CHAPTER 12

Endangered species management: the US experience

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To many people around the world, the conservation of endangered species is synonymous with the conservation of biodiversity. Ecologists, of course, understand that biodiversity encompasses far more than endangered species, but it is nonetheless true that endangered species are among the most visible and easily understood symbols of the ongoing loss of biodiversity (see Chapter 10). The protection of such species is a popular and important part of efforts to sustain the earth's natural diversity (see Box 12.1).

The process of conserving endangered species can be divided into three phases: (i) identification—determining which species are in danger of extinction; (ii) protection—determining and implementing the short-term measures necessary to halt a species' slide to extinction; and (iii) recovery—determining and implementing the longer-term measures necessary to rebuild the population of the species to the point at which it is no longer in danger of extinction.

Many countries today have laws or programs designed to protect endangered species, although the efficacy of these efforts varies widely. Most follow the identification/protection/recovery paradigm. One of the oldest and strongest laws is the United States' Endangered Species Act (ESA), which was passed in 1973 and has served as a template for many other nations. In this chapter, I shall focus on the three phases of endangered species management, emphasizing the US experience. My reason for emphasizing the US is not because I believe it has done a better job of protecting its endangered species than other countries. Rather, I am most familiar with conservation efforts in the US. Moreover, because the US has one of the oldest and strongest laws on the books to protect endangered species, it provides a useful case history.

My discussion is admittedly incomplete and, to some extent, idiosyncratic. Endangered species programs, especially those that impose restrictions on human activities, are invariably controversial, and that controversy results in much discussion and debate. The ESA, for example, has been the subject of many books, scientific articles, and popular articles; it has been debated in the halls of Congress and in town halls across the nation; and it has been litigated numerous times in the courts. Complete coverage of all of the issues associated with endangered species in the US or any other large country is simply not possible in a single book chapter. For that reason, I have chosen to review a subset of issues that are likely to be of interest to both scientists and decision-makers in countries with active programs to conserve endangered species.

12.1 Identification

12.1.1 What to protect

A fundamental question that quickly arises when scientists and decision-makers discuss endangered wildlife is what exactly should be conserved (see Box 12.2). Protection efforts can be directed at species, subspecies, or populations, with important tradeoffs. If, for example, protection is extended to subspecies and populations, the total number of plants and animals that are deemed in need of protection is likely to increase dramatically, resulting in greater

Box 12.1 Rare and threatened species and conservation planning in Madagascar
Claire Kremen, Alison Cameron, Tom Allnutt, and Andriamandimbisoa Razafimpahanana

The fundamental challenge of reserve design is how to maximize biodiversity conservation given area constraints, competing land uses and that extinction risk is already high for many species, even without further habitat loss. Madagascar is one of the world's highest priorities for conservation (Brooks *et al.* 2006) with endemism exceeding 90% for many plant and animal groups (Goodman and Benstead 2005). Recently, the President of Madagascar set the target for habitat protection at 10% of the land surface, representing a tripling of the region to be protected. This provided an unparalleled opportunity to protect Madagascar's biodiversity. To aid the government in site selection, we used a "systematic conservation planning" approach (Margules and Pressey 2000) to identify regions that would protect as many species as possible, especially geographically rare and threatened species, within that 10% target.

We obtained occurrence data for 2315 endemic species of plants, lemurs, frogs, geckos, butterflies and ants (see Box 12.1 Figure 1). We utilized a spatial prioritization decision-support tool (Zonation: Moilanen *et al.* 2005), and input models of species distributions (for 829 species) and point data for the remaining species (too rare to model, designated RTS for rare target species). The Zonation algorithm preferentially selects the best habitat for geographically rare (range-restricted) species. In addition, by supplying weights based on past habitat loss, we instructed Zonation to favor species that had suffered large range loss within the past 50 years (threatened species). In this manner, our decision support tool picked regions that not only represented all of the species in our analysis, but also identified the habitats most important to geographically rare and/or threatened species.

We ran Zonation in three ways: (i) for each of the six taxonomic groups alone; (ii) for all groups together; and (iii) for all groups together, after first selecting existing protected areas, totaling 6.3% of the country. We then assessed how well the selected regions for each Zonation run protected rare and threatened species by determining what proportions of their habitats (for modeled species) or occurrence points (for RTS species) were included. We also compared Zonation's selections based on all taxa (run ii

Box 12.1 Figure 1 *Mantella cowanii*, a critically endangered frog of Madagascar. It is one of the species that was used by Kremen *et al.* (2008) to determine priority sites for protection in Madagascar. Photograph by F. Andreone.

above) against the actual protected areas, from 2.9% area in 2002 to 6.3% area in 2006.

When individual taxonomic groups were utilized to define priority regions (run i), the regions selected by Zonation provided superior protection for members of the taxon itself, but relatively poor protection for species in other groups. It was therefore more efficient to utilize an analysis based on all taxonomic groups together (run ii). Comparing this analysis to the regions that had already been set aside showed that, on an area by area basis, Zonation selected regions that significantly increased the inclusion of habitat for geographically rare and threatened species. In addition, we found that the trajectory for accumulating species and habitat areas from 2002 to 2006 would be insufficient to protect all species within the area target, but that careful selection of the last 3.7% (Run iii) could greatly improve both representation of all species and the selection of habitat for the geographically rare and threatened species (Kremen *et al.* 2008).

Subsequently, this analysis was used along with other conservation inputs (Key Biodiversity Analyses, Important Bird Areas, and others; see Chapter 11) to justify the final regions for protection totaling 6.4 million hectares (Box 12.1 Figure 2, black zones totaling just over 10%), and served to designate an additional 5.3 million

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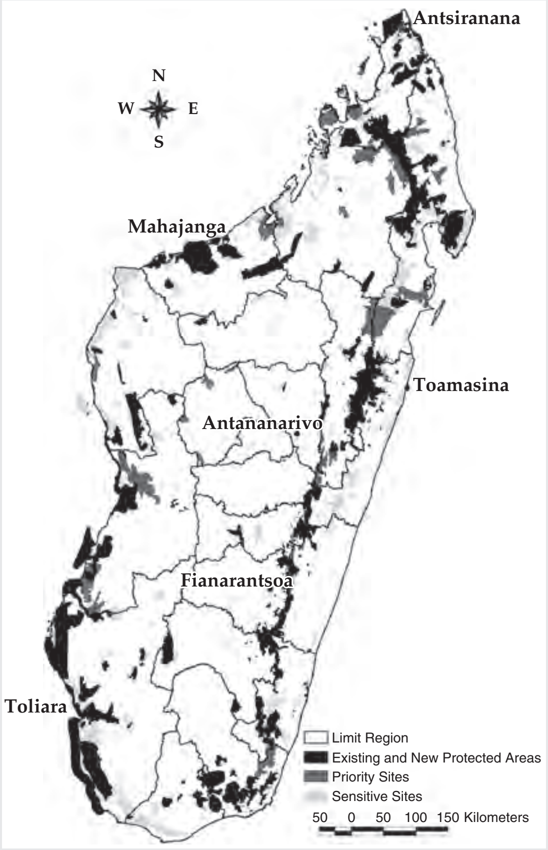
Box 12.1 (Continued)

hectares as important conservation regions subject to an inter-ministerial decree limiting



Box 12.1 Figure 2 This map portrays the Inter-Ministry decree of October 2008 delineating the new and existing protected areas (black), the priority biodiversity areas where no new mining permits may be issued (grey) and the sensitive biodiversity sites (light grey), which will be subject to environmental impact assessment prior to permission of forestry or mining activities. See also Figure 11.6.

mining activities. No new mining permits will be issued in the highest priority zones (grey zones), and the remaining areas (light grey zones) will be subject to strict control (e.g. following Environmental Impact Assessment). The rare target species, in particular, were utilized to define these zones, in particular the 505 species currently known from only a single site. Furthermore, as a significant proportion of these priority zones contain existing mining permits (14% of the existing parks and highest priority areas), the Zonation result is an ideal tool for negotiating trade-offs or swaps between mining and protected areas.

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demands for funding and, potentially, more conflicts with landowners, developers, and other resource users. On the other hand, it has been argued that populations should be the fundamental unit of biodiversity protection (see Box 10.1), since it is populations of plants and animals that provide the ecosystem services essential to human welfare (Hughes *et al.* 1997; Chapter 3).

A second consideration relates to geographic scale. Should the frame of reference for deciding whether or not a species is endangered be the entire world (the species' global status), a particular country (its national status), or a particular

Box 12.2 Flagship species create Pride
Peter Vaughan

Rare: Rare is a non-governmental organization whose mission is "to conserve imperiled species and ecosystems around the world by inspiring people to care about and protect nature" (see Chapter 15). Rare's *Pride* program utilizes social marketing to educate and motivate people who live in, or adjacent to, areas of high biodiversity to adopt new behaviors that either protect, or are less damaging to, the local environment.

Social marketing: Many commercial marketers "brand" their companies and/or products using symbols, such as Pillsbury's "doughboy", or Apple Computer's "bitten apple." Similarly, *Pride* brands its social marketing campaigns using "flagship" species. While concepts such as ecosystem and biodiversity are central to Rare's overall conservation strategies, they are complex and fail to evoke the emotional response that is required to motivate behavior change among most people. The purpose of a flagship is to create a simple, instantly recognizable symbol that evokes a positive emotional response among members of the target audience. As Mckenzie-Mohr (2008) states "All persuasion depends upon capturing attention. Without attention, persuasion is impossible. Communications can be made more effective by ensuring that they are vivid, personal and concrete." A good flagship evokes feelings of trust, affection, and above all for Rare, a sense of *Pride* in the local environment. Pride of place is a powerful emotion that can motivate people to change their behaviors and empower them to take environmental action.

What makes a good flagship? Unlike the concepts of "keystone", "indicator", "umbrella", and "endangered" species, which all have ecological or conservation implications, flagship species are chosen for their marketing potential (Walpole and Leader-Williams 2002). The key characteristics of flagship species are (based on Karavanov 2008):

- Be charismatic or appealing to the target audience; no slugs, worms, or mosquitoes!
- Be local or endemic to symbolize the uniqueness of the conservation target area to foster a sense of local pride.
- Be representative of the conservation target area by living in its habitat or ecosystem.
- Have no negative perceptions among local people, such as being a crop pest, being dangerous, or have existing cultural connotations that detract from or compete with the campaign's conservation messages.

How are flagships chosen? Flagship species are chosen through a lengthy process that includes input from local stakeholders, interviews with local experts, and results from surveys of the local human population. This process ensures that flagships have the requisite characteristics outlined above.

How are flagships used? Flagship species are used in most of the marketing materials produced during a *Pride* campaign, including billboards, posters, puppet shows, songs, videos, etc. such that they become ubiquitous in the community. Although flagship species are non-human, they become symbolic members of the local community, which

continues

Box 12.2 (Continued)

confers on them the credibility they need in order to be perceived as trustworthy sources of information. The flagship species serves as both the "face" of the campaign and as a "spokesperson" for the campaign's messages. This "opinion leadership role" activates the social diffusion networks that exist in all societies by stimulating interpersonal communication among members of the target audience, a key step in the behavior change process (Rogers 1995, Vaughan and Rogers 2000).

Rare's flagship species: Among Rare's first 71 campaigns, 59% chose a bird, 16% chose a mammal, and 11% chose a reptile to be their flagships species, but campaigns have also used fish, insects, crustaceans, amphibians, and plants. About half of the chosen species were endemic to the country or region, but only about 8% have been listed as endangered or critically endangered by IUCN. Because flagship species play such a prominent role in *Pride* campaigns, knowledge about them can serve as markers for campaign exposure and impact. For example, during the *Pride* campaign in Laos (Vannalath 2006), awareness among the campaign's target audience of the great hornbill (*Buceros bicornis*; Box 12.2 Figure) increased from 61% to 100%; the percentage of respondents who know that the hornbill is in danger of extinction increased from 22% to 77%; the percentage who knew that hunting or capturing the hornbill is prohibited increased from 31% to 90%; and the percentage that identified "cutting down the forest" as one of the greatest threats to the hornbill increased from 17% to 65%. In addition to increasing knowledge, improving attitudes, and changing personal behavior, *Pride* campaigns have been credited with contributing to the creation of protected areas, enactment of new laws and regulations, and the preservation of endangered species (Jenks *et al.* 2010). Central to all of these efforts has been the use of flagship species.

Box 12.2 Figure Pride campaign flagship mascot representing the great hornbill in Laos. Photograph by R. Godfrey.

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state, county, or municipality (its local status)? For example, the northern saw-whet owl (*Aegolius acadicus*) is widely distributed across the northern and western United States and in parts of Mexico. It is not in danger of extinction. But within the US, the State of Maryland considers the northern saw-whet owl to be an endangered species; Maryland is at the southeastern periphery of the owl's range and the bird is quite rare there. Conservationists continue to debate the wisdom of expending scarce resources on the protection of peripheral or isolated populations of otherwise common species. Yet such populations are often a source of pride to the citizens of a given region, and they may contain unique alleles that contribute to the overall genetic diversity of the species.

A third consideration is whether to extend protection to all types of endangered organisms or to limit such efforts to particular groups, such as vertebrates or vascular plants. Proponents of exclusion argue that it is impossible to identify and protect all of the imperiled species in any large area (see below), and that by targeting a few, select groups, it should be possible to protect the habitats of many other species. Although some studies have supported this notion, others have not.

Within the US, the ESA addresses these issues in the following ways: it allows for the protection of species and subspecies of plants and animals (including invertebrate animals). In the case of vertebrates only, it also allows for the protection of distinct population segments. In the early years of the ESA, the US Fish and Wildlife Service, the agency charged with protecting imperiled wildlife, allowed populations to be defined on the basis of political borders. Thus, bald eagles (*Haliaeetus leucocephalus*) in the coterminous 48 states (but not those living in Alaska or Canada) were added to the endangered list when their numbers plummeted due to pesticide poisoning. More recently, the Fish and Wildlife Service has turned away from using political borders to delineate vertebrate populations and has insisted that such populations be discrete ecological entities in order to be eligible for inclusion on the endangered list. An example of the latter would be some of the salmon runs in the Pacific Northwest that have been added to the endangered species list in recent years. To qualify for listing, a given run must show significant genetic, demographic, or behavioral differences from other runs of the same species.

One aspect of the ESA's identification process merits special attention. The law explicitly states that the decision to add a plant or animal to the endangered species list must be based "solely on the basis of the best scientific and commercial data . . . " (Endangered Species Act, Section 4(b)(1)(A)). In other words, whether or not a species is endangered is treated as a purely scientific question. Political considerations are not allowed to interfere with the identification phase (although in practice they sometimes do, leading to nasty legal battles).

12.1.2 Criteria for determining whether a species is endangered

How does one know that a given species is in danger of extinction? Biologists typically look for data that indicate vulnerability: a small population size, a declining population, ongoing losses of habitat (see Chapter 4), etc. In some cases, those data are combined with models to yield short and long-term projections of population viability (see Chapter 16); in other cases, where not enough data exist to construct good models, the determination is based on expert opinion.

Needless to say, different experts weighing different factors are likely to come to different conclusions as to which species are in trouble. Resources may be wasted on plants and animals that are not really endangered, while other, gravely imperiled species go unprotected. The need for a more transparent, standardized way to assess the status of species led the International Union for Conservation of Nature (IUCN) to develop a set of quantitative guidelines in 1994, now known as the Red List categories and criteria. These guidelines enable scientists to assign any plant or animal to one of six categories (Extinct, Extinct in the Wild, Critically Endangered, Endangered, Vulnerable, Near Threatened) based on factors such as range size, amount of occupied habitat, population size, trends in population size, or trends in the amount of habitat (www.iucnredlist.org/static/categories_crtiteria). The original Red List categories and criteria were designed to determine the global status of species, but conservation biologists subsequently have developed guidelines for applying those criteria to individual nations, states, provinces, etc.

The ESA, however, is notably vague in defining what constitutes a species at risk of extinction. It establishes two categories of risk, endangered and threatened, and defines an endangered species as "any species which is in danger of extinction throughout all or a significant portion of its range" and a threatened species as "any species which is likely to become an endangered species within the foreseeable future throughout all or a significant portion of its range" (Endangered Species Act, Sections 3(6) and 3(19)). In practice, most plants and animals have not been added to the US endangered species list until they were close to extinction. A study published in 1993 (Wilcove *et al.* 1993) showed that the median total population size of a vertebrate at time of listing was 1075 individuals; the median number of surviving populations was two. For invertebrate animals, the median total population size was less than 1000 individuals, and the number of surviving populations was three. In the case of plants, the median total population size was less than 120 individuals, and the number of surviving populations was four. One obvious consequence of waiting until species are so rare before protecting them is that recovery becomes far more difficult, if not impossible, to achieve.

12.2 Protection

In order to develop an effective protection plan for endangered species, one needs to know a minimum of two things: (i) What threats do the species in question face?; and (ii) Where do those species occur? Knowledge of the threats will determine protection and recovery efforts, while knowledge of the location and, in particular, the land ownership, will guide the choice of conservation strategy.

12.2.1 What are the threats?

Understanding the threats facing endangered species is complicated due to four factors: (i) threats may vary from taxon to taxon; the things that imperil freshwater fish, for example, may not necessarily be the things that imperil terrestrial mammals; (ii) threats may vary geographically, depending on economics, technology, human demography, land-use patterns and social customs in different areas; (iii) threats may change over time, again in response to technological, economic, social, or demographic factors; and (iv) for all but a handful of groups (e.g. birds, mammals, amphibians), scientists simply do not know enough about most species to determine which ones are imperiled and why they are imperiled.

For three groups—birds, mammals, and amphibians—the IUCN has determined the conservation status of virtually all extant and recently extinct species (Baillie *et al.* 2004). These data provide the best global overview of threats to endangered species (Figure 12.1). With respect to birds and amphibians, habitat destruction is by far the most pervasive threat: over 86% of birds and 88% of amphibians classified by IUCN as globally imperiled are threatened to some degree by habitat destruction. Agriculture and logging are the most widespread forms of habitat destruction (see Chapter 4). Overexploitation for subsistence or commerce contributed to the endangerment of 30% of imperiled birds but only 6% of amphibians (see Chapter 6). Alien species were a factor in the decline of 30% of imperiled birds and 11% of amphibians (see Chapter 7). Pollution affected 12% of imperiled birds and 4% of amphibians (see Box 13.1). Disease, which is often linked to pollution or habitat destruction, was a threat to 5% of birds and 17% of amphibians. Surprisingly, few species were identified as being threatened by human-caused climate change, perhaps because most threats are identified after the fact (see Chapter 8). However, Thomas *et al.* (2004) modeled the response of localized species of various taxa to climate change and concluded that 15–37% of them could be destined for extinction by 2050, making climate change potentially a grave threat.

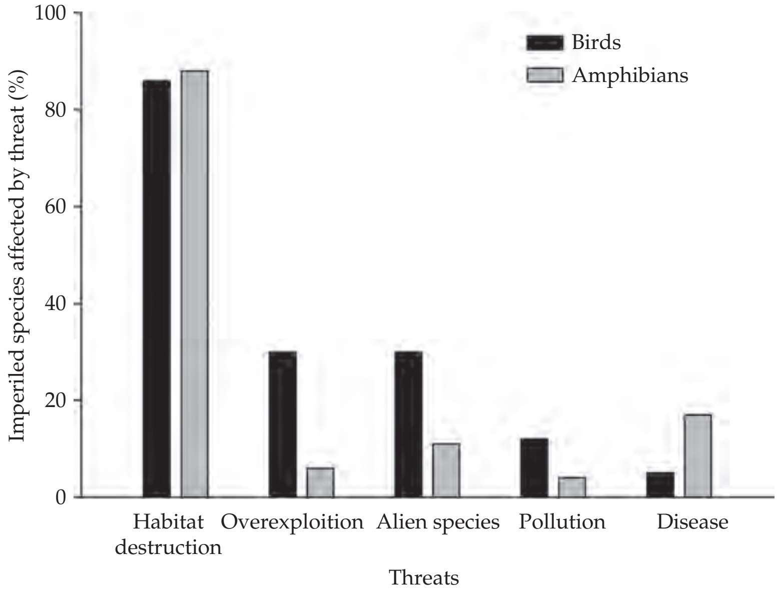

Figure 12.1 Percentage of the world's imperiled birds (black bars) and amphibians (grey bars) threatened by different factors, based on global analyses performed by the IUCN/World Conservation Union. The total percentages for each group exceed 100% because many species are threatened by more than one factor. Data from Baille *et al.* (2004).

A comprehensive status assessment of the world's mammals was published in 2008 (Schipper *et al.* 200; Figure 12.2). Unlike the analyses of birds and amphibians, the mammal assessment did not separate imperiled from non-threatened species in its breakdown of threats. Habitat destruction is the most widespread threat to mammals, affecting 37% of all extant and recently extinct species, followed by overexploitation (17%), invasive species (6%), pollution (4%), and diseases (2%). (The lower percentages compared to birds and amphibians reflect the fact that the mammal assessment covered both imperiled and non-threatened species). Accidental mortality, usually associated with bycatch in fisheries, affects 5% of the world's mammals; in the special case of marine mammals, it affects a staggering 83% of species (see Schipper *et al.* 2008).

These global analyses of threats mask some important regional differences that could influence conservation decisions. For example, in the US, the most pervasive threat to vertebrates is habitat destruction, affecting over 92% of imperiled mammals, birds, reptiles, amphibians, and fish. This was followed by alien species (affecting 47% of imperiled vertebrates), pollution (46%), overexploitation (27%), and disease (11%) (Wilcove *et al.* 1998). In contrast, the most pervasive threat to imperiled vertebrates in China is overexploitation, affecting 78% of species, followed by habitat destruction (70%), pollution (20%), alien species (3%), and disease (<1%) (Li and Wilcove 2005; Figure 12.3).

Ecologists have long recognized that island ecosystems are more vulnerable to alien species than most continental ecosystems. In the Hawaiian archipelago, for example, 98% of imperiled birds and 99% of imperiled plants are threatened at least in part by alien species (Figure 12.4 and Plate 14). Comparable percentages for imperiled birds and plants in the continental US are 48% and 30%, respectively (Wilcove *et al.* 1998).

12.2.2 Where do endangered species live?

There is now a burgeoning literature that aspires to identify key sites for endangered species, typically by developing sophisticated algorithms that optimize the number of rare species protected per acre or per dollar (see Dobson *et al.* 2007; see

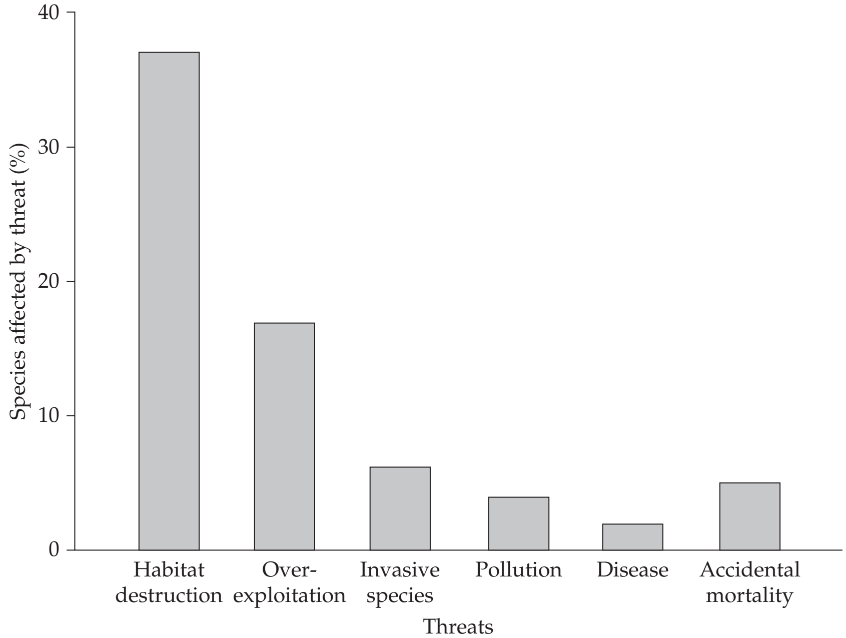

Figure 12.2 Percentage of the world's mammals threatened by different factors, based on a global analysis by Schipper *et al*. (2008). Note that this analysis covered both threatened and unthreatened species; as such, the data include threats to species that are not yet at risk of extinction, unlike Figure 12.1.

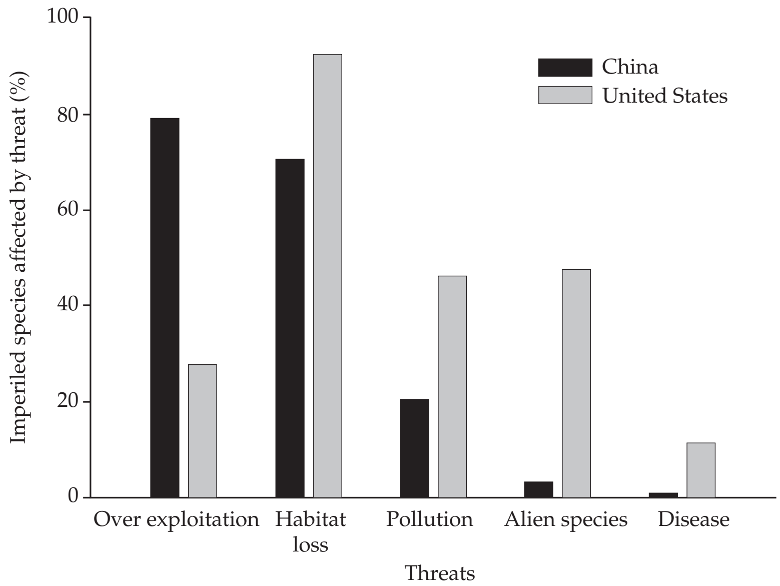

Figure 12.3 Percentage of imperiled vertebrates in China and the USA threatened by different factors. Reprinted from Li and Wilcove (2005) © American Institute of Biological Sciences.

Figure 12.4 Akohekohe (*Palmeria dolei*), an endangered Hawaiian honeycreeper. Like many Hawaiian honeycreepers, it is endangered by a combination of habitat destruction and diseases transmitted by introduced mosquitoes. Photograph by Jaan Lepson.

Chapter 11). In this section I shall focus on the simpler issue of land ownership: does the species in question occur on publicly owned (federal or state government) land or private land? In the US, at least, land ownership patterns are a prime consideration in devising effective protection and recovery strategies, given that approximately 60% of land in the US is privately owned.

In the most authoritative assessment of land ownership and endangered species in the US, Groves *et al.* (2000) estimate that private lands harbor populations of more than half of the nation's imperiled species; if one focuses exclusively on those imperiled species that have made it onto the official federal list, that value rises to two-thirds. Approximately one-quarter of all documented populations of federally protected endangered species occur on privately owned land. This figure almost certainly underestimates the degree to which private lands are important to endangered species because many landowners are reluctant to allow biologists to come onto their property to look for rare plants and animals.

12.2.3 Protection under the ESA

An effective law or program for endangered species must, at a minimum, be capable of protecting essential habitat, halting overexploitation, and slowing the spread of harmful alien species. In the US at least, it must also extend to both public and private lands.

In the US, once a species has been added to the official list of threatened and endangered species (making it a "listed species"), it is protected to varying degrees on both publicly-owned and privately-owned lands. Federal agencies, for example, are prohibited from engaging in, authorizing, or funding any activities that may jeopardize the survival and recovery of a listed species, including activities that damage or destroy important habitats. Depending on circumstances, such activities can range from timber cutting in the national forests to the construction of federally-funded dams or the allocation of funds for the construction of interstate highways. Federal agencies are required to consult with the US Fish and Wildlife Service, the agency charged with administering the ESA, prior to undertaking any activities that may harm listed species. This consultation requirement minimizes the risk that these other agencies will ignore the needs of imperiled species in the course of their day-to-day operations. Typically, the US Fish and Wildlife Service will work with other government agencies to modify projects so they no longer pose a threat to listed species or, if such modifications are impractical, to develop a mitigation plan that compensates for any harm to a listed species.

Private citizens are prohibited from harming listed animals. This includes direct harm, such as shooting or trapping, as well as indirect harm, such as habitat destruction. Listed plants, on the other hand, are not afforded protection on private lands unless the activity in question (e.g. filling a wetland) requires a federal permit for some other reason. This distinction between animals and plants dates back to English common law and does not have any ecological basis.

The decision to extend the ESA's reach to the activities of private citizens was revolutionary at the time, and it has been the source of considerable controversy ever since. When the ESA originally was passed in 1973, the prohibition on harming a listed species was absolute. But this rigid requirement had an unfortunate consequence: Landowners refused to discuss their endangered-species issues with the US Fish and Wildlife Service because they knew the agency could only say "no," and the US Fish and Wildlife

Service turned a blind eye to the activities of private landowners because it feared a political backlash if it slavishly enforced the law. Thus, paradoxically, the law was too strong to protect endangered species effectively. In 1982, the US Congress modified the ESA so that private landowners could obtain permits from the US Fish and Wildlife Service to engage in activities harmful to listed species provided the landowners developed a plan to minimize and mitigate the impacts of those activities, "to the maximum extent practicable." This change to the law, while controversial, probably averted a much greater weakening of the ESA down the road.

For both federal agencies and private citizens there is also an exemption process that permits important activities to go forward notwithstanding their impact on endangered species. It is reserved for cases where the project in question cannot be modified or mitigated so as to avoid jeopardizing the survival and recovery of a listed species. Because the exemption process is complicated, time-consuming, and politically charged, it has been very rarely used. Instead, the vast majority of conflicts are resolved through consultations with the US Fish and Wildlife Service and modifications to the proposed projects.

Finally, it should be noted that while the ESA can prevent a landowner from undertaking activities that are harmful to a listed species (e.g. habitat destruction), it is doubtful that it can compel an individual to take affirmative steps to improve the well-being of a listed species, for example by removing an invasive plant that is choking out the habitat of an endangered bird. This is an important limitation of laws, such as the ESA, that focus on prohibiting harmful activities; they may not be effective at dealing with more passive threats, such as invasive species or diseases. I return to this issue in my discussion of recovery programs (see below).

12.3 Recovery

12.3.1 Recovery planning

Recovery aims to secure the long-term future of the species, to rebuild its populations, restore its habitat, or reduce the threats such that it no longer is in danger of extinction and no longer requires extraordinary conservation measures. That process demands a careful balancing of science, economics, and sociology (see Chapter 14). For example, scientific tools like population viability analysis can be used to figure out how many populations must be protected, how large those populations should be, and how they must be distributed across the landscape in order to sustain the species in question (Chapter 16). Restoration ecology can be used to determine how to rehabilitate degraded habitats so as to increase the numbers and distributions of endangered species (see Chapter 13). But securing the cooperation of landowners in the targeted areas or obtaining the necessary funding to implement the restoration plan requires careful consideration of economics, politics, and social customs. All these steps need to be integrated in order to recover an endangered species.

In the US, the ESA requires that recovery plans be developed for all listed species. Those plans should, in theory, spell out the steps necessary to ensure that a given species is no longer in danger of extinction as well as provide a budget for achieving that goal. One might assume that recovery plans play a pivotal role in endangered species management in the US but, in fact, they rarely do. Part of the problem is that the plans are not legally binding documents. Moreover, according to several studies (Clark *et al.* 2002; Hoekstra *et al.* 2002), the plans often fail to make good use of available biological data for the purposes of developing quantitative recovery goals and outlining recovery actions. In addition, many plans lack adequate information on the threats facing endangered species or fail to link recovery actions to specific threats. And still others fail to set out a scientifically sound monitoring protocol for detecting changes in the status of species or assessing the impacts of recovery actions. In short, the recovery planning process has failed to deliver the sort of guidance needed to move species back from the brink of extinction.

12.3.2 The management challenge

In theory, the goal of endangered species management is to undertake a series of steps that eliminate the threats to the species in question and result in healthy populations that no longer require special protection or attention. And yet these sorts of success stories—sometimes termed "walk-away-species" because conservationists are able to walk away from them—will be few and far between. Instead, most endangered species are likely to require intensive management and protection for the indefinite future. The reasons are three-fold.

First, the leading cause of species endangerment worldwide is habitat loss (Chapter 4). If, as a result of this problem, species are reduced to living in small, fragmented patches of habitat, they are likely to remain at high risk of extinction until such time as more suitable habitat is created via ecological restoration. In places where human demands for land are great (e.g. southern California), there may be no practical way for conservation organizations or government agencies to acquire land for restoration. Moreover, even if the land is available, it can take decades, even centuries, to restore certain types of ecosystems, such as old-growth forests—if those ecosystems can be restored to anything resembling their pre-industrial state [see Hobbs and Harris (2001) for a discussion of key conceptual issues in ecological restoration; also Box 5.3].

Second, many species live in ecosystems that are maintained by natural disturbances such as fires and floods. Examples of such ecosystems include longleaf pine forests in the Southeastern United States and riparian forests in the Southwestern United States. As people dam rivers, clear native vegetation to build homes and farms, and settle those ecosystems, they disrupt or eliminate the natural disturbances. The result is a growing roster of endangered species for which overt habitat destruction is compounded by the elimination of the natural disturbances that were essential to maintaining the habitat. Given that people are unlikely to allow wildfires or floods to reappear in places where these forces have been "tamed," the only way to ensure the survival of disturbance-dependent species is to mimic the disturbances by using techniques such as prescribed fire, controlled releases of water from dams, or direct manipulation of the vegetation. In short, a growing number of species will not survive without constant human intervention.

Third, more and more species are becoming endangered by the spread of alien, invasive species. In most cases, scientists have no way to eliminate or permanently control the invasive species. Indeed, most attempts at biological control, such as introducing a predator or pathogen of the harmful alien, prove unsuccessful or, worse yet, end up harming other native species (Simberloff and Stiling 1996). Consequently, the usual recourse is to control invasive species by pulling them up, poisoning them, hunting them, or trapping them. Since these activities must be repeated whenever the population of the alien species rebounds, there is little prospect of declaring victory and "walking away."

Wilcove and Chen (1998) estimate that 60% of the species protected or proposed for protection under the ESA are threatened to some degree by alien species or fire suppression. For virtually all of these species, ongoing management of their habitats will be necessary to ensure their long-term survival. Wilcove and Chen (1998) further note that the longer the necessary management is delayed, the greater the risk of extinction of rare species and the greater the cost when the necessary management is finally performed. For example, *Tamarix*, an invasive woody plant, dominates riparian areas in the Southwestern US unless it is controlled via herbicides and cutting. In places where *Tamarix* has been allowed to grow for many years, the cost of removal can be as high as US$675 per acre in the first year, dropping below US$10 per acre in the second year. Subsequent maintenance requires an expenditure of under US$10 per acre every two to three years. We can think of endangered species management as having two cost components: an accrued debt reflecting a deferred maintenance problem that arises from inadequate management efforts in the past and an annual payment reflecting the necessary upkeep of properly managed habitats.

Scott *et al.* (2005) recommend that recovery be viewed as a continuum of states. At one extreme are the species that can survive in the wild with essentially no active management once key threats have been eliminated or enough habitat has been protected. At the other extreme are species that can persist in the wild, but only if people actively manage their habitats or control their competitors, predators, etc. A simple recovered/not recovered dichotomy, as exists under the ESA, does not reflect the complexity of contemporary conservation.

12.4 Incentives and disincentives

Policy tools to conserve endangered species can be divided into two categories: incentives and disincentives. An example of an incentive would be a cash payment to a landowner for maintaining the habitat of an endangered species. An example of a disincentive would be a fine or jail sentence for harming an endangered species; this latter approach is the one taken by the ESA.

Conservationists have long debated the merits of the two approaches. Theoretically, with unlimited financial resources, it should be possible to protect and restore endangered species without incurring much opposition. Landowners or resource users who stand to lose money or opportunities due to restrictions on development could be "bought off" at whatever price they demand. It's an appealing scenario but also a deeply unrealistic one. Conservation programs are chronically under-funded. Moreover, at least in the US, some of the regions of the country with the highest concentrations of imperiled species are also regions with some of the highest real estate prices (e.g. San Francisco Bay region; Ando *et al.* 1998), a congruence that would quickly break the budget of any incentives program. Fines and jail sentences are thus used to deter developers from destroying the habitat of endangered golden-cheeked warblers (*Dendroica chrysoparia*) in the US or poachers from killing black rhinoceroses (*Diceros bicornis*) in many African countries. These types of laws, however, are effective only if they are enforced, i.e., if violators feel there is a non-trivial chance they will be caught and punished.

Unfortunately, penalties sometime force people to engage in activities that are counterproductive for conservation. Consider the case of the red-cockaded woodpecker (*Picoides borealis*). This woodpecker is restricted to mature, open pine forests in the southeastern US. A combination of residential development and short-rotation forestry resulted in the elimination of most of the old-growth pine forests in the Southeast and led the US Fish and Wildlife Service to place the woodpecker on the endangered list in 1970. This action ultimately resulted in protection of much of the woodpecker's remaining habitat. However, reports began to trickle in of landowners cutting down stands of young pine trees because they were afraid that red-cockaded woodpeckers would colonize their property if the trees got much older. The landowners knew that once the woodpeckers arrived, their ability to cut down the trees at a later date could be severely restricted; they reasoned that cutting the trees now would ensure the woodpeckers never arrived. Similar fears prevented some landowners from participating in recovery efforts for red-cockaded woodpeckers and other endangered species. Why go out of one's way to restore habitat for endangered species if doing so could result in restrictions on the use of one's property?

To remedy this situation, the federal government implemented a program known as "safe harbor" in 1995. Under this program, the government assures landowners who engage in voluntary activities that benefit endangered species that they will not incur additional regulatory restrictions as a result of their good deeds. In other words, a landowner who restores a part of her property to benefit an endangered species—and agrees to maintain the restored habitat for a certain period of time—will be given permission to undo those improvements (i.e. develop the property) at a later date, notwithstanding the fact that endangered species may now reside there. The reasoning is that without such assurances, the landowner would never engage in the beneficial action in the first place. In some cases, government agencies or private conservation organizations have provided financial assistance to landowners to cover some or all of the costs of habitat restoration. To date, landowners have enrolled over 1.5 million hectares in the safe harbor program (www.edf.org), benefiting a wide variety of endangered species, from Houston toads (*Bufo* *houstonensis*) to northern aplomado falcons (*Falco femoralis septentrionalis*) to Utah prairie dogs (*Cynomys parvidens*).

Fee-hunting is another interesting and controversial incentives program that has been used in parts of Africa to raise revenues and build local support for wildlife conservation. A limited number of licenses to hunt game animals are sold, with a portion of the revenues being returned to the local communities on whose land the hunting occurs. The goal of such programs is to give these communities an economic incentive to conserve wildlife, including animals such as lions (*Panthera leo*) and African elephants (*Loxodonta africana*) that can be harmful to crops or dangerous to people (Corn and Fletcher 1997).

Both disincentives and incentives play important roles in endangered species conservation. Disincentives are most useful in the protection phase as a means to discourage killing of endangered species or further destruction of their habitats. Incentives are useful in the recovery phase as a means to encourage landowners to restore habitats.

12.5 Limitations of endangered species programs

Many conservation biologists believe that a focus on endangered species is misplaced. They argue that the sheer number of species at risk makes a species-by-species approach impractical or even futile. Thus, conservation efforts would be more efficient and successful if they were focused at the level of whole ecosystems and landscapes, rather than individual species.

The US experience highlights the extreme difficulty of identifying and protecting even a fraction of a country's imperiled species, even when that country is wealthy. To date, only about 15% of the known species in the US have been studied in sufficient detail to determine their conservation status (i.e. which species are in danger of extinction). Embedded in this figure is a tremendous variance between groups, reflecting a predictable bias in favor of vertebrates. Thus, the status of almost 100% of the mammals, birds, reptiles, amphibians, and freshwater fishes is known; in contrast, fewer than 4% of invertebrate species have been assessed (Wilcove and Master 2005).

Among the species that have been assessed by experts, over 4800 are considered possibly extinct, critically imperiled, or imperiled; a strong case can be made that all of them merit federal protection under the ESA. Yet as of November 2008, less than a third of these species had been added to the federal endangered species list. Adding a species to the federal list is a time-consuming and often controversial process. Moreover, the US Fish and Wildlife Service is chronically under-funded and under-staffed. One can only imagine how much more difficult the situation must be in most of the developing countries in the tropics, where the total number of species at risk is far greater, yet resources for conservation are far fewer. Hence, it does seem reasonable to conclude that a species-by-species approach to conservation inevitably will leave many imperiled plants and animals unprotected and vulnerable to further losses.

Nonetheless, it would be dangerous to assume that endangered species conservation is a poor use of conservation resources. First, efforts to protect particular endangered species, especially those with large territories or home ranges (e.g. northern spotted owl, *Strix occidentalis caurina*), often result in de facto protection for other endangered species that share the same ecosystem. By choosing the right species to focus on, conservationists can improve the efficiency of their efforts. Second, many conservationists would argue that an essential goal of ecosystem or landscape conservation should be to protect all of the constituent species within that system, including the endangered ones. Moreover, certain ecosystems, such as the Florida scrub or Hawaiian rainforests, have such high concentrations of endangered species that there is little practical difference between conservation programs aimed at endangered species and those aimed at the ecosystem as a whole. Finally, and perhaps most importantly, endangered species have always enjoyed tremendous support from the public. Species such as the whooping crane (*Grus americana*), giant panda (*Ailurapoda melanoleuca*), golden lion tamarin (*Leontopithacus rosalia*), and black rhinoceros have inspired millions of people around the world to care about biodiversity. While it may be impossible to identify and protect each and every species that humanity has brought to the brink of extinction, there will always be many that we care deeply about and cannot afford to lose.

Summary

- Endangered species conservation has three phases: identification, protection, and recovery.
- Protection can be directed toward species, subspecies, or populations. There are important economic and ecological trade-offs associated with protecting subspecies and populations.
- Consistent, quantitative criteria for determining the status of species have been developed by IUCN.
- Protection of endangered species requires accurate knowledge of the threats to those species, the location of existing populations, and land ownership patterns.
- Recovery of many endangered species will require continual, active management of the habitat or continual efforts to control populations of alien species.
- Incentives may be needed to entice people to participate in recovery programs.

Suggested reading

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Relevant websites

- US Fish and Wildlife Service, Endangered Species Program: http://www.fws.gov/endangered/.
- A list of endangered species: http://www.iucnredlist.org/.

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