southwestern Australia, southern California, and Chile, and in each case they are considered to be extremely threatened.

C. Inland Waters and Wetlands

About half of all inland water and wetland habitats were lost during the twentieth century and even this

TABLE II

Some endangered scrub, grassland, and savanna ecosystems

Region	Grasslands, savannas, and shrublands	Deserts and xeric shrublands	Mediterranean shrublands and woodlands
Africa	Angolan escarpment woodlands Zambezian flooded savannas Ethiopian highlands Zambezian montane savannas and woodlands South African montane grasslands and shrublands	Namib and Karoo Deserts and shrublands Madagascar spiny desert	Fynbos (South Africa)
Asia	Terai-Duar savannas and grasslands (north Indian subcontinent) Red Sea fog woodlands	Central Asian deserts	
Australia	Blue-grass grasslands Lowland temperate grasslands Brigalow and Ooline scrubs		Southwest Australia woodlands and heaths Buloke and grassy white box woodlands (southeastern Australia)
Europe and Russia		Atacama Desert	Mediterranean shrublands
Latin America and Caribbean			Chilean matorral
North America	Tallgrass prairies (United States) Everglades flooded grasslands		California chaparral and woodlands

amount is exceeded in parts of North America, Europe, and Australia, primarily as a result of draining for intensive agriculture. Given the long agricultural and industrial history of Europe and the Mediterranean region, it is not surprising that most of its wetlands have been significantly modified or lost. Only in the extreme north do large wetland ecosystems remain relatively intact. Of the more than 300 European and Mediterranean wetlands of international importance designated in the Ramsar Convention, 80% are considered to be threatened to some extent. Of major concern has been the continued loss and degradation of freshwater habitats in the Mediterranean Basin, including many inland lakes and coastal lagoons and estuaries. In Spain alone, more than 60% of all inland freshwater wetlands have disappeared during the last 25 years.

Large and relatively intact wetland ecosystems can still be found throughout South America, the largest and most famous being those within the Amazon River Basin. Even here, the rivers of this region are being increasingly polluted by industrial and urban wastewaters from large industrial cities, wastewater from mining industries, and agricultural runoff. As a result, many of the region's water resources are now chemically and biologically contaminated. Several rivers in Colombia, including the Medellín and the Bogotá, are almost totally devoid of life as a result of reductions in dissolved oxygen. Other rivers, especially in areas subjected to mining operations, are heavily contaminated with toxic wastes and overburden. Large quantities of agricultural contaminants are disposed off in streams flowing into the Caribbean Sea, where there is clear evidence of elevated levels of phosphorus, nitrates, potassium, pesticides such as DDT, and organic effluent. Pollution and saltwater intrusion also threatens groundwater supplies across the wider Caribbean. In Venezuela, for example, the overuse of aquifers has resulted in a reduced flow of freshwater to nearby reef areas.

1. Pollution of Wetland Ecosystems

The use of lake and river water for industrial purposes often affects water quantity (when abstracting water) and water quality (when reintroducing it as wastewater, sometimes polluted or of higher temperature). Many industries, such as pulp and paper production and mining, wash large quantities of particulate matter into lakes and rivers. Pollution and sedimentation threaten many inland waters and other wetlands. In some cases, the source of this pollution may be distant,

with contaminants being transported through the air in the form of industrial emissions. One of the best-known examples of this threat to wetland ecosystems was the acidification of European rivers and lakes, especially in the southern parts of Scandinavia. During the 1950s and 1960s, at the peak of sulfur deposition, the rate of acidification was several hundred times that of the natural process and thousands of Scandinavian lakes became too acidic to support their original fish populations. Despite a decline in atmospheric pollution over the last two decades and partial mitigation through liming activities, acidification continues to have detrimental effects on these lake ecosystems.

The harmful increase in nutrient levels (eutrophication) occurs widely where the catchments of lakes and other wetlands are intensively farmed or densely populated. Fish-farming operations and sewage effluent discharge may also result in the eutrophication of water bodies. As a result of increased nutrient levels (most commonly nitrogen- and phosphate-based fertilizers or animal and human wastes), there is an increase in phytoplankton production and microbial decay with consequent deoxygenation of the water and production of toxins.

Marshes, bogs, and fens are a group of vegetated wetlands that were once widespread in Europe. Since early medieval times, however, these habitats have been drained or mined for peat. Although some extensive areas of peatlands and similar ecosystems still exist in the northern (boreal) and eastern regions of Europe, extensive areas of the original peatlands of western Europe (including Scandinavia) have disappeared. The vast marshy wetlands of Finland, for example, have declined by about half, primarily as a result of natural drying, drainage for agriculture, and peat extraction.

2. The Aral Sea

The Aral Sea of southwestern Asia is one of the most threatened wetland ecosystems in the world, and will require major international effort and cooperation to restore it to a reasonable state of health. The Aral Sea is fed by the Amu Dar'ya and Syr Dar'ya Rivers, flowing from the mountains of Tian Shan and Pamirs. These waters are the main source of water for Uzbekistan, Kyrgyzstan, Tajikistan, Turkmenistan, and the southern part of Kazakstan. Traditionally, about half of the water was used for irrigation and the other half flowed into the Aral Sea. Intensive development of cotton and other irrigated crops over the last few decades has reduced the inflow of these rivers to about 3% of former levels. Since 1960, the Aral Sea has lost two-thirds of its volume and its salinity level is now approaching that of seawater. Almost all the native organisms have died out. The 3.3 million ha of exposed seabed has become a source of wind-borne salt and agricultural residues that has now spread over surrounding areas. The five republics developed a water distribution agreement in 1992 and an Aral Sea Programme in 1995, which aims to stabilize the region and improve the management of the waters in the basin. A recent collapse of agriculture in the region has since then lead to some alleviation of the pressure on what was once one of the world's largest inland wetlands.

3. The Great Lakes and Everglades

With about 18% of the world's fresh surface water, the Great Lakes system on the Canada–US border is one of the most extensive freshwater ecosystems. Spanning more than 1200 km from east to west, the Great Lakes—Superior, Michigan, Huron, Erie, and Ontario—together with the St. Lawrence River system, are surrounded by large human populations and dense concentrations of industry.

Beginning in the 1950s, concerns arose about the increasing eutrophication of the lakes, loss of wetlands, and other habitats, the impact of exotic species on native fish stocks and aquatic ecosystems, and environmental contamination by persistent toxic chemicals. Major efforts to manage the lake system have since done a great deal to restore environmental quality. Nutrient levels have been managed successfully and there has been a decline in the concentrations of some toxic chemicals such as persistent organic pollutants derived from pesticides and industrial processes. The flora and fauna of Lake Superior have recovered and are again in good condition. The system remains in a fragile balance, however, and concentrations of many toxic chemicals remain high. Aquatic habitats and wetlands are still in a poor state overall, and the aquatic ecosystems of Lakes Michigan, Ontario, and eastern Erie remain highly modified.

Equally famous are the Everglades of the Southeast United States—the largest example of a rare flooded grassland ecosystem. For the past 30 years, south Florida has experienced an accelerated loss of this large and unusual wetland complex. From the Kissimmee River, a series of marshy oxbow lakes flow into Lake Okeechobee, one of America's largest freshwater lakes. Okeechobee in turn feeds slowly into the Everglades itself, known as the fabled "River of Grass." To the south, the shallow estuary of Florida Bay once contained a very rich marine life, and an extensive coral reef system thrived off the Florida Keys. Excessive consumption of

water for agriculture and residential populations has led to a decline in wading bird populations by some 90%, and the Everglades have shrunk to a tiny fraction of what they were a half-century ago. Sea grass die-offs and massive algal blooms have contaminated much of the previously clear waters of Florida Bay with silt, which now threatens to smother the coral reefs. An introduced tree species of the genus *Melaleuca* is now widespread and has displaced some of the native flora. Altogether there are now some 55 federally listed endangered or threatened species in the area.

4. Wetlands of the Sunda Region

The rivers, lakes, and other freshwater habitats of the lowland Sunda region (western Indonesia, Malaysia, and Brunei) contain the most significant freshwater diversity of any Asian wetland ecosystem. Forest loss is by far the most serious threat to these freshwater ecosystems as it disrupts the flow of nutrients, leads to water temperature rise because of decreased shading, and lowers concentrations of dissolved oxygen, resulting in conditions that are unsuitable for many fishes and freshwater invertebrates. Road construction, logging, and shifting agriculture, particularly in mountainous regions, result in soil erosion and thus increased sediment loads in rivers, which further reduces water quality. Hunting also represents a major threat to some aquatic species such as crocodiles and freshwater turtles, in this ecoregion. Water pollution is a constant and increasing pressure on many water systems. Part of this problem stems from increased motor traffic on the larger rivers, but chemical runoff from agriculture and the dumping of untreated waste into lakes and rivers are also major concerns. Tourism will also contribute to pollution if it is allowed to develop in an uncoordinated manner and scenic areas such as Lake Toba in northern Sumatra are particularly vulnerable to pollution.

D. Marine and Coastal Ecosystems

Given that up to 60% of the world's human population lives along the coast, it seems inevitable that many highly diverse and productive coastal ecosystems should be particularly threatened. Early human settlements were common along coastlines as they offered a combination of marine- and land-based sources of food, navigable rivers, and access to maritime trading routes. With the advent of industrial development, coasts also offered a superficially simple solution to the growing human populations and their wastes, namely, dumping in large coastal rivers.

Endangered marine ecosystems are most obvious in those parts of the world subject to extensive industrialization, such as the North Atlantic Ocean and the Baltic, Caspian, Mediterranean, and other seas adjacent to Europe. Other ocean systems that would appear to be at a high risk include the Sea of Japan, South China Sea, Caribbean Sea, and Gulf of Mexico.

Although less threatened overall, the world's oceans contain some of the least explored areas of the world, and only a tiny percentage of the deep seabed has been subject to biological investigation. Nevertheless, studies have revealed a wealth of diverse ecosystem types in the deep sea, which include seamounts, cold water coral reefs, hydrothermal vents, deep-sea trenches, and submarine canyons. Of these, seamount ecosystems and cold water coral reef communities are particularly threatened by high-impact fishing methods, such as bottom trawling. Coastal ecosystems and near-shore marine areas are considered to be the most threatened of all ecosystem types. About 35% of mangrove ecosystems has been lost or converted, 20% of coral reefs have been destroyed, and up to 20% of coastal wetlands are lost in some places of the world on an annual basis.

Studies of European marine systems show that land-based pollution and diffused sources of pollution are the major causes of a general deterioration in water quality, from polychlorinated biphenyls (PCBs) in the Baltic to oil and pesticides in the Caspian. Organic wastes, including sewage, by-products from industries (pulp and paper mills or tanneries), and fertilizers contained in runoff from agriculture, are common throughout European marine ecosystems. Three-quarters of the region's pollution originates from only three countries—France, Spain, and Italy—and causes the contamination of seafood and eutrophication of enclosed bays. Throughout the region, 80% of municipal sewage is discharged untreated from coastal cities, and up to 600,000 t of crude oil are released annually from oil-related operations and shipping. Agricultural runoff in the form of pesticides, including persistent organochlorinated compounds, contaminate the food chain, and nitrate and phosphate runoff cause eutrophication and increased episodes of algal growth, including the poisonous "red tides." Chemical pollution, bottom-trawling fishing practices, and the introduction of exotic species have contributed to the depletion of indigenous marine life, such as *Posidonia* (sea grass) meadows.

Increasingly, overfishing is being implicated as a threat to marine ecosystems, particularly in areas such as the North Sea, which are subject to intensive exploitation. Depletion of commercial fish populations may cause changes in the species composition and adversely

affect populations of birds, seals, and cetaceans that feed on these species. In addition to depletion of fish stocks, some fishing techniques have a direct impact on nontarget populations. Trawling or dragging of fishing gear, for example, can have devastating local impacts on benthic ecosystems such as the rare Norwegian coral communities (*Paragorgia arborea*) or the diverse communities associated with the horse mussel (*Modiolus modiolus*) at Strangford Loch in Scotland. In many parts of the world, other fishing techniques have also severely damaged marine ecosystems. Drift netting is particularly notorious for the high by-catch of species such as sea turtles, cetaceans, and seals, whereas long-line fishing has been responsible for the deaths of tens of thousands of albatross and other seabirds in southern oceans. The trawling of seamounts has the potential to destroy these unique ecosystems and their numerous unusual, and restricted species.

1. The Wadden Zee

More than 70% of the European coastline is considered to be under a high degree of threat. Threats to coastal and marine ecosystems arise from a wide variety of human impacts and vary considerably in different parts of the world. In the temperate and industrialized regions, areas such as the Wadden Zee along the Netherlands coast show the effects of many centuries of human impact. Much of the biological richness of the Wadden Zee derives from its mudflats (waddens), which appear to be decreasing as a result of the construction of dykes and barriers that affect not only the immediate vicinity but also the flow and direction of water currents and sedimentation patterns. Pollution and eutrophication, caused by synthetic organic substances, heavy metals, oil, and a surplus of nutrients, have been identified as a major threat to the area's wildlife populations. The use of tributyl tin (TBT) as an antifouling agent in paint has resulted in a sharp decline of two species of whelk. Shorebirds are threatened by oil spillages in the Wadden Zee, and pollutants such as chlorinated hydrocarbons have caused reduced breeding success among common tern (*Sterna hirundo*) populations. High levels of pollutants may also interfere with the immune systems of certain species, and in 1988 a large number of harbor seals died from a viral outbreak. Many of the region's natural resources have been overexploited, and as early as the end of the nineteenth century native oysters began to disappear. Natural mussel beds have also dramatically declined, and in large parts of the Wadden Zee mechanized cockle fisheries continue to disturb the mud surface.

2. Coastal Ecosystems of Eastern Africa

Coastal marine ecosystems in eastern Africa are biologically diverse, but they are also increasingly threatened by expansion of coastal populations and development. Corals form an almost continuous fringing reef along the entire coastline of eastern Africa. The western coasts of the islands of Zanzibar, Pemba, and Mafia are characterized by patch reefs, whereas well-developed fringing reefs predominate on the eastern sides. One of the most biologically diverse areas—the Bazaruto Archipelago in Mozambique—supports a range of marine habitats, including deep-sea areas, coral reefs, rocky intertidal areas, sandy beaches, tidal sand flats, sea grass meadows, and mangrove communities. Marine turtles and many species of marine mammals are found in these coastal waters, including the highly threatened dugong (*Dugong dugon*). The mangroves are spawning nursery habitats for many fish and crustacean species, and provide an invaluable ecological service by filtering riverine sediments that can damage nearby coral reefs. Environmentally harmful fishing practices, such as dynamite fishing as well as overfishing, pollution, and uncontrolled tourism development, threaten the survival of these reefs and other coastal ecosystems throughout the region.

3. Island Ecosystems

Islands are particularly susceptible to invasion by exotic species or rapid depletion of their resources following human colonization. Some island ecosystems have evolved in long isolation from nearby landmasses and may contain many unique plant and animal species. They are also the breeding grounds for many marine species, such as turtles, seals, and seabirds that may be vulnerable to predators. In some cases, birds have become flightless as a result of the absence of predators, making them especially vulnerable should humans or exotic species arrive. It is not surprising then that most animal and plant extinctions that have occurred in historic times have been of island species. Islands that are of particular concern for both their significant biological richness and vulnerability to human impact include those of New Caledonia, Hawaii, Madagascar, and the Galápagos Islands.

Although the overall rate of island deforestation appears to have slowed down in the last decade, annual deforestation on islands is almost three times the world average rate. The main causes of deforestation include conversion for agricultural use and for infrastructure development such as roads, ports, housing,

and tourism development. Loss of forests in island systems often has more serious impacts on biodiversity than forest loss elsewhere due to their smaller extent, and the presence of endemic species and unique ecosystems.

The Galápagos Islands represent one of the most outstanding examples of the evolutionary processes that influence isolated island ecosystems, as well as susceptibility to human impacts. Across the many individual islands of the Galapagos group arid lowlands of open cactus forest, transitional subtropical forest, moist dense forest at higher elevations, and treeless upland areas covered with ferns and grasses can be found. Habitat destruction and degradation from grazing by introduced goats, sheep, and cattle, as well as uncontrolled fires, are a major threat. Introduced pest species such as rats and cats prey on native species. Poaching of rare and threatened species is increasing, as is the overexploitation of many marine species such as sea cucumbers (*Ischitopus fuscus*) and sharks. Tourism and settlement from the mainland pose additional pressures on an already stressed ecosystem.

4. Mangrove Ecosystems

Under the right conditions, extensive mangrove forests can be found throughout the tropics in shallow bays and inlets and along rivers. These biologically rich communities have been subjected to enormous pressure from human settlement. By 2001, it was estimated that about one-third of the world's mangroves had been destroyed. The main reasons for this loss in the past have been felling for firewood or the production of charcoal. The rapidly expanding shrimp aquaculture industry represents a new and increasing threat to the world's remaining mangroves. The clearing of mangrove forests to make way for shrimp ponds is responsible for about half of all the mangrove loss in recent years, and has greatly reduced the extent of mangroves in Southeast Asia, South Asia, and Latin America. Thailand has lost more than half of its mangrove forests since 1960 as a result of the booming shrimp aquaculture industry. In Ecuador, estimates of mangrove loss range from 20% to nearly one-half of Ecuador's original 362,000 ha of mangrove forest. Typically, the shrimp ponds are abandoned after a few years and new areas have to be cleared.

5. Coral Reefs

It is estimated that ~20% of the world's coral reefs have been destroyed and more than a further 20% badly degraded or under imminent risk of collapse. Although coral reefs occupy a small fraction (<0.2%) of the total area of the world's oceans, they are among the most biologically diverse of all ecosystems. Formed by the accumulation of calcium carbonate deposited by certain coral species over thousands of years, coral reefs cover some 600,000 km^2 and are the largest structures formed by living creatures. The destruction of coral reefs is caused by many human activities, ranging from coastal development and destructive fishing practices to overexploitation of resources, marine pollution, and runoff from agricultural activities and deforestation. A number of reefs of particular biological interest are also under the most serious threat, including almost all the reefs of the Philippines and coral communities in coastal Indonesia, Tanzania, the Comoros, and the Lesser Antilles in the Caribbean.

Of all the world's ecosystems, coral reefs may be the most vulnerable to the effects of climate change. Bleaching does not automatically kill corals, but successive bleaching events in close proximity, or prolonged bleaching events, often do lead to mass mortality. Some recovery may occur given sufficient time between bleaching episodes, and ~40% of the reefs that were seriously damaged in the 1998 coral bleaching events are either recovering well or have fully recovered. Climate change also has other detrimental impacts on coral. For example, rising carbon dioxide levels change the pH of water, reducing calcium carbonate deposition (reef building) by corals. Climate change also facilitates the spread of pathogens leading to the spread of coral diseases. It has been suggested that climate change will reduce the world's major coral reefs in exceedingly short time frames with one estimate suggesting that all current coral reefs will disappear by 2040 due to warming sea temperatures.

Even coral reefs in developed countries are not immune to human impacts. The Nansei Shoto Islands, a chain of 200 islands off southwestern Japan, for example, contain some of the most extensive and biologically diverse coral reefs in the western Pacific. The relative isolation of the islands' marine and terrestrial ecosystems has produced unusual patterns of endemism. On Shiraho reef there are at least 120 species of coral, including the oldest and biggest community of blue coral (*Heliopora coerulea*) in the Northern Hemisphere and extensive colonies of the massive porous coral (*Porites australiensis*), Madracis coral (genus *Madracis*), and staghorn coral (family Acroporidae), as well as more than 300 species of fish. These coral reef ecosystems have become seriously threatened since 1972, with up to 90% lost as a result of silt runoff from construction, farming, and logging activities.

6. Other Endangered Coastal Ecosystems

A variety of ecosystems can be found in the coastal zone depending on geographic location and the local physical environment, including sand dunes, coastal wetlands and lagoons, sea grass beds, salt marshes, and mudflats. These ecosystems are among the most restricted in extent, as well as highly threatened by coastal development, pollution and human exploitation.

Sand dunes are unique ecosystems occurring at the margins of the land and sea, founded upon the sands that are washed up by the movements of the sea. In Europe there are $<$428,000 ha of dunelands remaining on Atlantic coasts and widespread planting with exotic species has changed their character. The situation is more acute along the southern European coastline, where sandy beaches are the main attraction for many of the 100 million tourists who visit the Mediterranean each year. Construction of coastal towns and resorts has resulted in an estimated 71% loss in dune areas since 1900.

Salt marshes and coastal peat swamps have also undergone massive change and destruction, whether they are within estuarine systems or along the coast. Salt marsh subsidence has occurred in part due to restricted sediment delivery from watersheds. Peat swamps in a number of Southeast Asian countries have declined from 46% to 100% in countries monitoring changes. Rocky intertidal, nearshore mudflats, deltas, beaches, and dunes also provide ecosystem services such as food, shoreline stabilization, maintenance of biodiversity (especially for migratory birds), and recreation. In the United States, the rocky intertidal zone has undergone major transformation in the last few decades: the California mussel (*Mytelus californianus*) has become very rare, the sea star *Pisaster* sp. is now almost never seen. The once abundant black abalone (*Haliotis cracherodii*) can no longer be found in southern California and dozens of formally abundant nudibranch species are now rare. Similar trends have been observed elsewhere in the world. Along the Yellow Sea coast, China has lost around 37% of habitat in intertidal areas since 1950, and South Korea has lost 43% since 1918.

III. THE CONSERVATION OF ECOSYSTEMS

A. Global Drivers of Ecosystem Change

1. The Major Human Impacts on Ecosystems

The conservation of ecosystems depends on the management of human-induced impacts. Factors that threaten ecosystems can be seen as falling into three categories: factors that reduce the extent of an ecosystem, factors that alter the species composition of an ecosystem, and factors that disturb ecosystem processes. Many ecosystems are at the point of disappearing, or being irreparably modified. Table III gives a summary of threats to major ecosystem types.

Ecosystems can be considered endangered when their extent, species composition, or the natural processes that sustain life become sufficiently disrupted or degraded. The difficulty in describing the exact extent and status of an ecosystem, however, makes precise assessment of their conservation status much more difficult than it is for a species of organism. In particular, the conservation status of an ecosystem depends greatly on the scale at which the ecosystem is considered. From the major global biomes such as tropical forests, or deserts, to the regional and local scale, various threats operate that affect the likely persistence of that ecosystem, or its components. The ecoregional approach developed in the late 1990s (Olson and Dinerstein, 1998) is now a widely used approach for classifying, assessing, and managing ecosystems at the regional scale—combining environmental and geographic attributes to identify specific regions of high biodiversity.

2. Conversion of Ecosystems for Food Production

The recent expansion of mechanized agriculture has been the main factor in a rapid conversion and loss of terrestrial ecosystems. Large areas of forest, woodland, and grassland have been destroyed following the early expansion of agriculture, starting in southwestern Asia, China, the Mediterranean, and Europe and in the past 100 years North and South America, and Australia. Many temperate ecosystems are now endangered as a result. Similar trends are now obvious in the tropical regions of the world, exacerbated by poor forestry practices and the replacement of forests with cash crops. Even where natural ecosystems have not been subject to deliberate modification, human impacts are detectable as a result of exploitation, pollution, and the presence of foreign species.

Within the marine environment, near-shore ecosystems such as coastal, island, and coral ecosystems are the most threatened. In the open oceans it has become apparent in recent years that certain deep-water ecosystem types such as seamounts and deep-water corals are also threatened, particularly as a result of destructive fishing practices such as bottom-trawling.

TABLE III

Threats to the world's major ecosystem types

Ecosystem type	Main threats
Tropical moist forests	Clearing for agriculture and plantations, large-scale forestry operations, development of roads, towns, and other urban infrastructure, fire.
Temperate forests	Clearing for agriculture and plantations, large-scale forestry operations, development of roads, towns, and other urban infrastructure, fire, introduced exotic species, air pollution.
Boreal forests	Large-scale forestry operations, fire, development of roads, towns, and other urban infrastructure
Tropical woodlands and savannas	Clearing for agriculture and plantations, irrigated crops, pastoral development and grazing by domestic stock, feral animals (e.g., goats), development of roads, towns, and other urban infrastructure, fire, introduced exotic species.
Temperate woodlands	Clearing for agriculture and plantations, large-scale forestry operations, development of roads, towns, and other urban infrastructure, fire, introduced exotic species, air pollution.
Scrubs and grasslands	Clearing for agriculture and plantations, irrigated crops, pastoral development and grazing by domestic stock, feral animals (e.g., goats), development of roads, towns, and other urban infrastructure, fire, introduced exotic species.
Deserts	Large-scale irrigation developments, changes in water regimes (e.g., water extraction for irrigation), changes in fire regimes, introduced plant and animal species, urban encroachment.
Tundra and ice sheets	Pollution (land and marine), climate change.
Freshwater wetlands	Water extraction, pollution (especially eutrophication, persistent organic pollutants, and heavy metals), drainage and altered flows, large-scale dams and weirs, urban development, introduced species (especially nonnative fish, invertebrates, and water plants).
Coasts and shallow seas	Direct impacts from dredging and reclamation, coastal development and urban infrastructure (including cities, ports, and harbors), marine and land-based sources of pollution, introduced marine organisms, climate change (especially for coral reefs and coastal wetlands), overfishing and destructive fishing practices (e.g., dynamite and cyanide fishing, bottom trawling).
Oceans	Marine pollution (including oil pollution and dumping of toxic chemicals), overfishing, and destructive fishing practices.

Efforts to conserve ecosystems are being made throughout the world, but these are often hampered by conflicting land-use issues and a general lack of understanding of ecosystem processes. At the global level, international conventions and agreements have established a legal framework for ecosystem conservation. Following the development of the CBD in 1992, many countries have begun the task of classifying ecosystems and determining threats. Assessments of the progress in achieving the goals and targets of the CBD indicate that the conservation of natural ecosystems will require much greater action at a variety of levels, from international to local, and will require a fundamental change in the patterns of resource exploitation and consumption.

Nearly 60 years after the development of the concept of an ecosystem, it is now apparent that many have been lost through human activities, or so significantly altered that they may be considered endangered. Our understanding of ecosystems has changed profoundly, with much greater recognition now given to their dynamic and complex nature and the potential for human activities to change their biological and physical components.

There is an urgent need to improve our knowledge of the distribution and conditions of the world's ecosystems. Current national and international initiatives for developing habitat classifications and evaluation methodologies need further coordination. The information that is available points to the inescapable fact that the extent and quality of remaining natural ecosystems are in decline and in certain cases this decline is accelerating.

3. Changes in Species Composition of Ecosystems

Apart from complete destruction, most of the world's remaining natural ecosystems show some effects of human intervention. Commonly, these are factors that alter the distribution or abundance of species within an ecosystem. Although species populations constantly change, disruptions to these natural cycles can have widespread effects. Certain species, for example, are referred to as "keystone" species because of their vital role in maintaining the populations of other species (e.g., they may pollinate flowers or be large predators). When such changes affect the so-called keystone species, then larger impacts may be observed in the rest of the ecosystem. Extensive hunting, the

harvesting of timber, grazing of livestock, exploitation of fisheries, and other natural resources, often affect populations of keystone species and thus alter natural ecosystems, sometimes to the point where they can no longer sustain their original plants and animals.

The deliberate or accidental spread of exotic animals and plants also disrupts the ecosystem as these new predators or competitors flourish at the expense of the original species. The pollution of land, water, and air may affect ecosystems by introducing additional nutrients or toxic substances into food chains, causing deaths or reduced reproductive success and consequent changes in species composition. The cumulative impact of these factors can often be observed at some distance or point of time from the original impact. The modification of a river high in the mountains, for example, may eventually affect the water quantity and quality reaching a coastal marine ecosystem, changing that ecosystem and in turn affecting the viability of coastal communities. In such cases it may be possible to manage these uses sustainably, and even to restore and rehabilitate many of the attributes of the original ecosystem.

4. Climate Change Impacts on Ecosystems

The effects of climate change will pose new threats to natural ecosystems, particularly those at the edge of their climatic tolerance. Species composition might change rapidly as specialized species are replaced by more generalist species able to take advantage of changing conditions. Of course change is a natural part of evolution and ecosystems should not be considered as static and unchanging in time. As continents drift over millennia, climates change, and species evolve and disappear, ecosystems are constantly being modified. However, it is the pace at which climate change is now occurring that threatens the capacity of ecosystems to respond and adapt.

Ecosystems that exist within a narrow geoclimatic range are expected to be those most at risk from climate change. Coral reefs may be the earliest and most obviously impacted ecosystems as a result of temperature-induced coral bleaching. Other ecosystems at obvious risk include alpine and polar ecosystems where temperature increases are likely to result in loss of snow cover, the extinction of cold-adapted species, and increased invasion by warm-tolerant species.

5. Ecosystem Resilience

The successful maintenance, protection, and restoration of endangered ecosystems will depend to a significant degree on the extent to which they remain resilient to negative change from human impacts. Much of the effort directed toward ecosystem conservation is therefore increasingly focused on the maintenance of ecosystem resilience (Walker, 1995).

In extreme cases, the species composition of an ecosystem or its natural processes may be so disturbed from the original that they do not appear to be capable of recovery. Such disturbance may occur, for example, with the loss of nutrients, soils, or water supply. A good example of changes in ecosystems brought about by disruptions in natural processes can be seen in case of fires. Many ecosystem types (particularly some open forest, shrubland, and grassland communities) are adapted to frequent fires and their species may exhibit a range of responses to the latter, that ensure their survival and continuation. On the other hand, ecosystems such as temperate and tropical rain forests may be extremely susceptible to fires and the subsequent loss of nutrients that follows heavy rains and leaching.

One of the earliest responses to the loss of ecosystems was the development of national parks and other protected areas. Originally established largely as a means of providing outdoor recreation for increasingly urbanized societies, protected areas now fulfill many important functions. One of the most important functions of a protected area system is to safeguard a representative sample of major ecosystems from development, and most countries now have some form of protection for achieving this goal. It has become clear, however, that protected areas cannot provide sufficient ecosystem protection in isolation from other measures. In particular, as ecosystems become fragmented, many of the ecological processes that sustain these areas degrade, and resilience is lost. Pollution, soil erosion, the invasion of exotic species, and changes in the frequency or intensity of fires can all have an impact on the viability of all but the largest protected area. Ecosystem conservation needs to take into account all of these factors, and this is one reason why planning models such as the ecoregion approach are being adopted.

Legal protection and management are clearly necessary in many cases to halt the rapid loss of ecosystem types. Although the first stated goal of the US Endangered Species Act is "to provide the means whereby the ecosystems upon which endangered species and threatened species depend may be conserved," it is clear that even this relatively powerful legislation has only limited ability to achieve the aim of ecosystem conservation. The situation is obviously much more difficult in many poor and developing countries. In many cases, the intent of environmental law vastly exceeds the willingness or capacity of the country to

effectively implement its provisions. In such cases, international agencies, organizations, and funding bodies are required to help build this capacity and to provide training and institutional strengthening. International treaties and conventions, such as the CBD, established as a result of the 1992 Earth Summit, provide an important framework and guidelines for such international cooperation.

See Also the Following Articles

ENDANGERED BIRDS • ENDANGERED FRESHWATER INVERTEBRATES • ENDANGERED MAMMALS • ENDANGERED MARINE INVERTEBRATES • ENDANGERED PLANTS • ENDANGERED REPTILES AND AMPHIBIANS • ENDANGERED TERRESTRIAL INVERTEBRATES • MARINE ECOSYSTEMS

Bibliography

Myers, N. (1997). Threatened biotas: "Hot spots" in tropical forests. *The Environmentalist* **8**, 187–208.

Olson, D. M., and Dinerstein, E. (1998). The Global 200 A representation approach to conserving the Earth's most valuable ecoregions. *Conserv. Biol.* **12**, 502–515.

Reid, W. V., Mooney, H. A., Copper, A., *et al.* (2005). *Millenium Ecosystem Assessment Synthesis Report*. Millenium Assessment and World Resources Institute, Washington, DC.

Walker, B. (1995). Conserving biological diversity through ecosystem resilience. *Conserv. Biol.* **9**, 747–752.

Endangered ecosystems were found in all major regions of the United States except Alaska. The greatest losses occurred in the Northeast, the South, and the Midwest, as well as in California.Â Table 4.6 provides a similar list for the endangered coastal sage scrub ecosystem in California. Table 4.7 lists species associated with the critically endangered longleaf pine and wiregrass communities of the southern coastal plain (which includes parts of North and South Carolina, Georgia, Florida, Alabama, Mississippi, and Louisiana). Saving all the endangered marine species might well cost far more. Why should we spend all that money on wildlife when we could spend it to stop people dying of starvation or disease?Â You often hear it said that we should keep ecosystems like rainforests because they probably contain useful things, in particular medicines. The classic challenge is "what if a plant goes extinct that could be the cure for cancer?" What happens to all the species that don't make useful things like medicines? Endangered Species Affect Our Ecosystems Species on the brink of extinction affect us all more than we may realize. Sure, the pandas are cute, and the rhinos are fun to look at, but is there any more to it than that? Absolutely. All animal and plant life is part of a complex ecosystem that also includes our lands and our waters. Remove one or more of those parts and you damage the ecosystems, sometimes beyond restoration.