## Which species are most vulnerable to extinction? https://www.britannica.com/science/conservation-ecology/Which-species-are-most-vulnerable-to-extinction#ref959922

Before a species becomes extinct, it must first be rare. Some species are naturally rare, while others have that rarity imposed upon them by one or more of the factors discussed above. Some species are much more [vulnerable](https://www.merriam-webster.com/dictionary/vulnerable) than others to becoming dangerously rare, and other species, when rare, are more likely than others of equal rarity to [succumb](https://www.merriam-webster.com/dictionary/succumb). These and other factors affecting a species’ susceptibility to destruction are discussed in this section.



Baikal seals (Phoca sibirica), endemic to Lake Baikal, southeastern Siberia, Russia.© Doug Allan/Oxford Scientific Films Ltd.

## [Endemism](https://www.britannica.com/science/endemism) and rarity

As previously discussed, a small geographic range makes a species particularly vulnerable to global extinction. Many of the threats to species are geographically restricted, so species with large ranges will survive somewhere even if they are locally extirpated. Species with small ranges do not have this “reserve.” Moreover, as also was mentioned above, species with small geographic ranges tend to be rare within them—they have low population densities.

The collections of plants and animals on islands are often rich in [endemic](https://www.merriam-webster.com/dictionary/endemic) species; those species that are restricted to particular islands must inevitably have small ranges. Since 1600 the great majority of known bird extinctions have been on islands. The problem of extinction is not just limited to islands, however, as the previous sections amply describe.

In sum, combined endemism and rarity are the factors that confer the greatest risk of extinction.

## Body size and related reproductive characteristics

Generally, the larger the body size of an animal, the longer it lives and the fewer offspring it produces each year. Relatively large animals also tend to have relatively low [population densities](https://www.britannica.com/science/population-density); thus, a viable population of, say, [elephant](https://www.britannica.com/animal/elephant-mammal)s occupies considerably more space than an equal-sized population of [rabbit](https://www.britannica.com/animal/rabbit)s. Large predators such as [tiger](https://www.britannica.com/animal/tiger)s (Panthera tigris) have lower population densities than the herbivores on which they feed. A tiger has a home range that may occupy 100 square km (40 square miles), while a rabbit may survive in 1 hectare (0.004 square mile).



**Tiger** Learn about the declining numbers of various tiger populations. Encyclopædia Britannica, Inc.

Large animals, by virtue of their low population densities, are at increased risk of extinction. Moreover, an animal species that produces few offspring each year and that suffers a major loss in numbers from human activity will need more time to recover than a species with high reproductive rates. Again taking the tiger as an example, a tiger population large enough to avoid all the perils of low population size (including the chance that all offspring will be the same sex or that genetic [inbreeding](https://www.britannica.com/science/inbreeding) will occur) requires extremely large areas. Although the tiger is not considered an endemic species—it has a very large geographic range, stretching over much of eastern and southern Asia—its rarity in that range means that it is nonetheless vulnerable to extinction from human activity.

## [Behaviour](https://www.britannica.com/science/animal-behavior)

## Size of home range

In the case of lions, wolves, and wild dogs, population size alone is a poor predictor of their local extinction, even when the animals live in protected areas. For these species, conflict with people on the borders of the protected areas is the major cause of mortality. Border areas are population “sinks,” areas where the [death rate](https://www.britannica.com/science/mortality-demography) of the population exceeds the [birth rate](https://www.britannica.com/science/birth-rate) and into which individuals enter through migration from more-central portions of the protected area. This explains, for example, why [African wild dogs](https://www.britannica.com/animal/African-hunting-dog) (Lycaon pictus; see[African hunting dog](https://www.britannica.com/animal/African-hunting-dog)) are under particular threat—more so than other species, such as cheetahs and leopards, that also are afforded protected areas. Wild dogs live in large packs that roam very large areas, in contrast to the two cat species, which are mostly solitary and which have smaller home ranges. The more widely a species moves (i.e., the larger its [home range](https://www.britannica.com/science/home-range)), the more likely it is to move beyond areas where it is protected.

## Concentration

Some species have aggregation behaviours that make them vulnerable to disturbance or hunting. For example, [bat](https://www.britannica.com/animal/bat-mammal)s may congregate in large numbers in particular caves to have their young, making significant portions of their total population especially susceptible when their habitat is disturbed by human visitation or damaged by the cave’s commercialization or flooding. The various species of [grouper](https://www.britannica.com/animal/grouper)s often come together to spawn on a few nights of each year tied to phases of the moon and at traditional mating sites. Fishermen who know these sites and the timing of spawning can devastate large populations of these species by concentrating their efforts during this most vulnerable time in the fish’s life cycle.

## Low dispersal

Because small populations are so much more at risk than large ones, individuals of species that can readily disperse can rescue local populations on the verge of extinction. The previously discussed example of the checkerspot butterfly (see above [Surviving but threatened small populations](https://www.britannica.com/science/conservation-ecology/Calculating-background-extinction-rates#ref272670)) illustrates, first, the rescue of some small populations by the dispersal of individuals from larger “reservoir” populations nearby and, second, the subsequent extinction of the reservoirs as urban development isolated them from still other butterfly populations that could have rescued them. Species that have low dispersal rates are at a disadvantage because it is unlikely that one population can save another.

## [Mating](https://www.britannica.com/science/mating) systems

Small populations suffer from [inbreeding](https://www.britannica.com/science/inbreeding), an inevitable tendency of mating individuals in a small isolated population to be more closely related than they would be in a larger one. When population size is severely reduced, inbreeding may be the final insult that will cause the remaining population to go extinct. The likelihood that this will happen, however, seems related to the social structure of the species involved.

A comparison of two species, a seal and a rhinoceros, serves to explore the issue in more detail. The northern [elephant seal](https://www.britannica.com/animal/elephant-seal)(Mirounga angustirostris) of the Pacific Coast of [North America](https://www.britannica.com/place/North-America) was thought to have been hunted to extinction in the late 1800s, though it later became apparent that perhaps 20–30 individuals persisted locally for a couple of decades before the population began to recover gradually under protection. The Indian [rhinoceros](https://www.britannica.com/animal/rhinoceros-mammal)(Rhinoceros unicornis) in the early 20th century was reduced to two isolated populations—one numbering between 12 and 100, the other between 60 and 80—before protection allowed it to make a limited recovery. Moreover, not all of the rhinoceros males in the reduced population were likely to have bred. Today the elephant seal is genetically uniform, suggesting that a high degree of inbreeding occurred during the time its population was at a minimum, whereas the rhino has probably lost little of its genetic variability. The population histories of the two species are similar, so why the differences in their genetic variability?



Northern elephant seal (Mirounga angustirostris).© Radkol/Dreamstime.com

The social structures of elephant seals and rhinos are dramatically different. Each year, the one dominant bull seal that guards the harem is likely to father all of the young. An isolated seal population thus may become genetically uniform relatively quickly because very few males father each generation of young. Rhinos, on the other hand, are largely monogamous, so a group of them will have a greater number of fathers than a comparably sized group of seals.

## Insularity

The vulnerability of island species is likely a combination of two factors previously discussed—their [endemism](https://www.britannica.com/science/endemism) and rarity and their ecological naivete, the latter being exemplified by the greater effect of [domestic cat](https://www.britannica.com/animal/cat) introductions on unwary island bird species than on more “streetwise” mainland species. Nevertheless, some island bird species are less likely to be threatened than similar bird species found on continents. The reason lies in the abundance of island species—they are often quite numerous on their islands, for they have fewer competitors than do mainland species.

## Human use

Many species are hunted for meat and other products, including whales and various fish, as discussed above. Less familiar is the widespread trade in bushmeat, which is essentially everything that can be hunted—from [mice](https://www.britannica.com/animal/mouse-rodent) to [chimpanzee](https://www.britannica.com/animal/chimpanzee)s and [gorilla](https://www.britannica.com/animal/Gorilla-primate-genus)s—and is especially prevalent in West and Central Africa. Yet other species are harvested for body parts, such as tiger bones and rhino horns, which are used in Asian medicines. A wide variety of plants are harvested too, again often for medicinal purposes. Simply put, any species that is used for food, wood, or medicine or as pets or houseplants, that is collected (such as butterflies or invertebrate shells), or that attracts attention for any other reason suffers an increased risk of extinction.

## Preventing The Loss Of Biodiversity

A thorough knowledge of the factors that cause extinction and the vulnerability of different species to them is an essential part of conserving species. In large part, conservation is about removing or reducing those factors and doing so for the most vulnerable species and in the places where species are most vulnerable. Much of the task of conservation professionals is to protect habitats large enough to house viable populations of species, first deciding where the priorities should be and sometimes restoring habitats that already have been destroyed. Local conservation groups often spend time removing introduced species, which can mean physically weeding invasive plants or trapping invasive animals. These activities must be accompanied by efforts to prevent introductions of new threats. Others work to reduce harvesting directly or to reduce the incidental catch of nontarget species. Nonetheless, there are a variety of specific tools that can be applied to different circumstances, as categorized below and illustrated by case histories. Sometimes, when working with very rare species, scientists may not know the exact causes of threat, which can lead to intense arguments about exactly how to proceed.



**camera traps** Camouflaged camera traps are useful for understanding how an animal behaves in the wild. Science in Seconds (www.scienceinseconds.com)

## Species interventions

## Protective custody

Some species become so rare that there are doubts about whether they will be able to survive in the wild. Under such circumstances, the species may be brought into protective custody until areas can be made suitable for their release back into the wild.

Protective custody is an important tool in plant conservation, where a large number of seeds can be easily stored. In addition, botanic gardens can grow rare plants, protecting the species until such times as they can be planted in the wild. Of a total of about 300,000 described species of flowering plants, Botanic Gardens Conservation International has estimated that about 80,000 species are protected in botanic gardens and a few thousand additional species in other facilities—together about one-third of the total.

For animals, [zoo](https://www.britannica.com/science/zoo)s provide an important refuge for some vertebrate species but not for the vast majority of animals, which are invertebrates. Of species protected in zoos, a number of them have later been returned to the wild. To do so, however, substantial problems need to be overcome.

Determining that a species should be brought into captivity and then deciding what to do with the individuals are illustrated by the [California](https://www.britannica.com/place/California-state) [condor](https://www.britannica.com/animal/condor). The first key decision was whether to bring the birds into protective custody or to manage their small population in the wild. There was no dispute that the condors were once widespread, ranging across the southern and western United States and northern Mexico. As long ago as the turn of the 20th century, however, they were restricted to the mountains of southern California. The widespread practice of setting out poisoned carcasses to kill [livestock](https://www.britannica.com/animal/livestock) predators was likely the major cause of their decline. Exactly how many condors still survived was at the core of the debate. Some thought their numbers had been declining constantly, from 150 in the 1950s to 60 in 1970. Others posited constant numbers, and, according to one opinion, if there was no decline, there was need for neither explanation nor intervention—the condors, though rare, should be left alone.

Eventually, photographic surveys completed the catalog of individuals, removing doubts about which individuals were alive, which were dead, and why. Studies of nesting showed that those birds that bred did so with reasonable success. Radio-collared birds showed that the species foraged far beyond the remote areas of its nesting sites, so simply leaving the birds alone and protecting the habitat near the nest would not be sufficient. Birds died from ingesting lead in animals that had been shot or the toxic substances in poison-laced carrion. In the 1980s all the remaining birds were brought into captivity, although not without a lawsuit over the issue.

Because captive populations are almost always small, there is a high risk of inbreeding. Thus, the condors were carefully screened genetically to ensure that as much as possible of the genetic variability of the species was preserved (see below). The captive-breeding program was ultimately a success, and between 12 and 20 fledglings were produced each year after 1991. Earlier production had been lower, likely as a consequence of the birds’ inexperience in nesting and rearing. Efforts to teach captive-reared birds through artificial means—some nestlings were fed by puppets resembling condor heads—were much less successful. These birds were particularly inept when released, as real parents teach their young many important things about living in the wild. Eventually, scientists released birds in Arizona, California, and Baja California, and some of these birds have reared young of their own in the wild.

## Genetic intervention

In small populations, [inbreeding](https://www.britannica.com/science/inbreeding) can cause [genetic](https://www.britannica.com/science/genetics) variability to be lost quite quickly. A simple example is provided by the Y [chromosome](https://www.britannica.com/science/chromosome) in humans (and other mammals), which confers maleness and which behaves like human surnames do in large parts of the world. If every human couple had just two children each generation, then by chance alone 25 percent of the couples would have two sons, each with one Y chromosome from the father; 25 percent would have two daughters, each with no Y chromosome; and the remaining 50 percent would have one son and one daughter. The surnames of the fathers with two daughters would be lost as they married and had their own children, as indeed would be those fathers’ Y chromosomes. In a small breeding population, after just a few generations, every individual would have the [last name](https://www.britannica.com/topic/surname) of the same male ancestor—perhaps a great-great-grandfather—and the same Y chromosome.

Many genetic mutations are [deleterious](https://www.merriam-webster.com/dictionary/deleterious), reducing the individual’s chances of survival, but are also recessive (see [recessiveness](https://www.britannica.com/science/recessiveness)), requiring the inheritance of one mutant gene from each parent to [manifest](https://www.merriam-webster.com/dictionary/manifest) their effect. This means that in a large population, their effect will be masked by the overwhelming numerical superiority of the normal dominant gene ([allele](https://www.britannica.com/science/allele); see [dominance](https://www.britannica.com/science/dominance)). For the reasons explained above, in a small population chance events cause the loss of genetic variability and so increase the likelihood that individuals will suffer harmful genetic diseases.

Studies on mammals kept in zoos illustrates the harmful effects of [inbreeding](https://www.britannica.com/science/inbreeding). In the past, to maintain sufficient productivity, zookeepers often bred animals that proved to be good at producing young. Because of this practice, some breeding pairs quickly came to have the same grandparents and, in some cases, the same parents. The studies showed that such pairs produced young that were much less likely to survive than young from pairs of unrelated individuals.

The practical problem for conservation is whether to place efforts on genetic intervention—bringing in “new blood,” that is, individuals and so genes, from the outside—or to concentrate on the factors causing the initial decline.

This issue was at the heart of the management dilemma posed by the [Florida panther](https://www.britannica.com/animal/Florida-panther) (Puma concolor coryi), a distinct subspecies of [puma](https://www.britannica.com/animal/puma-mammal-species) (P. concolor) confined to a small, isolated, and inbred population in southern Florida. The specific question was whether to introduce pumas from Texas into the Florida population. Florida panthers once had been part of a continuous widespread population. In the 19th century they became isolated in southern Florida. As their numbers declined, the occurrence of genetic defects increased, including sperm and heart defects and [undescended testicles](https://www.britannica.com/science/cryptorchidism) in males. Conservation scientists hoped that the introduction of pumas from outside Florida would reverse the genetic damage. This proposal was highly controversial; as with the example of the California condor, some argued that the population was doing well in its limited range and did not need additional animals. Despite concerns, in the mid-1990s eight females from Texas were released, and scientists closely followed the fates of them, of their young, and of the young of cats with only Florida parents. It was found that, although hybrid cats—those with both Florida and Texas parents—do not seem to live longer than pure Florida cats and hybrid females do not produce more kittens than pure Florida females, hybrid kittens survive about twice as well. Since the introduction of the Texas females, numbers of Florida panthers have increased, and hybrid cats were expanding the known range of their habitats.



Florida panther (Puma concolor coryi).Courtesy, Stuart L. Pimm

## Associated difficulties and costs

Previous discussions have covered the release of individuals into the wild to reestablish populations that have gone extinct or to rescue inbred populations. They also have noted that protecting species from human harvesting and removing invasive species are major techniques in saving biodiversity. These and other species-by-species interventions are often high-profile actions that attract considerable media attention. This does not mean that they are easy or cheap, as the following examples demonstrate.

## Protecting species

For species that are hunted or collected, direct protection may be an essential conservation tool. National laws, such as the [Endangered Species Act](https://www.britannica.com/topic/Endangered-Species-Act) in the United States, make collecting or killing an [endangered species](https://www.britannica.com/science/endangered-species) or threatened species illegal. An example of such a protected species in the United States is the country’s national bird, the [bald eagle](https://www.britannica.com/animal/bald-eagle) (Haliaeetus leucocephalus). International laws protect whales of various species, and such agreements as the [Convention on International Trade in Endangered Species](https://www.britannica.com/topic/Convention-on-International-Trade-in-Endangered-Species) prohibit commercial trade in designated species. Enforcing these laws and conventions is another matter, however.



**bald eagle**Bald eagle (Haliaeetus leucocephalus).Alan & Sandy Carey/Getty Images

The problems of [implementing](https://www.merriam-webster.com/dictionary/implementing) protection are illustrated by the conservation of the two African species of [rhinoceros](https://www.britannica.com/animal/rhinoceros-mammal). The population of the [black rhinoceros](https://www.britannica.com/animal/black-rhinoceros) (Diceros bicornis) fell to about 2,400 individuals in 1995, down from a likely number of several hundred thousand at the start of the 20th century, when it ranged over most of southern Africa. The [white rhinoceros](https://www.britannica.com/animal/white-rhinoceros) (Ceratotherium simum) historically had a smaller geographic range. Today its northern subspecies occurs only in the [Democratic Republic of the Congo](https://www.britannica.com/place/Democratic-Republic-of-the-Congo), where it is very rare. The southern subspecies lives almost entirely in [South Africa](https://www.britannica.com/place/South-Africa), [Namibia](https://www.britannica.com/place/Namibia), [Zimbabwe](https://www.britannica.com/place/Zimbabwe), and [Kenya](https://www.britannica.com/place/Kenya). Together, they numbered under 12,000 in 2001, again likely a small fraction of their original numbers.



White rhinoceros (Ceratotherium simum), Mkuze Game Reserve, South Africa.© Digital Vision/Getty Images

Although conversion of habitat land to agricultural use and sport hunting caused the earlier rhino declines, the major threat is now [poaching](https://www.britannica.com/topic/poaching-law)—entering reserves where the animals are protected and killing them for their horns, which are in high demand in parts of the world for dagger handles and, in powdered form, as an ingredient of traditional medicines. The costs of protecting rhinos are considerable. [WWF](https://www.britannica.com/topic/WWF) has estimated that it costs $1,400 per square km ($3,600 per square mile) per year to detect and deter poaching. Reserves that hold rhinos often cover tens of thousands of square kilometres; the multimillion-dollar budgets required are beyond the means of many African governments.

## Removing [invasive species](https://www.britannica.com/science/invasive-species)

Many conservation programs have tackled invasive species, and, once again, the message from the two case studies that follow is that, although these programs can be successful, they are often expensive.

As previously described, introduced domestic cats have caused the extinction of many island species. In the 1970s scientists estimated that the cat population on [Marion Island](https://www.britannica.com/place/Marion-Island), one of the two Prince Edward Islands in the subantarctic [Indian Ocean](https://www.britannica.com/place/Indian-Ocean), was killing 450,000 seabirds each year, jeopardizing the birds’ survival. The cats, which were estimated to number at least 2,000, were descended from five animals brought to the island in 1949 to deal with a mouse problem at a meteorological station there. Islands are small and isolated, and because cats are predators, they tend to have much smaller populations than their prey. Nonetheless, it took 19 years of an intensive eradication program to remove the last cats.

The second case study is the purple [loosestrife](https://www.britannica.com/plant/loosestrife) (Lythrum salicaria), a plant that has overrun thousands of square kilometres of North American wetlands, replacing the naturally [diverse](https://www.merriam-webster.com/dictionary/diverse) vegetation of grasses, sedges, and other wetland plants. It is native to Europe and was introduced into North America in the early 1800s. It now occurs across most of the continental United States and is most prevalent in the northeastern and north-central part of the country and in Canada.

Like other exotic weeds, purple loosestrife can spread rapidly. Control measures have included the use of herbicides and the release of herbivorous insects, including different species of beetles that eat the leaves, roots, and seeds of the plant. The latter strategy, an instance of [biological control](https://www.britannica.com/science/biological-control), is not risk-free. It involves introducing a second nonnative species to control a nonnative species introduced earlier. The effects of the insect introductions have not always been clear, and, as with other examples of biological control, there is a danger that the introduced herbivorous insects will harm native plant species.

## [Introducing species](https://www.britannica.com/science/introduced-species)

The introductions of Texas pumas into the Florida panther population and of captive-reared condors back into parts of their original habitat were successful, as discussed above. So were the introductions to North America of the starling, also discussed above, and the [house sparrow](https://www.britannica.com/animal/house-sparrow) (Passer domesticus), which was introduced to New York City from Europe in the 1850s. What is often overlooked, however, is that many other attempts have failed. This in fact is the typical result.

For example, after extensive efforts in the 19th and early 20th centuries to introduce nonnative game birds to the United States, it was found that, even with releases of large numbers of birds, most of the attempts failed. An exception has been the [common](https://www.britannica.com/animal/common-pheasant), or ring-necked, [pheasant](https://www.britannica.com/animal/pheasant) (Phasianus colchicus), native to China and introduced to the United States in the 1890s. This low rate of success has an important implication—even when it is known from hindsight that an individual introduction can succeed, as did the pheasant, most such introductions still will fail. When returning species to the wild that have already gone extinct there, the prognosis is even bleaker. One reason in some cases is that the cause of the extinctions—for instance, the [brown tree snake](https://www.britannica.com/animal/brown-tree-snake) responsible for bird extinctions on Guam—is still present.

## [Habitat](https://www.britannica.com/science/habitat-biology) protection

Because the loss of habitat is the primary reason that species are lost both locally and globally, protecting more habitat emerges as the most important priority for conservation. This simple idea raises difficult questions. Which habitats should be protected? And because it seems unlikely that all habitats can be protected, which ones should receive priority?

If [reserves](https://www.britannica.com/science/nature-reserve) were judiciously placed over the identified hot spots of biodiversity, the special places where vulnerable species are concentrated, a large fraction of species might be saved. Presently, the allocation of reserves around the world is poor. Reserves larger than 100,000 square km (40,000 square miles) are generally in high mountains, tundras, and the driest deserts, areas that are not particularly species-rich. On the other hand, hot spots such as Madagascar and the Philippines protect less than 2 percent of their land.

The same kinds of questions hold on smaller scales, as illustrated by a study reported in the late 1990s. The Agulhas Plain at the southern tip of Africa is one of the world’s “hottest” spots for concentrations of vulnerable [plant](https://www.britannica.com/plant/plant) species. An area only some 1,500 square km (600 square miles) in size was found to house 1,751 plant species, 99 of them endemic. Whereas most of the state forests and private nature reserves in the area are coastal, most of the hot spot’s endemic plants live inland. Given that new reserves must be created if these plants are to survive, where should they be situated to [encompass](https://www.merriam-webster.com/dictionary/encompass)the maximum number of species at minimum cost?

Fortunately, the data available to make these decisions included a knowledge of the distribution of plant species over the Agulhas Plain in fairly good detail—the kind of information not likely to be available in most hot spots. This allowed the plain’s plant-species [composition](https://www.merriam-webster.com/dictionary/composition)to be divided into a grid of cells, each 3 × 3 km on a side. Computer [algorithms](https://www.britannica.com/science/algorithm) (systematic problem-solving methods) were then used to select sets of cells from the grid according to their complementary species composition—that is, the aim was to encompass as many species or as many [endemics](https://www.merriam-webster.com/dictionary/endemics) as possible in as small an area (as few grid cells) as possible.

Naively applied, these [algorithms](https://www.merriam-webster.com/dictionary/algorithms) will not give useful results. For example, the sites they select may not be available for reserves. Also, the choice of too small a cell size can lead to the selection of protected areas containing populations so small and widely scattered that they would be unlikely to persist. This is fittingly dubbed the “Noah’s Ark effect,” because the ark held only two individuals of each species for a short time. [Reserves](https://www.britannica.com/science/nature-reserve) need to be large enough to support species indefinitely. The choice of a cell size of 3 × 3 km is politically [feasible](https://www.merriam-webster.com/dictionary/feasible) because reserves of this size already have been established in the region and are probably ecologically sensible for many plant species. Other factors had to be included in the final selection of cells. Some areas are unsuitable for various reasons—for instance, some are overrun by alien weeds, while others are mostly in urban areas or croplands. In contrast, other areas are particularly desirable—for example, they may be [adjacent](https://www.merriam-webster.com/dictionary/adjacent) to existing reserves, and it is easier to expand such reserves than to create new ones. The results of this study thus provided advice for establishing reserves that combined ecological information on species distribution with practical and political considerations.

Saving the most species for the least money likewise was the consideration that motivated another study published in the late 1990s, of which counties in the United States should be conservation priorities. An earlier study that attempted to locate sites for new reserves in the United States had equated [efficiency](https://www.merriam-webster.com/dictionary/efficiency) with the minimum number of counties needed to achieve a given coverage of endangered species. That approach would have been sensible if land were much the same price everywhere. Unfortunately, the study’s targets had included counties [encompassing](https://www.merriam-webster.com/dictionary/encompassing) [San Diego](https://www.britannica.com/place/San-Diego-California), Santa Cruz, and San Francisco in California, Honolulu in Hawaii, and certain counties in Florida, all of which are among the highest-priced land in the country. The later study asked how many species could be protected for a given total cost. It found that considerable savings in cost per species [accrue](https://www.merriam-webster.com/dictionary/accrue) from selecting larger, more-complementary areas and lower total costs and that, as a consequence of this approach, the places identified for protection were often quite different from those recommended in the earlier study.

## Habitat connections

Habitats that are not completely destroyed may be fragmented to the degree that individual fragments are too small to hold viable populations of many species—they may suffer from inbreeding or the increased [demographic](https://www.merriam-webster.com/dictionary/demographic) risks previously discussed. Yet in total the fragments may actually be of sufficient area to support these species. An obvious conservation intervention is to find ways of connecting fragments by corridors. These corridors can be created from currently unprotected land between existing reserves or by restoring land between existing habitat fragments.

Many contemporary efforts to create corridors are small-scale; they can be as simple as hedgerows that connect woodlots, a strategy that likely works for some small species. Other efforts are far more ambitious. One of the earliest large efforts involved a plan to connect various parks and other protected areas in [Florida](https://www.britannica.com/place/Florida) by corridors of land that would have to be purchased or otherwise protected from development. From this initial effort, a conservation group, the Wildlands Project, has developed an extensive set of plans for many areas in North America intended to set priorities for the acquisition of land for a mosaic of corridors that would eventually link together large parts of the continent.

A regional example of corridor creation is in [Costa Rica](https://www.britannica.com/place/Costa-Rica). Situated in the Caribbean lowlands, La Selva Biological Station is one of the major centres for research on tropical forests. Occupying an area of about 16 square km (6 square miles), the station is bordered on the south by Braulio Carrillo National Park, a much larger area of forest covering 460 square km (180 square miles). The [national park](https://www.britannica.com/science/national-park)extends to La Selva through a forest corridor that descends in elevation from nearly 3,000 metres (nearly 10,000 feet) at Barva Volcano down to 35 metres (115 feet) above [sea level](https://www.britannica.com/science/sea-level) at La Selva. The corridor had been threatened by agricultural development until conservation groups, realizing that La Selva would become an isolated forest “island,” purchased the corridor to protect it.

## Habitat management

Once protected, areas must often be managed in order to maintain the threatened species within them. Management may involve the removal of alien species, as previously discussed. It can also involve restoring natural ecological processes to the area. Original fire and flooding regimes are examples of such processes, and they are often controversial because human actions can alter them significantly.

## Fire control

Despite the often valid reasons for suppressing [wildfires](https://www.britannica.com/science/forest-fire), the practice can change vegetation dramatically and sometimes harm species in the process. As previously noted, human activities have changed fire regimes across large areas of the planet, including some biodiversity hot spots. Getting the fire regimes right can be essential for conserving species.

An example of a species for which the control of [fire](https://www.britannica.com/science/fire-combustion) regimes has proven both possible and essential is [Kirtland’s warbler](https://www.britannica.com/animal/Kirtlands-warbler) (Dendroica kirtlandii; see [woodwarbler](https://www.britannica.com/animal/wood-warbler)). This endangered species nests only in the Upper Peninsula of Michigan, an exceptional case of a bird species with a tiny geographic range well outside the tropics. The bird places its nest in grasses and shrubs below living branches of [jack pines](https://www.britannica.com/plant/jack-pine) (Pinus banksiana) that are between 5 and 20 years old. The region’s natural wildfires originally maintained a sufficient area of young jack pines. As elsewhere, modern practices suppressed fires, and the habitat declined. Active management of fires to ensure that there are always jack pines of the right age has steadily increased the population of warblers since the early 1990s, when it had included only about 200 singing males. By the early years of the 21st century, there were about 1,300 singing males.

## [Flood control](https://www.britannica.com/technology/flood-control)

In much the same way that human actions suppress fire regimes, they also control water levels, and the resulting changes can have important consequences for endangered species. An example of a species so affected is the Cape Sable seaside [sparrow](https://www.britannica.com/animal/sparrow) (Ammodramus maritimus mirabilis) found in the Florida [Everglades](https://www.britannica.com/place/Everglades). The Everglades once stretched from [Lake Okeechobee](https://www.britannica.com/place/Lake-Okeechobee) in the north to [Florida Bay](https://www.britannica.com/place/Florida-Bay) in the south. Water flowed slowly over a wide area, and its levels varied seasonally: summer rains caused the levels to rise in late summer and early fall; then the dry season dropped the levels to their lowest in late May. Under this natural regime, some prairies were continuously flooded for many years, drying out in only the driest years, whereas others were flooded for only a few months each year. It is in these drier prairies that the sparrows nest from about the middle of March until the water floods their nests in the summer.

Water-management actions have diverted the flow of water to the west of its natural path, making the western part of the Everglades unnaturally wet in some years during the bird’s nesting season. Unnatural flooding during the four years that followed 1992 reduced the bird population in the west to less than 10 percent of its 1992 level. In the east the prairies have become unnaturally dry and so have become subject to an increased number of fires, which has jeopardized the sparrow population there. It is clear that rescuing the Cape Sable seaside sparrow requires the [restoration](https://www.britannica.com/science/ecological-restoration) of the natural water levels and flows within the Everglades and the consequent return to natural fire regimes.

## Habitat [restoration](https://www.britannica.com/science/ecological-restoration)

Once a habitat has been destroyed, the only remaining conservation tool is to restore it. The problems involved may be [formidable](https://www.merriam-webster.com/dictionary/formidable), and they must include actions for dealing with what caused the destruction. Restorations are massive ecological experiments; as such, they are likely to meet with different degrees of success in different places. Restoration of the Everglades, for example, requires restoring the natural patterns of water flow to thousands of square kilometres of southern Florida.

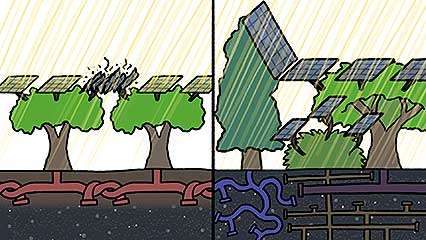
A case history of habitat restoration comes from the Midwestern United States. In [Illinois](https://www.britannica.com/place/Illinois-state), natural ecosystems cover less than 0.1 percent of the state, so restoration is almost the only conservation tool available. North Branch is a 20-km (12-mile) strip of land running northward from Chicago along the north branch of the [Chicago River](https://www.britannica.com/place/Chicago-River). Early in the 20th century, it was protected from building but later abandoned. Beginning in the 1970s, a group of volunteers first cleared out introduced European buckthorn (Rhamnus cathartica), removed abandoned cars, and planted seeds that they had gathered from combing the tiny surviving remnants of original [prairie](https://www.britannica.com/science/prairie)s in places such as along railways and in cemeteries. The initial effort to replant the prairie species failed, however; animals ate the small growing plants. The solution was to restore the natural fire regime, although controlled burns—setting fires safely near homes—posed a difficult technical challenge. But once it was accomplished, the results were immediate and dramatic. The original prairie plants flourished and the weeds retreated, although with an important exception. Under the native trees grew nonnative thistles and dandelions.

The original habitats locally called barrens [constituted](https://www.merriam-webster.com/dictionary/constituted) a visually striking and ecologically special habitat. Restoring them was a particular challenge, and the main conservation problem was finding the right mix of species. One recommendation was to use remnant barrens as models, but the [North Branch](https://www.britannica.com/place/Glenview-Illinois) volunteers rejected them as being too degraded. In the early 20th century, naturalists had speculated that barrens were special because they lacked some characteristic prairie species and, at the same time, had their own distinctive species. The volunteers examined habitat descriptions in old [treatises](https://www.merriam-webster.com/dictionary/treatises) of local plants looking for such species, many of which certainly would now be scarce. The key discovery was a list of barrens plants published by a country doctor in 1846. The scientific names had changed in 150 years, but, by tracking them through the local literature, the volunteers found many of their [putative](https://www.merriam-webster.com/dictionary/putative) barrens-specific plants on the doctor’s list. In possession of this vital information, the group succeeded in restoring barrens sites that by 1991 held 136 native plants, including whole patches consisting of species that, until restoration, had been locally rare.

The example above illustrates two rules of [ecological restoration](https://www.britannica.com/science/ecological-restoration). The first is that one must be able to save all the component species of the original ecological [community](https://www.merriam-webster.com/dictionary/community). The second, which is illustrated by the doctor’s list, is that one needs to know which species belong and which do not. Without the right species mix, restorers must constantly weed and reseed.

## Putting a price on conservation

Estimating the [economic](https://www.britannica.com/topic/economics) value of biodiversity is controversial. The value of whales, for example, once would have been just the price that traders would have paid for their parts, mostly oil and baleen. Today whales have an obvious economic value that comes from what tourists spend to watch them from boats—vessels that often now sail from the same ports that once supported whaling. Less obvious as an economic factor are the deeply held beliefs that hunting whales is cruel or that whales have a right to exist. Many people throughout the world object to whaling even though they may rarely or never have seen whales. Economists incorporate these ideas into their calculations of value by asking how much the public would pay to protect whales.



**biodiversity; conservation**Why biodiversity is good for the economy.© MinuteEarth

A relevant real-world example is found in the aftermath of the [oil spill](https://www.britannica.com/science/oil-spill)from the tanker [*Exxon Valdez*](https://www.britannica.com/event/Exxon-Valdez-oil-spill), which ran aground in [Prince William Sound](https://www.britannica.com/place/Prince-William-Sound), Alaska, in 1989. When the spill polluted the spectacular scenery of Alaska’s coast, many Americans felt that they had suffered a personal loss. [Exxon](https://www.britannica.com/topic/Exxon-Corporation) was forced to pay for cleaning up the mess and was fined not only for harming people’s livelihoods but also for incurring that loss.

Whereas the propriety of decisions that put [monetary](https://www.merriam-webster.com/dictionary/monetary) values on [moral](https://www.merriam-webster.com/dictionary/moral) issues is [contentious](https://www.merriam-webster.com/dictionary/contentious), in 1997 a team of ecologists and economists attempted to do just that on a grand scale when they reported their calculations of how much the diverse services provided by Earth’s ecosystems are worth. Their approach was to group these services into 17 categories and to classify the planet’s surface into 16 ecosystem types. Many combinations of services and ecosystem types were not estimated. Mountains, the Arctic, and deserts certainly have cultural values and devoted ecotourists, but these were absent, as were urban areas with city parks. Nonetheless, the total value of $33 trillion per year at which the team arrived is roughly twice the value of the global economy.

A challenge for today’s society is to comprehend the economic values of Earth’s ecosystems, for often they are taken for granted. One effort to do this is found in the steps taken by [New York City](https://www.britannica.com/place/New-York-City) to improve its [water supply](https://www.britannica.com/science/water-supply) by protecting the watersheds that supply that water. The cost of this protection was small compared with the [alternative](https://www.merriam-webster.com/dictionary/alternative) of greatly expanding the city’s system of water-treatment plants. Another example, aimed at slowing the rate of [deforestation](https://www.britannica.com/science/deforestation), can be seen in the Costa Rican government’s willingness to pay for protecting forest watersheds. A global example [comprises](https://www.merriam-webster.com/dictionary/comprises) efforts to reduce carbon emissions worldwide by rewarding those who protect existing forests or restore forests on deforested land.

Governments and international agencies often encourage the destruction of biodiversity by providing financial [subsidies](https://www.britannica.com/topic/subsidy) in the interests of [economic growth](https://www.britannica.com/topic/economic-growth). For example, many countries massively support their national fishing fleets by subsidizing the price of fish. The [Soviet Union](https://www.britannica.com/place/Soviet-Union) was such a country, but on its breakup the Russian government withdrew the subsidies, with the result that much of the fishing fleet has rusted in harbour. A study conducted in the late 20th century by the [Food and Agriculture Organization](https://www.britannica.com/topic/Food-and-Agriculture-Organization) of the [United Nations](https://www.britannica.com/topic/United-Nations) estimated that the total annual value of the world fish catch was about $70 billion. Yet the cost of catching these fish was $92 billion, reflecting a loss of $22 billion. The cost included routine maintenance, fuel, insurance, supplies, and labour. The magnitude of the loss was certainly an underestimate, for any private company would also include in its total cost the annual costs of paying off the loans for the fishing boats and other facilities. Those loans, the study concluded, would account for another $32 billion, making the annual deficit $54 billion per year.

Agricultural subsides worldwide are even larger—a global review of all subsidies estimates that they total trillions of dollars per year. The review suggests that a powerful strategy for conservation would be to examine whether these subsidies are sensible given concerns about the [environment](https://www.britannica.com/science/environment) and the need to be fiscally responsible.