Chapter 1

Figure 1.1 The roots of conservation can probably be found among the earliest *Homo sapiens*, such as the people who painted this mural in the Lascaux cave in France. (Photo from Art Resource, New York.)

Figure 1.2 Mount Fuji has been a sacred mountain for the Buddhists and Shintoists of Japan for many centuries. (Painting by Katsusika Hokusai from the British Museum, London; photo from HIP/Art Resource, New York.)

Figure 1.3 Put yourself in the shoes of Aldo Leopold, John Muir, and Gifford Pinchot (depicted from left to right) to view the landscape opposite. How does this influence your perspective? (Photos from Aldo Leopold Foundation, USDA Forest Service, Yosemite National Park Archives, and M. Hunter.)

Figure 1.4 A schematic view of the relationship between conservation biology and other disciplines. (Redrawn after Jacobson 1990.)

Figure 1.5 The Society for Conservation Biology began publishing *Conservation Biology* in May 1987 and held its first conference that June.

Figure 1.6 This Española tortoise was among the very first repatriated to the island as a small hatchling some 25–30 years ago, once goats had been removed and the island’s habitat restored. It is likely one of the tortoises now responsible for the new hatchlings appearing again on the island, representing the first reproduction in this population in many decades. (Photo from J. Gibbs.)

Chapter 2

Figure 2.1 There are few places where biodiversity is as conspicuous as a coral reef. (Photo from the Florida Keys National Marine Sanctuary Staff.)

Figure 2.2 Conservationists do not consider all species to be equally important. For example, the Iberian lynx, a species confined to southern Spain, is a higher priority for Spanish conservationists than the Eurasian lynx, which has a huge range that just reaches northern Spain.

Figure 2.3 The distribution of four hypothetical lizard species showing alpha diversity (within an ecosystem, A plus B), beta diversity (among ecosystems, A/B plus C), and gamma diversity (geographic scale, A/B/C plus D). See text.

Figure 2.4 Clear Lake in northern California used to be inhabited by 12 native species of fish until fisheries managers began introducing new fish species, 16 in all. These introductions decimated the native fish populations, but still produced a net increase in alpha diversity of 13 species. This increase came at the expense of global diversity because two of the original species, the Clear Lake splittail and the thicktail chub, are now globally extinct.

Figure 2.5 What is the state of this Pacific kelp forest? From a biodiversity perspective we would focus primarily on having a complete set of the native species (especially any that might be in danger of disappearing from the system), as well as genetic and ecological attributes. A biotic integrity perspective would be similar, but would put more emphasis on having an appropriate density of each species and the appropriate rate of ecological processes. In terms of ecosystem integrity, the emphasis would be on the ecological processes driving this system. A focus on sustainability would center on the prospects for maintaining this system in the future. (Photo from David Zippin.)

Chapter 3

Figure 3.1 Hypothetical example illustrating the relationships between species A and B, Evolutionary Significant Units (ESU), and populations as discussed in Box 3.1. The lengths of the lines joining species, ESUs, and populations are generally equivalent to the genetic distances among them. In this example all populations could be considered separate Management Units (MU) except populations 3 and 4, which are too closely related to be managed separately.

Figure 3.2 Roughly 1.7 million species have been described by scientists; arthropods, primarily insects, constitute almost half this number. The estimated number of species is far greater, especially for smaller life-forms. (The data presented here are summarized from Table 3.1-2 of Heywood and Watson 1995. Redrawn from Hunter 1999.)

Figure 3.3 The depth of unexplored biodiversity is greatest among small species. Here are two examples. (a) An oribatid mite, *Gozmanyina majesta*, that lives in mosses and leaf litter in sphagnum bogs, where it feeds on fungi; it erects the large white setae on its back as a defense against predators. (Photo by Valerie Behan-Pelletier and Roy A. Norton.) (b) A tiny fungus, *Botryandromyces ornatus*, one of a diverse group, the Laboulbeniales, that live obligately on the integument of living arthropods; these specimens are growing on a beetle's leg. (Photo from Alex Weir.)

Figure 3.4 These caterpillars represent ten sibling species of what was long thought to be a single butterfly species, *Astraptes fulgerator* (Hebert et al. 2004). The interim names reflect the primary larval food plant and, in some cases, a color character. (Photo from Dan Janzen; © 2004, National Academy of Sciences, USA.)

Figure 3.5 A species's intrinsic value is independent of its relationship with any other species, as depicted on the left, whereas its instrumental value depends on its importance to other species, including people. This tree fern supports an epiphytic bromeliad that contains a small pool of water, home to many invertebrates. (Photo by M. Hunter.)

Figure 3.6 Although most of our food comes from domestic species, a wide variety of wild species are consumed, ranging from the predictable, such as fruits, to the rather unusual, such as fruit bat soup. (Photos of gathering blueberries in Maine from M. Hunter and soup in Guam © Merlin D. Tuttle, Bat Conservation International, www.batcon.org.)

Figure 3.7 Silphion was a plant of such great commercial value that it was depicted on Greek coins. However, its use (as a contraceptive) was short-lived because it was apparently overharvested into extinction roughly 2000 years ago. (Photo courtesy of wildwinds.com.)

Figure 3.8 People enjoy the diversity of nature in many ways.

Figure 3.9 Other organisms teach us about our world. Here biologists attach a radio-transmitter to a giant armadillo in Emas National Park Brazil. (Photo from Leandro Silveira.)

Figure 3.10 The ecological impacts of keystone species take many forms. The purple sea star is a keystone species because its predatory activities allow many species to coexist, while beavers (overleaf) shape entire communities because of flooding by their dams. (Sea star photo by Lindsay Seward.)

Figure 3.11 Because jaguars range over a broad region and many different types of ecosystems, efforts to save them can benefit many other species, thus making jaguars an umbrella species. The map depicts both the range of ecosystems used by jaguars 100 years ago and the current range (in cross hatching). (From Sanderson et al. 2002b: Photo by M. Hunter.)

Figure 3.12 The neem tree provides an extraordinary array of useful products ranging from medicines to insect repellants, livestock fodder, and building material. (Photo from Gerald Carr.)

Chapter 4

Figure 4.1 Deciding where one ecosystem begins and another ends is a complex task because the web of ecological interactions does not have clean breaks. In this example, distinguishing between the forest ecosystem and the lake ecosystem may be relatively easy, but is the young forest on the left a different ecosystem from the older forest on the right?

Figure 4.2 Great Lakes Alvar System in Jefferson County, New York, USA, 1994. (Photo from Don Faber-Langendoen.)

Figure 4.3 This map depicts 825 terrestrial ecoregions that have been delineated by the World Wildlife Fund; an analogous map for freshwater ecoregions is under development. (From Olson et al. 2001, © American Institute of Biological Sciences.)

Figure 4.4 Are ecosystems tightly connected systems of closely coevolved species, or are they a loose assemblage of species that happen to share similar habitat needs and end up interacting with one another?

Figure 4.5 Relatively few species can tolerate the special conditions of salt marshes, but those that do create ecosystems of great importance. This is in part because salt marshes export large amounts of organic matter to adjacent estuaries, which constitutes a key component of the estuarine food web. (Photo of the Bay of Fundy from M. Hunter.)

Figure 4.6 The strategic value of ecosystems is illustrated by the coarse-filter–fine-filter approach to conserving biodiversity. Protecting a representative array of ecosystems constitutes the coarse filter and may protect most species. However, a few species will fall through the pores of a coarse filter because of their specialized habitat requirements or because they are overexploited. These species will require individual management, the fine-filter approach. In this example, a coral reef ecosystem with all its constituent species is protected by the coarse-filter approach, but fine-filter management is still required for the hawksbill turtle and spiny lobster.

Figure 4.7 The extreme climatic conditions of a high-latitude or high-altitude ecosystem (tundras and the alpine ecosystem shown here) are just two reasons why they support far fewer species than the coral reef depicted in Fig. 4.6. Such ecosystems still merit conservation because of their unique biota and other attributes. (Photo from Marc Adamus.)

Figure 4.8 Ecologists refer to a mosaic of interacting ecosystems as a landscape. How many different types of ecosystem can you recognize in this fine-scale landscape on the coast of Maine, USA? (Photo from Aram Calhoun.)

Figure 4.9 Mangroves are marine wetlands that occur along many tropical coast lines like this one in Sarawak, a state of Malaysia. (Photo from Aram Calhoun.)

Chapter 5

Figure 5.1 Genetic diversity is partitioned within versus among populations to varying degrees with important implications for conservation strategies. In the first case ("between") the two alleles present ("W" or "w") are each sequestered into different populations. Here conserving genetic diversity can be accomplished only by protecting both populations. In the second case ("within") each population has both alleles present and protecting a single population captures all the diversity present.

Figure 5.2 The relative distribution of genetic variation between and among populations of desert fishes differs substantially. Meffe and Vrijenhoek (1988) describe two models: the Death Valley Model (a) in which populations reside in isolated desert springs; and the Stream Hierarchy Model (b) in which populations are connected by a stream system and can exchange genes at a rate that will be affected by their proximity and by the permeability of the intervening habitat. D_{st} (variability among the populations) will probably be significantly higher in populations that fit the Death Valley Model.

Figure 5.3 Genetic diversity allows species to adapt to changing environments, as when dark forms of certain moths helped the species to survive after air pollution darkened the trees they inhabited.

Figure 5.4 Collecting one species of snow lotus, *Saussurea laniceps* (a), for use in traditional Tibetan and Chinese medicine has led to a decline in height based on herbarium specimens and field collections over the past 100 years, while another species that is seldom collected, *S. medusa* (b), showed no significant decline. (From Law and Salick 2005, © 2005, National Academy of Sciences, USA.)

Figure 5.5 Relationships between reproductive fitness and genetic diversity summarized across many studies by Reed and Frankham (2003). The strength of the relationship is measured by the correlation coefficient, which ranges from –1 when higher fitness is associated with lower genetic diversity (and vice versa) to +1 when higher fitness is associated with higher genetic variation (and vice versa). If there was no relationship then most studies would report correlations between fitness and genetic diversity around zero, but as this figure clearly indicates relationships tend to be quite positive (averaging about 0.4).

Figure 5.6 Juvenile mortality in 44 species of mammals (16 ungulates, 16 primates, ten rodents, one marsupial, and an elephant shrew) bred in captivity. Red bars represent mortality rates with inbred parents; green bars represent mortality rates from matings between unrelated parents. Species are arranged from left to right by increasing mortality from unrelated parents. Numbers on the tops of the bars are the sample size. (Data from Ralls and Ballou 1983.)

Figure 5.7 Deformities resulting from population isolation and inbreeding, in this case in dorsal fins of white-spotted charr on a small tributary cut off by dams from the Sufu River, Honshu Island, in Japan (from Morita and Yamamoto 2000). The control is from a larger, more connected population from the Toyohira River.

Figure 5.8 Outbreeding among ibex translocated from Austria, Turkey, and the Sinai led to a population that produced offspring in the winter. The young perished, and the population disappeared. This is one of the species involved in the dysfunctional crosses: *Capra ibex ibex*. (Photo by Amadej Trnkoczy.)

Figure 5.9 Inbreeding pedigrees for matings between: (a) a half-sister with her half-brother, (b) full sister and brother, and (c) full cousins (different parents but identical grandparents). See the text for an explanation of (a) and (b).

Figure 5.10 An endangered "Cerro Fatal" tortoise identified by Russello et al. (in press) through genetic assays as representing an evolutionarily distinctive and new taxon of Galápagos giant tortoises. (Photo from J. Gibbs)

Figure 5.11 Cheetahs, the world's fastest sprinters, represent a genetic conundrum that has perplexed conservation geneticists for two decades. (Photo from Don Getty, www.DonGettyPhoto.com.)

Chapter 6

Figure 6.1 The rise and occasional fall of biodiversity as indicated by the fossil record of families of marine organisms. Marine organisms are used as an index of past biodiversity because they have left the most complete fossil record. (They are more likely than terrestrial taxa to leave corpses in places where they might be quickly covered with sediments and thus protected from scavengers and physical disturbance.) The number of families is used as an index of biodiversity rather than species or genera because a single species or genus might be missing from the known fossil record, but the fossil record for families is likely to be nearly complete. (Redrawn from Sepkoski 1982.)

Figure 6.2 Permian organisms included, from left to right, therapsid reptiles, crinoid echinoderms, trilobites, monuran insects, sarcopterygian fish, nautiloid molluscs, and bryozoans.

Figure 6.3 Three long-term cyclical changes in the earth's movements collectively generate a 100,000-year cycle of climate. See the text for a description. The shapes in (b), (c), and (d) are exaggerated to make the illustrations clearer. (Based on figures in Imbrie and lmbrie 1986.)

Figure 6.4 Global mean temperature record of the past 150,000 years. (Redrawn by permission from Imbrie and Imbrie 1986.)

Figure 6.5 Changes in the geographic ranges of American beech and eastern hemlock indicate that these two species are responding to their environment independently of one another. Ka = 1000 years ago. (From Hunter et al. 1988 and Hunter 1990 as redrawn from Jacobson et al. 1987. Reprinted by permission of Prentice-Hall, Englewood Cliffs, New Jersey.)

Figure 6.6 Biota particularly sensitive to global climate change include some unlikely bedfellows. For example, some inhabitants of tropical mountains, like this Panamanian golden frog, occupy narrow thermal niches that are easily disrupted (photo: N. E. Karraker), whereas polar creatures, like these polar bears (photo: M. Hunter) rely on predictable and also easily disrupted patterns of ice pack formation to reach seals, their main prey.

Figure 6.7 Average decadal changes in the timing of important biological events in various organisms from around the world (negative values indicate a tendency to shift to earlier dates). (Redrawn from Root et al. 2003.)

Chapter 7

Figure 7.1 (a) A study of bighorn sheep populations living on semi-isolated mountain ranges (primarily in deserts of the southwestern United States) demonstrated that larger populations were likely to persist longer than smaller populations. All populations of less than 50 were extinct within 50 years. (Also see Wehausen 1999 and Berger 1999.) (b) Similarly, a study of the risk of extinction for populations of 62 birds species on 16 small islands off the coast of Britain and Ireland indicated that, in general, species with smaller populations were at greater risk. In this figure, risk of extinction is the reciprocal of the average time to extinction in years. (Also see Tracy and George 1992; Duncan and Young 2000; Eisto et al. 2000; Vucetich et al. 2000.) (Part (a) redrawn from Berger 1990; part (b) redrawn by permission from Pimm et al. 1988.)

Figure 7.2 There are three basic ways that a species can be rare. Some, such as the olm (a cave salamander) and the northeastern beach tiger beetle, are confined to rare habitats (*left circle*). Others have small geographic ranges (*right circle*), such as *Pseudotropheus heteropictus*, a cichlid fish from Lake Malawi, and the coco-de-mer from two small islands in the Seychelles archipelago. Still others, such as the maned wolf, occur at low population densities, often because they are large or require resources that are widely dispersed (*bottom circle*). Some are rare in more than one respect. For example, the proboscis monkey lives in mangrove swamps on the island of Borneo, and the Hawaiian hawk lives at low densities on the island of Hawaii. The dwarf naupaka numbers about 350 individuals in four populations growing on beach dunes on the Hawaiian island of Maui. (See Pitman et al. 1999 and Ricklefs 2000 for a recent analysis of these patterns among tropical forest trees in Peru.)

Figure 7.3 The ability of species to survive in the face of environmental change is often correlated with their reproductive capacity. For example, this female elephant will typically produce one calf every five years (the little one beneath is likely her newest baby – the others may be her older calves or belong to other females) whereas the mantis is guarding an egg case full of hundreds of eggs that she will produce every year or even more often. (Photos from Dan L. Perlman.)

Figure 7.4 If we use an area-based definition of population, the perch in the two ponds are readily recognized as separate populations. From a population dynamics perspective, the perch will be separate populations if interchange is so limited that the populations have different levels of mortality, natality, etc. Using a reproductive isolation definition, we can define all the perch in both ponds as a single population as long as at least one breeding individual per generation is exchanged between the two ponds.

Figure 7.5 A schematic depiction of a metapopulation in two years. Occupied patches are shaded; empty ones are unshaded. Arrows represent movement among patches, with the width of arrow corresponding to the number of dispersers. Patch A is a source of butterflies (a net producer of emigrants). Patch B is a sink (net recipient of immigrants). The butterfly subpopulation in patch C has become extinct, while in patch D a new subpopulation has begun to develop from dispersers that have colonized the patch. Patch A is probably a core subpopulation because of its size and persistence, whereas C and D are satellites. We would need data from more years to say if B is a core or a satellite.

Figure 7.6 Metapopulation structure of the world's smallest butterfly, the Sinai baton blue. Patches of Sinai thyme (the butterfly's host plant) in which a colony of Sinai baton blue butterflies was persistently present are depicted in black; patches persistently lacking the butterfly are open, and patches in which a colony was occasionally present are in gray. Patches A and B were determined to be key to the metapopulation's persistence. Numbered boxes are the area's main settlements of St Katherine (1), Wadi Arbaein (2), and Wadi Zuwetein (3). (From Hoyle and James 2005.)

Figure 7.7 Deterministic projections.

Figure 7.8 Ten projections with survival-related stochasticity.

Figure 7.9 Projections with survival-related stochasticity.

Figure 7.10 Projections with survival- and gender-related stochasticity.

Figure 7.11 Projections with survival- and gender-related stochasticities and reproductive catastrophes.

Figure 7.12 A combination of factors drove the heath hen, once widespread in the eastern United States, into extinction, including environmental stochasticity (unusual weather events), demographic stochasticity (skewed sex ratios), genetic stochasticity (loss of genetic variation due to small population size), and catastrophes (fires). (Photo by Steven Holt/ Aigrette Stockpix.)

Chapter 8

Figure 8.1 This map shows the human footprint, a quantitative depiction of human influence on the land surface, based on geographic data on human population density, land transformation, transportation and electrical power infrastructure, and normalized to reflect the continuum of human influence across each terrestrial biome defined within biogeographic realms. Further details are available at the "Atlas of the Human Footprint" website (www.wcs.org/humanfootprint) and in Sanderson et al. (2002a). (Map provided by the Wildlife Conservation Society.)

Figure 8.2 Fumes from a copper smelter killed most of the vegetation in the Copper Basin, Tennessee. This photo was taken in 1945, about 25 years after the fumes were controlled. (Photo from USDA Forest Service.)

Figure 8.3 Analysis of the spatial patterns of dominant winds (arrows) and agricultural lands (shaded areas) indicated that air pollution by pesticides is likely to have played a major role in the decline of four species of frogs in California (Davidson et al. 2002). Two other species seemed to have been more affected by direct habitat loss; climate change and ultraviolet radiation did not seem important in this system.

Figure 8.4 Persistent pesticides and similar compounds accumulate in the tissues of one species and then are passed up the food web to other species where they become more concentrated. This process is called biomagnification or bioamplification. In this figure DDT has entered the food web of Lake Kariba in Zimbabwe and reached its highest levels in top predators such as crocodiles, tiger-fish, and cormorants. Numbers are parts per billion of DDT and its derivatives in the fat of the species illustrated. (Redrawn by permission from Berg et al. 1992.)

Figure 8.5 Roads act as filters to the movements of many animals, especially because of collisions such as the one that killed this tayra in Belize. (Photo from M. Hunter.)

Figure 8.6 Exotic and native plant species richness in plots 50 meters away from paved, improved-surface, graded, and four-wheel-drive (4WD) roads through grasslands, shrublands, and woodlands in southern Utah, USA (Gelbard and Belnap 2003). Error bars represent 1 SE. Different letters indicate significant differences ($p < 0.05$) among levels of road improvement.

Figure 8.7 Survival of wild, juvenile, chinook salmon migrating toward the sea before (1966–8) and after (1970–5) completion of two dams on the Snake River in Washington. (Redrawn by permission from Raymond 1979; also see Petrosky et al. 2001.)

Figure 8.8 Soil erosion has profoundly degraded ecosystem productivity in many regions, although it is most noticeable in mountainous areas, as in this photo from the Himalayas. (Photo from M. Hunter.)

Figure 8.9 Clearcuts have a dramatic effect on forest biota but the key issue is what happens in the following years; will the forest regenerate or will it be converted to another use, such as housing or agriculture, and thus constitute deforestation? We also need to consider to what extent a clearcut does or does not resemble the natural disturbance regime for a particular type of forest. (Photo from Marc Adamus.)

Figure 8.10 This photo from the Khyber Pass in Afghanistan reveals some of the classic signs of desertification: virtually no ground vegetation (at least of palatable plants), a browse line on the tree indicating how high livestock can reach, and soil erosion. (Photo from M. Hunter.)

Figure 8.11 A complex of aquatic ecosystems before and after human alterations. In the lower right a housing development that was previously surrounded by dikes is being extended by filling the wetland. Nearby, the channel is being dredged. Upstream the river has been channelized and the adjacent wetlands ditched. A tributary on the right side of the main river has been dammed to create a reservoir. In the real world it would be highly unusual to have all these activities in a small area.

Figure 8.12 A graphical representation of island biogeography theory. (From Hunter 1990, reprinted by permission of Prentice-Hall, Englewood Cliffs, New Jersey.)

Figure 8.13 The number of species in a sample plot or on an island increases as area increases, but the steepness or slope of the curve varies considerably among taxa. Note that in these graphs for taxa on islands in the Baltic Sea some of the y axes are linear and some are logarithmic. All of the x axes are logarithmic. Recall from Chapter 6 that these lines are described by the formula $S = CA^z$, where S is number of species, A is area, and C and z are constants. (Redrawn from Järvinen and Ranta 1987.)

Figure 8.14 People usually initiate fragmentation by building a road into a natural landscape, thereby *dissecting* it. Next, they *perforate* the landscape by converting some natural ecosystems into agricultural lands. As more and more lands are converted to agriculture, these patches coalesce and the natural ecosystems are isolated from one another; at this stage *fragmentation* has occurred. Finally, as more of the natural patches are converted, becoming smaller and farther apart, *attrition* is occurring. (Terminology from R. Forman, personal communication, and 1995; also see Collinge and Forman 1998.)

Figure 8.15 Three principles of geometry that affect the edge-to-area ratios of patches. (a) Small patches have relatively longer edges than large patches. (b) Patches that are less circular in shape have longer edges than circular patches. (c) The interior zone of a small or non-circular patch is relatively small compared with that of a large, circular patch. (In these patches the shaded edge zone is 100 meters wide.)

Figure 8.16 Penetration distances of different edge effects into forest remnants of the Biological Dynamics of Forest Fragments Project in the Brazilian Amazon. (From Laurance et al. 2002.)

Figure 8.17 Madagascar is home to many unique species such as the indri, the largest species of lemur. (Photo by M. Hunter.)

Chapter 9

Figure 9.1 Many scientists believe that human overexploitation was responsible for the extinction of many large North American mammals about 11,000 years ago. The woolly mammoth depicted here was apparently one victim, although the caribou shown in the background continue to survive. © American Museum of Natural History.

Figure 9.2 In this 1903 photo two Maori medical students pose beside a reconstruction of a moa. (Photo from A. Hamilton. Reproduced courtesy of the National Museum, New Zealand.)

Figure 9.3 Commercial exploitation for urban markets has devastated populations of many species. This is a 1912 photograph from Orange, Texas, USA; the bushmeat trade is a current manifestation of the same phenomenon. (Photo from the William Hornaday Collection of the US Library of Congress.)

Figure 9.4 In many tropical forests wild animals, so called "bushmeat," are overexploited for sale in urban markets. Logging roads provide the transportation network that facilitates this commerce. (Photo by Richard Ruggiero, US Fish and Wildlife Service, provided by the Bushmeat Crisis Task Force.)

Figure 9.5 Subsistence use of wild plants and animals is very important for many rural people. This boy is carrying part of a mandrill carcass, a type of baboon that lives in the forests of West Africa. (Photo by David Wilkie, Wildlife Conservation Society, provided by the Bushmeat Crisis Task Force.)

Figure 9.6 Even nonconsumptive use of wild life can be harmful. These tourists tromping through a colony of brown noddy terns in Australia may be causing considerable damage. (Photo from M. Hunter.)

Figure 9.7 Most of the animals killed by shrimp trawlers are thrown overboard, and they include endangered species such as this loggerhead turtle. (Photo from Michael Weber, The Ocean Conservancy.)

Figure 9.8 This graph shows how whalers have overexploited a series of great whales, starting with fin and blue whales and then switching to sperm and sei whales. (Redrawn by permission from Miller 1992.)

Figure 9.9 Mortality resulting from human fishing tends to increase as fish become larger (line *B*), whereas natural mortality is greatest when fish are small (line *A*). This mismatch may exacerbate the effects of overfishing, especially because large fish have more offspring. (Graph based on personal communication with Robert Steneck.)

Figure 9.10 Hunting pressure shifts the community structure toward smaller species of game vertebrates, based on research at 25 Amazonian forest sites. These are scatterplots of the relationship between level of hunting pressure (N, none; L, light; M, moderate; H, heavy) and the percentage contribution of species within three size classes to the overall density and biomass. Spearman correlation coefficients (r_s) indicate statistical significance. (From Peres 2000.)

Figure 9.11 Consumers provide the market for wild life trade items and thus are at least half the problem, despite government agents who attempt to stop illegal wild life trade. (Photo from John and Karen Hollingsworth, US Fish and Wildlife Service.)

Figure 9.12 The decline of large, predatory fish in the Gulf of Maine (e.g. codfish that are large enough to prey on adult lobsters) has dramatically affected the entire marine community. (Photo taken on Monhegan Island; from Edward W. Coffin.)

Figure 9.13 Temporal trends in fractional trophic levels of harvested species over the past 43,000 years. (a) Entire record of trophic level (TL) analysis from archeological studies to the past three decades (in rectangle at far right of the trend line). (b) Expanded trend in fractional trophic levels since 1970. (Modified from Steneck et al 2004.)

Chapter 10

Figure 10.1 Ships have spread Norway rats and black rats to virtually every corner of the earth, even remote islands, where they have caused hundreds, perhaps thousands, of extinctions and billions of dollars of losses for humans. (This photo of a black rat attacking a fantail nest was taken by David Mudge and provided by the Department of Conservation, New Zealand.)

Figure 10.2 International trade leads to invasion of exotic species as reflected in the relationship between imports of merchandise into the USA and the accumulation of exotic (a) mollusks, (b) plant pathogens, and (c) insects since 1920 in 10-year increments. Lines represent different species-accumulation models. USD are 1999 US dollars. (From Levine and D'Antonio 2003.)

Figure 10.3 Game fishes have been introduced widely, sometimes by anglers carrying a bucket, sometimes by professionals using specially designed vessels and trucks. (Photo from the US Fish and Wildlife Service.)

Figure 10.4 In Australia, eastern barred bandicoots (shown here), other small marsupials, and ground-nesting birds have been severely affected by predation by foxes. (Photo from Vertebrate Pest Research Unit, Department of Primary Industries, Victoria, Australia.)

Figure 10.5 After sea lampreys used the Welland canal to bypass Niagara Falls and enter the upper Great Lakes, two of their host species, the deepwater cisco and blackfin cisco, became extinct and the lampreys continued to forage on other fish such as the lake trout shown here. (Photo from Great Lakes Science Center, Hammond Bay Biological Station.)

Figure 10.6 Perhaps the most ironic victim of an exotic species was the Stephen Island wren, apparently wiped out by a single cat brought to the island by a lighthouse keeper.

Figure 10.7 The introduction of Nile perch to Lake Victoria led to the extirpation of over 200 species of fish and significant changes in the lake's food web. (Redrawn by permission from Witte et al. 1992b.)

Figure 10.8 The rate at which New Holland honeyeaters visited *Callistemon rugulosus* flowers decreased as the abundance of exotic honey bees increased. (Redrawn by permission from Paton 1993.)

Figure 10.9 The giant weta, a huge flightless insect weighing up to 70 grams, is one of many native New Zealand animals that probably declined soon after Polynesian colonization of the island brought the kiore, or Polynesian rat, to the islands. (Photo from C. R. Veitch, Crown Copyright, Department of Conservation, New Zealand.)

Chapter 11

Figure 11.1 These maps depict global patterns of reptile distributions based on the terrestrial ecoregions shown in Fig. 4.3. (a) The relative species richness of reptiles in different ecoregions. (b) The ecoregions that have the most species that are endemic to a given ecoregion. (Maps reproduced with permission from the World Wide Fund for Nature; see worldwildlife.org/wildfinder/printableMaps.cfm for maps for birds, reptiles, and amphibians.)

Figure 11.2 The idea of focusing conservation in areas with high species richness and endemism and high degrees of threat has led Conservation International to propose a set of global hotspots for conservation action. Different colors are used to distinguish adjacent hotspots. (Map reproduced with permission from Conservation International; see Mittermeier et al. 2004.)

Figure 11.3 Conservation biologists have used geographic information systems (GIS) to combine maps representing distributions of many different species and existing reserves (layers of information) into composite maps. In this simple figure (redrawn by permission from Scott et al. 1993), a composite map based on the ranges of just three species of Hawaiian finch shows that the existing reserves did not coincide well with the areas of finch diversity. See Scott et al. (1993) for a description of these techniques. See Fig. 11.1 for more complex examples.

Figure 11.4 In Nepal there are few protected areas at middle elevations because, historically, most of the people lived in these areas. High altitude areas are represented in reserves because they are scenic and have few people; the reserves in low-lying areas are a legacy of the past when malaria limited human populations. Many species are found exclusively in the ecosystems characteristic of the middle altitudes, and thus this is an important gap in the network of existing reserves.

Figure 11.5 Schematic representations of design principles for nature reserves. In each pair the design on the left will probably have a lower extinction rate and thus may have higher species diversity. (Redrawn by permission from Diamond 1975.)

Figure 11.6 The reserve depicted in the center of this drawing illustrates many desirable features, although it is fairly small for ease of illustration. It encompasses a wide range of ecosystems spanning elevations from river level to mountaintop. It fully occupies a watershed by lying within natural boundaries, the watershed line and river shore, and is fairly circular in outline. It is buffered by seminatural forests from plantation forests, and by plantation forests from agriculture. It is connected to other reserves by natural vegetation along both the mountain slope and the river shore.

Figure 11.7 Final zoning plan for the Asinara Island Marine Reserve in Italy, which shows how core protected areas can be buffered by zones in which some uses are allowed. In both zones A1 (no-entry, no-take) and A2 (entry, no-take) no fishing is allowed; only park personnel are allowed in A1 for research and management. Zone B (general reserve) is open for recreation and fishing but with special limits on fishing, while in zone C (partial reserve) a greater range of fishing activity (both commercial and recreational) is allowed. (From Villa et al. 2002.)

Figure 11.8 The top map depicts core areas of tiger habitat in the terai region of India and Nepal in green colors (NP, national park; TR, tiger reserve; WR, wildlife reserve; WS, wildlife sanctuary). The potential for dispersal is indicated, with darker reds representing areas with the lowest biological costs for dispersal (e.g. good food and cover) and yellows representing areas with higher biological costs. The bottom map shows potential tiger dispersal corridors, with Level 1 corridors representing the best pathways for dispersal (as defined by low biological cost), Level 2 corridors representing the next best pathways, and Corridor Buffers the next best. Existing tiger subpopulations are delineated by the dashed line. (From Wikramanayake et al. 2004.)

Figure 11.9 Recently described vertebrate species from the Annamite Range include: Morafka's cascade frog (top) and Ba Na cascade frog (third from top) (Bain et al. 2003); Large-antlered muntjac (second panel, left) (Schaller and Vrba 1996); Annamite muntjac (second panel, right) (Pham Mong Giao et al. 1998); Annamite striped rabbit (second from bottom) (Averianov et al. 2000); and saola (bottom) (Vu Van Dung et al. 1993). Also pictured are species closely related to these newly described ones: green cascade frog (second from top) and red muntjac (middle panel: female on left, male on right). (Paintings by Joyce A. Powzyk, © Center for Biodiversity and Conservation, American Museum of Natural History.)

Figure 11.10 As of 2004, Vietnam's protected area network covered approximately 1.7 million ha (5% of the country); if all the conservation areas currently proposed were approved, coverage would increase to roughly 2.5 million ha, or around 7.5% of the land area, exceeding the goals proposed in 1998. (Map produced by Kevin Koy, American Museum of Natural History.)

Chapter 12

Figure 12.1 Conservationists cannot afford to adopt a siege mentality, protecting reserves and ignoring the rest of the landscape. (The idea for this figure was shared by Eduardo Santana, but its originator is unknown.)

Figure 12.2 The assemblage of species associated with a forest changes as the forest undergoes a cycle of succession and disturbance. Even a single old tree will support a different biota than a small tree, perhaps because it is taller or its bark more fissured. (From Hunter 1990, reprinted by permission of Prentice-Hall, Englewood Cliffs, New Jersey.)

Figure 12.3 The grazing effects of cattle may be analogous to those of wild ungulates but there are differences. For example, cattle are even more dependent on riparian zones than are bison. (Photo from R. Robinson, provided by Yellowstone National Park.)

Figure 12.4 Regulating fishing is the primary way that fisheries managers control aquatic ecosystems. Here a fisheries observer measures the size of commercial fishing nets. (Photo from the Alaska Fisheries Science Center.)

Figure 12.5 Whether it is a stone-wall lined pasture in New England or a hillside in Nepal carved into terraces, a key factor in maintaining biodiversity in agricultural landscapes is maintaining patches of native vegetation, especially along streams and lakes. (Photos from M. Hunter.)

Figure 12.6 Farmers who maintain natural vegetation may benefit from increased rates of pollination. A study of California watermelon farms compared organic (O) and conventional (C) farms that were near (N) natural vegetation (over 30% of the landscape within a 1 km radius) or far (F) (less than 1% native vegetation). (a) Total estimated pollen deposition by native bees (±SE) on organic near, organic far, and conventional far farms. (There were no conventional farms near natural vegetation.) The horizontal line indicates the level of pollen deposition required for production of marketable fruit. (b) Native bee diversity (circles) and abundance (triangles) (±SE). During a two-year study, all CF, one OF, and no ON farms brought managed honeybee colonies to the fields to achieve adequate pollination. (From Kremen et al. 2002, © National Academy of Sciences, USA.)

Figure 12.7 The current allocation of Maine's forests from a triad perspective and what the allocation could be if some trade-offs between cultivated ecosystems and reserves were made.

Figure 12.8 In urban landscapes oases for quite a few species of wild life can be found in parks, backyards, cemeteries, etc. Canberra, the capital of Australia, is home for over 300,000 people and a remarkable diversity of wild species because of city planning that maintained large areas of open space. (Photo from M. Hunter.)

Figure 12.9 A conceptual representation of ecosystem degradation, restoration, and related processes. See the text for an explanation; for each line on this graph there is an italicized term in the text. (Redrawn by permission from Bradshaw 1984.)

Figure 12.10 The forests of the Pacific Northwest are some of the richest temperate forests on the planet in terms of both their biological wealth and their value for timber. (Photo by Marc Adamus.)

Figure 12.11 A vast wetland complex in southern Iraq, home to the Marsh Arabs and abundant wild life, has been devastated by conflicts but is now being restored. (Photo from Jassim Al-Asadi, Center for the Restoration of Iraqi Marshlands, Iraq Ministry of Water Resources.)

Chapter 13

Figure 13.1 The numbers of cranes appearing at Japanese feeding stations increased markedly over time, suggesting that availability of winter food had limited populations (Archibald 1977b, personal communication). Of course, other factors could have contributed to the increase, including the possibility that cranes were simply more concentrated at feeding stations in later years.

Figure 13.2 Populations of some arid land animals such as reticulated giraffes can be limited by the availability of drinking water during years when drought occurs. Populations can be increased by constructing water holes, although overbrowsing of the surrounding vegetation may then occur. (Photo from Don Getty, www.DonGettyPhoto.com.)

Figure 13.3 Many small cacti benefit from other species, sometimes called nurse plants, sheltering them from temperature extremes and grazing livestock. Small cacti have sprouted here under the protection of fallen trunks of trees and cacti. (Photo from J. Gibbs.)

Figure 13.4 Puffin decoys are used to provide a social stimulus for puffins establishing a new colony. (Photo from Steve Kress.)

Figure 13.5 In some countries conservation officials are dehorning rhinos to dissuade poachers from killing them. Here a white rhino is being dehorned near Lake Kyle, Zimbabwe. (Photo from Tom Claytor, www.claytor.com.) A white rhino with intact horn from Lake Nakuru National Park, Kenya is shown for comparison opposite. (Photo from Don Getty, www.DonGettyPhoto.com.)

Figure 13.6 Tunnels can allow toads and other amphibians to pass under roads during their spring migrations. The effectiveness of these particular tunnels is being evaluated by researchers who introduce large numbers of amphibians into the center and note which tunnels the animals choose (in this case long versus short tunnels). The resulting information is used to design behaviorally palatable road-crossing structures. (Photo from J. Gibbs.)

Figure 13.7 Population changes of Indiana bats hibernating in a cave after a stone wall was built to exclude human intruders and after the wall was replaced with a grate. The wall increased temperatures, which increased the bats' rate of fat metabolism; apparently, many did not survive hibernation. (Redrawn by permission from Richter et al. 1993.)

Figure 13.8 Fences around piping plover nests may reduce predation.

Figure 13.9 Despite taking precautions like wearing surgical masks, researchers spread canine distemper to the only known wild population of black-footed ferret. (Photo from US Fish and Wildlife Service.)

Figure 13.10 Conservationists often burn grasslands to control the competitors of rare plants. Here a kerosene drip can is being used to set a perimeter fire during a prescribed prairie fire burn during autumn at the University of Wisconsin-Madison Arboretum's Greene Prairie. Controlled fires rid plant debris and kill off woody plant growth and thereby help the prairie thrive during the next growing season (Photo © UW-Madison University Communications 608/262-0067, credit Jeff Miller.)

Figure 13.11 Translocations can be particularly useful to reintroduce species such as barrel cacti that are often overharvested by collectors for the ornamental plant industry.

Figure 13.12 Addition of 20 male adders to a declining island population apparently rescued the population from the effects of inbreeding. The graph shows an index of population size (total number of individual males captured; females were not counted because they were much harder to catch) that indicates a slow decline and then a dramatic recovery. The 20 translocated males were not counted in the population estimates. Other data showed an increase in genetic variability after 1996 and a decrease in the number of stillborn young. (Redrawn from Madsen et al. 1999.)

Figure 13.13 Gathering turtle eggs and raising them in captivity can reduce predation losses and give young turtles a head start. This wooden box contains five-year-old Galápagos giant tortoises hatched in captivity. They have been raised to a size large enough to survive the predators and harsh conditions they will encounter when reintroduced back to their native habitat on Española Island (to which they are now en route). Each individual has a unique set of notches filed along the margins of the shell and a temporary number painted on its back so researchers can keep track of them. (Photo from J. Gibbs.)

Figure 13.14 Efforts to replace the eastern peregrine falcon sought to maximize genetic diversity by using individuals from as far away as Australia and Europe. (Photo from Don Getty, www.DonGettyPhoto.com.)

Figure 13.15 A diverse array of techniques was used to bring the black robin back from the very brink of extinction. Photo by G. Taylor, Crown copyright, Department of Conservation, New Zealand.

Chapter 14

Figure 14.1 Public zoos, aquariums, and gardens have long emphasized educating visitors, as well as entertaining them. Close encounters with wild creatures like this blacktip reef shark create a unique and memorable experience at California's Monterey Bay Aquarium. (Photo from Randy Wilder, © Monterey Bay Aquarium Foundation.)

Figure 14.2 Some species that would probably be extinct today without *ex situ* conservation. Most disappeared from the wild for some period; in some cases (e.g. the nene) a few individuals persisted in the wild, but probably in numbers too small to be viable. Clockwise from the center top they are European bison, red wolf, nene goose, viviparous tree snail, Przewalski's horse, Guam rail, Pere David's deer, *Paphiopedilum delenatii*, black-footed ferret, California condor, Arabian oryx, *Tecophilaea cyanocrocus*, and, in the center, *Franklinia alatamaha*.

Figure 14.3 The quagga, dusky seaside sparrow, passenger pigeon, po'ouli, pink-headed duck, and thylacine apparently became extinct when the last known individual died in captivity.

Figure 14.4 The top part shows a small section of the studbook for red pandas, and below is an ISIS entry for one individual red panda. (Provided by Miles Roberts, National Zoological Park, Washington, DC.)

Figure 14.5 Many domestic plant species come in a startling variety because of the efforts of farmers and plant breeders. Much of this diversity is maintained in *ex situ* facilities like this one in Colorado, USA, that holds over a million samples, although some still exists in farmers' fields. (Photo by Scott Bauer, ARS, US Department of Agriculture.)

Figure 14.6 The Sumatran rhinoceros is highly endangered, and this led to a concerted effort to breed them in captivity, an effort that has proven almost fruitless to date. (Photo provided by S. David Jenike/Cincinnati Zoo and Botanical Garden.)

Figure 14.7 Arabian oryx have been reintroduced to the wild in Oman (as seen here), Saudi Arabia, Jordan, and Israel. (Photo used with permission of the Office of the Adviser for Conservation of the Environment, Sultanate of Oman.)

Chapter 15

Figure 15.1 Snakes epitomize widely divergent attitudes held by humans toward wild life. For example, snakes are typically vilified in European cultures owing to myths such as that of Medusa, punished for her beauty by Athena, who turned her beautiful tresses into snakes, which gave her the power to turn to stone anyone who looked at her. (Peter Paul Rubens/Art Resource.) In contrast, at religious ceremonies in Asia snakes are often given offerings. In this sculpture from Thailand Buddha is in repose upon Naga, a serpent-being that can both bestow wealth and assure crop fertility as well as decline these blessings. (Artist unknown/Art Resource.)

Figure 15.2 Women and men often interact with the natural world in different ways that may reflect or shape their values. (Georges Seurat/Art Resource, top; Claude Monet/Art Resource, bottom).

Figure 15.3 Wolves fit into the human psyche in various ways. Wolves may embody nurturance, as in the case of the twin brothers Romulus and Remus abandoned on the banks of the River Tiber and found by a she-wolf who fed them with her own milk. (Musei Capitolini, Rome, Italy. Scala/Art Resource, NY.) Wolves may also be villainous, as in the tale of *Little Red Riding Hood* and the conniving and evil intentioned wolf that has profoundly spooked generations of small children. (Broune, Tom (1872–1910). 1990. Private collection. Image Select/Art Resource, NY.) Why do we ascribe such complex attributes to these highly social canines? (Photo from Don Getty, www.DonGettyPhoto.com.)

Figure 15.4 This figure conceptualizes an ethical sequence as a nested hierarchy, with concern for oneself at the lowest, narrowest level and concern for ecosystems and the whole biosphere at the highest, broadest level. The success of conservation hinges on people expanding their level of concern to fully encompass all species and ecosystems. (Redrawn by permission from Noss 1992.)

Figure 15.5 A key part of the success of the early public relations campaign to promote support for Bahama Parrot conservation has been Quincy – a person wearing a parrot costume – who taught children a song about the Bahama parrot, led them in a parrot dance, and told them about the plight of the bird. (Photo from Lynn Gape, Bahamas National Trust.)

Chapter 16

Figure 16.1 Strong tensions arise when those asked to bear the costs of protecting biodiversity do not perceive that they receive any benefits for doing so. Here anger is being expressed at restrictions to logging in government-owned forests in the US Pacific Northwest designed to protect the spotted owl under the Endangered Species Act. (Photo from Steven Holt/stockpix.com.)

Figure 16.2 Harvesting trees from natural forests for fuel, fiber, and construction materials is a major source of goods derived from wild species. (Photo from J. Gibbs.)

Figure 16.3 In many parts of the world, wild meat is an important source of protein for people, such as these subsistence hunters with recently captured tortoises in northern Amazonia. (Photo from Joel Strong.)

Figure 16.4 Gorillas are an excellent example of a species with significant existence value. Despite the remote possibility that the average person will ever get to see an actual gorilla many people still derive great satisfaction out of knowing that gorillas exist in the wild and are willing to contribute financially to support gorilla conservation. (Photo from M. Hunter.)

Figure 16.5 Fisheries such as this for tuna are recurring examples of the “tragedy of commons” dilemma. (Photo from U.S. National Oceanic and Atmospheric Administration.)

Figure 16.6 If carefully structured, ecotourism is one mechanism for allowing local people to obtain economic benefit from sharing their environment with tourists. (Photo from Thane Joyal.)

Figure 16.7 Butterfly ranching involves cultivation of productive larval habitat to attract members of wild butterfly populations to lay eggs in the cultivated areas. Ranchers can then harvest a portion of the eggs deposited, hatch the eggs, rear the larvae to metamorphosis, and sell the adults on the marker. The undertaking can be both sustainable and lucrative. Many tropical butterflies such as this blue morpho have been used in ranching schemes. (Photo from Dan Perlman/EcoLibrary.)

Chapter 17

Figure 17.1 A consortium of conservation groups called the Alliance for Zero Extinction (Ricketts et al. 2005) has mapped 595 "centers of imminent extinction," sites that harbor the only remaining population of highly threatened species of mammals, birds, reptiles, amphibians, and conifers. Given that just one-third of these sites are currently protected, they are a high priority for avoiding a wave of extinctions ("open" dots represent sites that have some degree of protection, whereas the filled dots represent sites with little or no protection). (Map courtesy of Alliance for Zero Extinction, data version 2.1.)

Figure 17.2 Eric Dinerstein and Eric Wikramanayake (1993) used the extent of protected areas and estimates of deforestation to create an index that would guide international conservation organizations in setting priorities among 23 Indo-Pacific countries. They divided the countries into four classes. Category I: countries with a relatively large percentage (>4%) of forests under formal protection and that will have a high proportion (>20%) of unprotected forested areas left in ten years. Category II: countries with a relatively large percentage of forest (>4%) under formal protection, but that will have little (<20%) unprotected forests left in 10 years. Category III: countries with a relatively low percentage (<4%) of forests presently protected. However, under current deforestation rates these countries will still have a relatively large proportion (>20%) of their unprotected forests remaining in ten years. Category IV: countries with a relatively low proportion (<4%) of forests presently protected. Obviously, Category IV countries require urgent action, while Category II and III countries should be shifted toward Category I status expeditiously.

Figure 17.3 We need to deal with the root causes of the biodiversity crisis. Maintaining biodiversity by limiting human population growth and wisely caring for entire ecosystems is much more efficient than saving critically endangered species. It is analogous to saving lives through public-health programs versus emergency-room surgery.

Figure 17.4 Based on a *Miami Herald* cartoon, June 1992. (Reprinted with special permission of King Features Syndicate.)

Figure 17.5 Remaining a life-long learner is one of the most important traits of any successful conservation biologist. These people are keenly inspecting a basin full of leaf litter in hopes of seeing a small forest-dwelling frog, Kihansi Gorge, southeastern Tanzania. (Photo from J. Gibbs.)

Figure 17.6 There are many things you can do as an individual to "think globally, act locally" like the environmental educator shown here. Remain informed, gain experience, learn to communicate effectively, make your lifestyle consistent with your values, support conservation groups, and even consider becoming a professional conservationist. (Photo from D. Andrew Saunders.)