1

What Is Conservation Biology?

Gary K. Meffe, C. Ronald Carroll, and Martha J. Groom

When the last individual of a race of living things breathes no more, another heaven and another earth must pass before such a one can be again.

William Beebe, 1906

Expanding Human Demands on Earth

The natural world is a far different place now than it was 10,000 years ago, or even 100 years ago. Every natural ecosystem on the planet has been altered by humanity, some to the point of collapse. Many species have gone prematurely extinct, natural hydrologic and chemical cycles have been disrupted, billions of tons of topsoil have been lost, genetic diversity has eroded, and the very climate of the planet may have been disrupted significantly. What is the cause of such vast environmental change? Very simply, the cumulative impacts of 6.4 billion people (Figure 1.1), have stressed the many ecological support systems of the planet. Although it took hundreds of years for the human population to reach 1 billion people, we increased to six times that size in a little more than a century. As a consequence, biological diversity (**biodiversity**, for short), the grand result of evolutionary processes and events tracing back several billion years, is itself at stake and rapidly declining. One of the many species suffering the consequences of ecological destruction is *Homo sapiens*, the perpetrator of it all.

All people should recognize the degree to which human impacts affect the natural world, and in turn, diminish our abilities to prosper. Our population explosion over the past century is not yet over, as annually the world's population increases by 77 million each year (the equivalent of adding the population of the United States every 3.8 years). Fortunately, global population growth rate finally slowed beginning in the 1990s. Worldwide, human populations should reach nearly 9 billion by 2050 (8.92 billion, range 7.4–10.6 billion; World Population Prospects 2002; United Nations 2004), and our population is unlikely to stabilize at a size much below 9–11 billion (United Nations 2004) (Figure 1.2). But it is not solely how many of us that is the problem, but how damaging our use of resources has been.

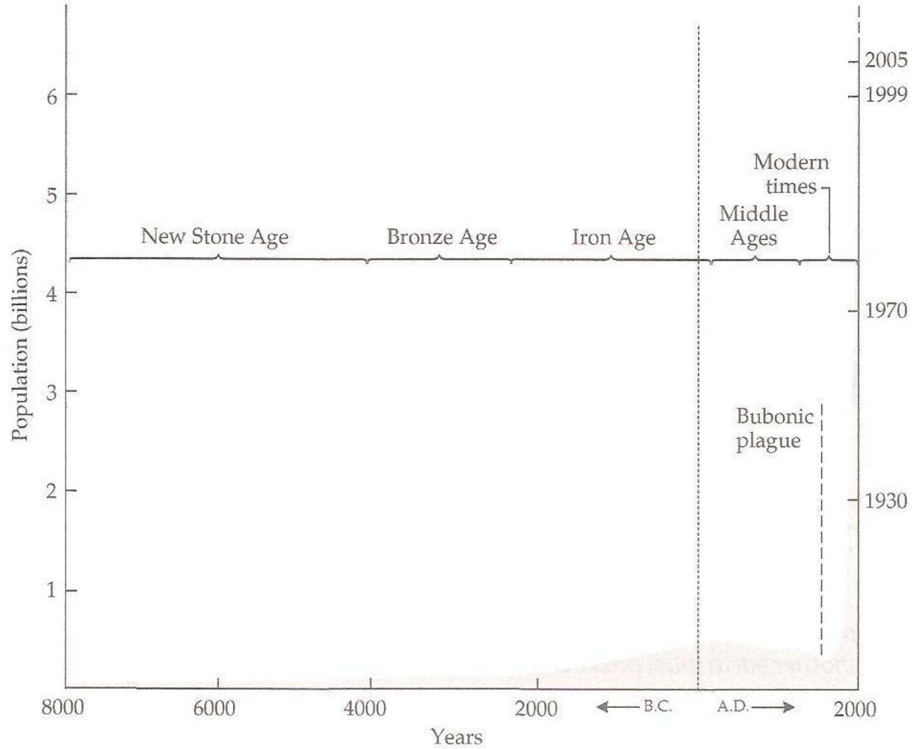

Figure 1.1 Estimated global human population size from the last Ice Age to the present, illustrating the exponential nature of human population growth since the Industrial Revolution. Notice that we reached 6 billion people in 1999 and now number more than 6.4 billion.

The fraction of the world's natural resources consumed by humans is staggering. For example, 35% of productivity from the ocean shelf (Pauly and Christensen 1995), and 60% of freshwater runoff are claimed for our use (Postel et al. 1996). **Net primary productivity (NPP)**—the energy from the sun that is transformed into plant biomass, and that is the base of all food webs—is co-opted to an alarming extent by our species, with estimates ranging from 20% (Imhoff et al. 2004) to 31%–32% globally (these higher estimates include loss of productivity due to land clearing; Vitousek et al 1986; Rojstaczer et al. 2001). Per capita consumption worldwide has increased 3% per year for the past 30 years (Hawken et al. 1999), and will continue to increase in the future.

Importantly, the level of human appropriation of NPP is highly unequal throughout the world, with cities in industrialized nations of North America and Western Europe and the large populations in Southeast Asia consuming up to 60%–80% of their regional NPP (Imhoff et al. 2004). Consumption levels in the U.S. particularly, are unsustainable and vastly higher than those in other countries. For example, with about 4% of the world's population, the U.S. alone accounts for 30% of the

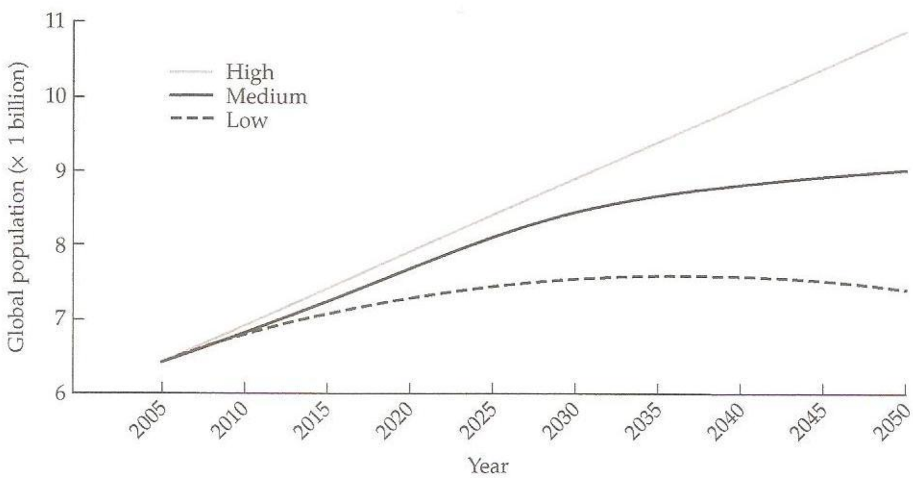

Figure 1.2 United Nations projections for human population growth to 2050. (Data from UN World Population Division, World Population Prospects 2002.)

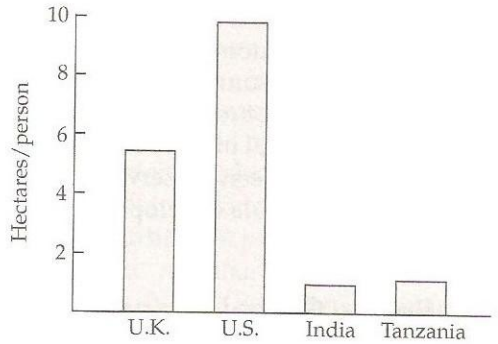

Figure 1.3 Number of global hectares per person needed to support current lifestyles in the U.K., U.S., India, and Tanzania. (Modified from World Wildlife Fund 2003.)

world's daily oil consumption (U.S. Department of Energy 2002), or 250 times as much as India, which has about a sixth of the world's population (Myers 1987). As some less industrialized, but more densely populated countries, such as China, adopt cultural consumptive habits more similar to the U.S., the increasing demands will be enormous and unsustainable.

To help place these impacts in perspective, several studies estimate the "ecological footprint" of our impacts on the globe (e.g., Wackernagel et al. 2002). An ecological footprint calculates how much land and water resources we consume to grow our food, support our lifestyles, and assimilate our wastes. The aggregate portrait is sobering—beginning in the mid-1970's our consumption patterns exceeded Earth's annual production capacity, and our demands continue to grow due to ever-increasing demands for energy, food, and forests (Figure 1.3). A number of footprint calculators are available for individuals to get a rough estimate of their own impacts, and compare their consumption rates with those elsewhere in the world (e.g., at www.myfootprint.org). Many countries and local communities are using these indices for public education and regional planning to encourage reductions in resource use. These indices indicate that it would take four Earths to support the world's population at the level of consumption typical of the U.S. (Wilson 2002).

A final compelling portrait of our "human footprint" was recently produced that shows that more than 83% of Earth's surface bears the imprint of our activities (Sanderson et al. 2002). By overlaying datasets depicting human population density, land use data showing degree of transformation from natural habitats to built up areas, road densities and other means of access to natural areas, and networks of electrical power across the globe, Sanderson and his colleagues were able to provide a more tangible map of our impacts that is neither aggregated as the ecological footprint calculations are, nor restricted to impacts on NPP. The map shows that 83% of the land surface is influenced by one or more of the following: human population density greater than $10/km^2$, agricultural land use, built up areas, access within 15 km of a road, major river or coast, and night-time light bright enough to be picked up by satellite sensors (Figure 1.4). Further, fertile lands that can grow wheat, rice, or maize are almost entirely transformed (98%; Sanderson et al. 2002).

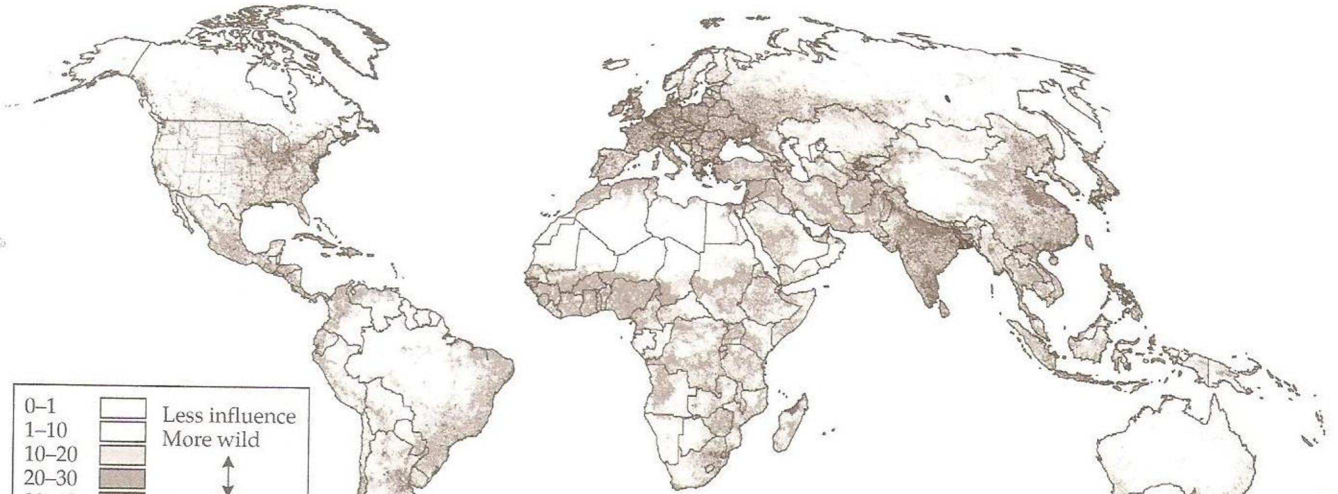

Figure 1.4 Map of the human footprint. Darker regions have borne a greater impact from human development than lighter regions. (From Sanderson et al. 2002 © American Institute of Biological Sciences.)

In summary, we have arrived at the age where human influences predominate across the globe—what some have termed the "Anthropocene" era of Earth (Steffen and Tyson 2001). Although the enormity of this realization and the seeming inevitability of human consumption patterns and population growth outstripping our planet's resources can easily lead to a feeling of helplessness and apathy in the face of so much destruction, there are reasons for optimism.

First, world population growth rates have slowed substantially in the last three decades, and a number of countries were able to significantly lower their population growth rates in a short period of time. Examples include Costa Rica, Cuba, Mexico, Venezuela, and Thailand. Most European countries, such as Hungary and West Germany, have even had periods of negative growth in the past few decades. Birth rates are high where family survival depends on being successful in an unskilled and uneducated labor pool, that is, where there are strong economic incentives for large families. The corollary is that education and the appropriate kinds of economic development can greatly reduce population growth rates. This insight should give us hope that equitable and sustainable development will reduce population growth while relieving intense poverty, and also help preserve biodiversity.

Second, in addition to encouraging signs of slowing human population growth, we all have the potential to change how much and what we consume. In developing countries the expansion of highly commercialized agriculture and forestry has displaced the rural poor into city slums or onto steep hillsides and other ecologically fragile areas. In the industrialized world, the wealthiest nations consume a disproportionate share of global resources, and produce the most waste. These patterns are reversible, given enough will.

For example, the U.S. is currently the largest consumer of energy and producer of greenhouse gases. Politicians and citizens of the U.S. are often worried that any significant efforts to reduce consumption of energy and greenhouse gas emissions would cause a sharp decrease in our "standard of living," and thus are cautious about reversing our consumptive habits. Germany, despite its current economic problems, provides an interesting benchmark. Germans enjoy a high standard of living, but use only about half the amount of energy as U.S. citizens. Further, Germany plans to meet half of its energy needs with low-emission renewable sources by 2050 and to reduce greenhouse gas emissions 21% by 2012. Thus, by following practices similar to Germany's, the U.S. should be able to reduce its consumption of energy and emission of greenhouse gases substantially, without compromising the general standard of living.

The many ways that human population growth rates and consumption patterns can be humanely reduced have several features in common: gender equity, access to education, equitable distribution of rural income, and development of rural economies that are not based on exploitation of natural resources. The take-home message is that we must think broadly about conservation. The **stewardship** of natural biodiversity requires that a strong link be forged between conservation biology and environmentally **sustainable development**.

Responding to Global Change: The Field of Conservation Biology

The field of **conservation biology** is a response by the scientific community to this biodiversity crisis. It is a relatively recent, synthetic field that applies the principles of ecology, biogeography, population genetics, economics, sociology, anthropology, philosophy, and other theoretically based disciplines to the maintenance of biological diversity throughout the world. It is recent in that it is a product of the 1980s, although its roots go back centuries. It is synthetic in that it unites traditionally academic disciplines such as population biology and genetics with the applied traditions of wildlife, fisheries, and land management and allied fields. It is most of all challenging and imperative, in that it is motivated by human-caused global changes that have resulted in the greatest episode of mass extinction since the loss of the dinosaurs 65 million years ago.

Environmentally, we are at the most critical point in the history of humanity, and the current population of students and professionals has a unique place in that history: Of the hundreds of thousands of human generations that ever existed, no previous generation has had to respond to possible annihilation of a large percentage of the species diversity on the planet by humans. Unless humanity acts quickly and in a significant way, the next generation may not have this opportunity. The necessity to act now, not later, makes conservation biology, in every sense of the word, a "crisis discipline" (Soulé 1985); but as Redford and Sanjayan (2003) argue, crises are not excuses for weak science. One of the major developments needed in conservation is a shift from a reactive analysis of each crisis to a proactive science that permits us to anticipate developing crises and to prepare scientifically grounded contingency plans. Beyond this, we also must find the means to lead in the formation of solutions (Redford and Sanjayan 2003).

Many would ask, "What's so new about conservation biology? People have been doing conservation for decades, even centuries." This is true, but conservation biology as a field of endeavor differs in at least three ways. First, it now includes, and has been partially led by, major contributions from theoretically oriented academicians, whose ecological, genetic, and social models are being applied to real-world situations. The unfortunate and false dichotomy of "pure" and "applied" research is finally breaking down, as academic researchers, policy makers, and resource managers have joined intellects, professional experience, and perspectives to address local to global conservation problems.

Second, much of traditional conservation was rooted in an economic, **utilitarian** philosophy whose primary motivation was to maintain high yields of selected species for harvest. Nature was seen as providing benefits to people, mostly from Western nations, through highly visible, selected components such as deer, trout, minerals, or timber, and was managed for maximization of a single or a few species, a small subset of the huge diversity of nature. Conservation biology views all of nature's diversity as important and having inherent value. With this perspective, management has been directed primarily toward stewardship of the world's biodiversity and natural ecosystems, rather than toward management of single species only for our benefit. Four detailed perspectives on the field of conservation biology are offered in essays in this chapter from academic (Essay 1.1 by Erica Fleishman), government agency (Essay 1.2 by Jamie M. Clark), nongovernmental organization, or NGO (Essay 1.3 by Kathryn S. Fuller), and private landowner (Essay 1.4 by Bill McDonald) viewpoints.

Conservation biologists recognize that diverse and functioning ecosystems are critical not only to the maintenance of the few species we harvest, but also to perpetuation of the nearly limitless variety of life forms of which we know little or nothing. The conservationist realizes that intact and functioning ecosystems are also important as life-support systems for the planet, and are critical to our own continued survival and well-being as a species (Odum 1989; Daily 1997).

Third, conservation biology fully recognizes and embraces the contributions that need to be made by nonbiologists to the conservation of biodiversity. In particular, the social sciences, economics, and political sciences may ultimately have more impact on real advances or losses in conservation than the biological sciences. Unless major changes can be made in the way that humanity does business with the natural world, and in humanity's destructive patterns of population growth and resource consumption, it would appear that much of our biological knowledge of conservation will be rendered useless under the sheer weight of the human presence.

A goal of conservation biology is to understand natural ecological systems well enough to maintain their diversity in the face of an exploding human population that has fragmented, simplified, homogenized, and destroyed many ecosystems. Thus, conservation biology tries to provide the basis for intelligent and informed management of highly disrupted ecosystems.

In 1965, the ecologist G. Evelyn Hutchinson described the natural world as an "ecological theater" serving as a stage for an "evolutionary play." Perhaps no better metaphor sums up the mission of conservation biology: to retain the actors in that evolutionary play and the ecological stage on which it is performed. Conservation biology strives to maintain the diversity of genes, populations, species, habitats, ecosystems, and landscapes, and the processes normally carried out by them, such as natural selection, biogeochemical cycling, photosynthesis, energy transfer, and hydrologic cycles. It is a dynamic play, with players and action on many different spatial and temporal scales, old actors disappearing and new ones arriving. But the play ultimately comes down to one thing: dynamic evolutionary processes in a changing ecological background. Conservation biology attempts to keep those normal evolutionary processes working within a functioning ecological setting.

A Brief History of Conservation Biology

The global effort to conserve and protect the natural environment is a recent phenomenon, though efforts to conserve economically important natural resources have a long history. Although we may think of environmental destruction as a product of recent times—and certainly the scale of contemporary destruction is unprecedented—significant environmental degradation has always accompanied humankind (Chapters 3 and 6). Prehistoric humans caused extinctions through overexploitation, habitat modification, and species introductions, and often changed ecosystems drastically through burning, clearing, and cultivation (Chapter 3).

In the classical Greek period, Aristotle commented on the widespread destruction of forests in the Baltic region. At the same time in southern Asia, forests were felled to meet the growing need for timber to build trading ships to serve expanding mercantile centers such as Constantinople (now Istanbul). The barren landscapes that we associate with much of Turkey, Syria, Iraq, and Iran are unnatural deserts resulting from massive exploitation of fragile woodlands. Indeed, this part of Asia had been known in earlier times as the "land of perpetual shade." The Mediterranean region of Italy and Greece was likewise heavily wooded before human settlement.

Diamond (1992) argues that virtually wherever humans have settled, environmental destruction has been the rule; he and others (e.g., Redford 1992) largely debunk the notion of the "noble savage," primitive but wise peoples who had great concern for natural resources. In the humid Tropics, early agrarian societies dealt with declining resources by moving when yields

ESSAY 1.1

A Perspective on the Role of Academia in Conservation Biology

Permeable Walls in the Ivory Tower

Erica Fleishman, *Stanford University*

Academia esteems the growth and exchange of ideas and information. By sanctioning the pursuit of knowledge for its own sake, academic institutions allow conservation science to evolve and flourish. Yet academic conventions also can hinder application of conservation science. Accordingly, many action-oriented conservation biologists use academia as a base camp rather than a fixed residence. We value the autonomy academia grants us to formulate and evaluate theory, but recognize that theory alone cannot solve most conservation challenges.

Like it or not, conservation and land use decisions are not based strictly on science. Trade-offs between ecological, social, and economic criteria are inevitable and often necessary. Any science that enters the decision-making process, however, must be objective and reliable, with uncertainties articulated fully. High standards of scientific quality increase the probability that a conservation strategy will be successful once implemented. High standards also enhance the credibility of science in the eyes of managers, politicians, and the public. Consequently, I believe that conservation biologists in academia have three primary responsibilities. First, we must ensure that our scientific assumptions, methods, and inferences are clear and justified. Second, we must direct our science toward the needs of practitioners and decision-makers. Third, we must advocate—by deeds, not dictates—the relevance of science for real-world conservation.

Many disciplines are germane to conservation efforts in the twenty-first century. Academia provides an open forum for interaction among biological, physical, and social scientists, historians, legal scholars, and experts in other fields. Multidisciplinary collaborations unite depth with breadth, and frequently generate creative solutions to contemporary management challenges. The emergence of predictive approaches to conservation planning, for example, is largely due to partnerships among ecologists, geographers, and statisticians.

Scientists today have ample field and analytic techniques to identify and explain observed distributions of species and their habitats. Planning for the future, however, demands that we consider how current patterns may respond to different types of environmental and social change. We also must evaluate whether and how humans realistically can affect those alternative outcomes. Emerging predictive approaches are statistically robust and practical, with flexibility to consider economic and social priorities. Academia's characteristic intellectual freedom encourages development of scientific tools that incorporate both ecological and human dimensions of conservation.

In academia, research and teaching are intertwined. Like many of my colleagues, I can testify to the influence of mentors throughout my education who encouraged my interests and stood as examples of dedication to science and service. Because conservation biology emerged as a distinct field in the late 1980s, just one generation has been trained formally as conservation biologists. But as universities and colleges develop synthetic programs in conservation biology, students still need grounding in the conceptual and empirical traditions from which conservation biology emerged. Rapid responses to many environmental crises are possible only because we can draw from decades and even centuries of careful research in disciplines such as evolution, landscape ecology, and population biology. We must bear in mind that overlooking past contributions is not only disingenuous, but wastes time that we frankly don't have.

Because most students are unlikely to pursue careers in resource sciences, conservation biologists in academia have a pivotal opportunity to educate the general public about biological diversity and its relationship to land use. We also can cultivate scientific literacy within society at large by illustrating how critical thinking—in essence, confronting assumptions or hypotheses with data—can be applied to any situation that benefits from informed assessment and reaction.

Moreover, academia increasingly is appreciating the importance of outreach. As a result, colleges and universities are making concerted efforts to train both students and professors to connect more openly with the media. As communication improves, conservation biologists are realizing that the challenges of balancing objectivity and opinion, and of capturing an audience without compromising the facts, are inherent to both science and journalism. Several formal programs (some based at universities, some in partnership with museums, aquaria, or other educational institutions) have been founded on the principle that the academic voice is a vital component to societal debates about the future of all levels of biological diversity. Such programs provide rigorous training to both early and later-career conservation biologists in the hope that all will become more effective communicators whether they are interacting with corporations or with reporters.

To inform or influence management and policy, it is essential to engage in active dialogue with those making decisions on the ground. Conservation science is far more likely to be integrated into the management process when academics make the effort to understand the everyday opportunities and constraints of practitioners. Publication is an essential part of the scientific process. Publication furnishes access to information, at least some degree of quality assurance, and validation by a knowledgeable community of scientific peers. But because relatively few managers have time or desire to read journal articles, appending "conservation recommendations" or "conservation implications" to a manuscript has little real impact. Instead, academics must work directly with practitioners, emphasizing that cooperative research will be truly applicable to management only when practitioners define their objectives and management alternatives honestly and explicitly. For example, academics need to be far more vocal in explaining that even the most exacting monitoring plan has limited value if data are not used to guide work on the ground. Academics must work closely with agencies and stakeholders to evaluate what environmental changes will trigger changes in management, and what those management changes might be.

Within our home institutions, academics need to advocate modification of the standard reward structure to facilitate communication with practitioners and, by extension, to build conservation capacity. Academia typically recognizes publication as a researcher's greatest achievement—and preferably publications with high "impact," as measured by number of citations in other publications. This metric of accomplishment is unambiguous and equitable, but its correlation with conservation action arguably is weak for the reasons described earlier. Thus, in addition to publication and teaching, academia should reward meaningful partnerships with resource professionals in the public and private sectors. How can we affect such changes? Junior researchers can work to include nontraditional measures of success in their employment contracts and performance reviews. Senior researchers, meanwhile, can exert their influence as department heads or as leaders of new environmental initiatives.

From an academic base, conservation biologists have considerable latitude to collaborate with other academics, managers, and local communities. Especially before they have become well established, some academics fear they will lose professional integrity by communicating freely with industry representatives or grassroots environmental organizations. Their concern is not entirely without justification. Personally, I think the potential benefits of accepting any good-faith invitation to participate in tangible conservation efforts far outweigh the potential risks. Conservation biologists cannot expect agencies and the public to heed science if we perpetuate barriers between academia and the policy process. This certainly does not mean that we should compromise our scientific principles. Conservation biologists must resist pressure to misrepresent science even if doing so might promote certain conservation objectives. Likewise, misrepresentations of science by others must be corrected promptly and, if necessary, publicly. In 2004, the Society for Conservation Biology developed a code of ethics to better equip its members around the world to grapple with ethical dilemmas. Among other things, the code encourages all conservation professionals to volunteer their services for the public good at a level appropriate to their financial abilities. The code also emphasizes responsibilities to human welfare and social equity.

Academia can be the best of both worlds. Many conservation biologists chose their career because they are fascinated by the natural world and want to protect its integrity. Thanks to laboratory facilities, field stations, sabbaticals, library networks, and other advantages, academics typically can spend a portion of their time conducting research and communicating their enthusiasm to the next generation of conservation professionals. At the same time, we can reach out to colleagues and communities whose management concerns are literal and immediate. With the freedom of academia comes the responsibility to ensure that, as the paradigms of conservation biology shift to meet new conservation challenges, so do the walls of the ivory tower. ■

---

began to drop and local game became scarce, an apparently sustainable strategy given enough land base. Yet, even these shifting cultivators drove species to extinction, and changed the character of natural communities. Many, if not most societies have had some lasting, destructive impact on the natural world.

However, some societies have certainly minimized their environmental influences and lived in a more sustainable fashion than most. Some shifting cultivators practiced, and some still practice, forms of conservation management. In many tropical regions, complex tree gardens helped stabilize land use (see Carroll 1990 for examples), and some shifting cultivators practiced a kind of management of natural succession. Today, in "Dammar" agroforestry in Sumatra, for example, natural forest plots are converted over a period of 10–20 years into complex modified forests based primarily on dammar (*Shorea javanica*), a tree that is tapped for resins, and other economically important native trees (Mary and Michon 1987). The plots are structurally similar to natural successional plots and likely help support regional biodiversity. In terms of financial returns, Dammar agroforestry outperforms rubber plantations, cinnamon/coffee polyculture, and rubber agroforestry. Compared to these systems, Dammar agroforestry also sequesters more carbon and shelters more biodiversity. Indeed, Dammar agroforestry contains about half of the bird and plant species found in primary forest (Ginoga et al. 2002). Although we may think of conservation management as a modern Western notion, management of natural resources has been practiced in many other cultures, often for much longer periods (Figure 1.5).

We would be remiss, however, if we failed to point out the fragility of these traditional systems in the modern, interconnected global marketplace. While shifting cultivation may be sustainable over a large area, it is not when people are confined to small indigenous reserves. As smaller indigenous cultures become connected with modern societies, their choices and practices change, often toward less sustainable practices. To continue with the Dammar example, the practice is disappearing in one region for two unexpected reasons. First, the establishment of Burkit National Park appropriated a major portion of Dammar forestry land and put severe constraints on the use of the remaining land. In particular, the long fallow period needed became increasingly difficult to accommodate. Second, a growing urban market created great demand for rice and, to a lesser extent, coffee and cloves. In response to these two factors, Dammar agroforestry around Burkit National Park has

Figure 1.5 Highly diverse agroforestry systems, such as the Dammar system from Indonesia, can be found in many tropical regions. This photograph shows a similar agroforestry system from southeastern Mexico, locally known as a "huerto," or tree-garden. These traditional agroforestry systems of mixed, cultivated perennials are structurally similar to old, second-growth natural forests, and may contain nearly as many tree species per hectare. (Photograph by C. R. Carroll.)

been largely replaced by dryland rice and coffee cultivation.

Nevertheless, Dammar agroforestry remains a viable agroforestry system when the land base is adequate. The contribution of Dammar agroforestry to both human welfare and biodiversity conservation has been recognized, and the practices are now regarded as a significant contributor to the United Nations Millennium Development Goals (Garrity 2004).

For many centuries, societies recognized and worked to counteract some of the harm caused by overexploitation of species and lands. In Europe, where most land was held by royalty or the very wealthy, early conservation efforts took the form of private game management and maintenance of royal preserves and private manor lands. Yet, until the eighteenth and nineteenth centuries, little notice was given to problems of the **commons**, the public lands. As a consequence, exploitation of these common-use resources led to the deforestation of most of Europe by the early eighteenth century. This occurred even earlier in Great Britain, where many of the native forests were destroyed by the twelfth century (McKibben 1989); the demand for charcoal to supply home heating and industrial needs led to virtual elimination of the remaining public forests by the late eighteenth century. Similarly, in Asia, conservation efforts were game-oriented and largely restricted to the private lands of the privileged. An artist's early rendition of a forest and pastoral scene in China juxtaposed against a later photograph of the same place, which depicted an eroded and barren landscape, is said to have been the telling argument made to the Theodore Roosevelt administration by forester Gifford Pinchot in his successful campaign to establish the U.S. Forest Service in 1905.

Since the end of the nineteenth and throughout the twentieth century, conservation began to become an important goal for many nations, and broadened from efforts to safeguard important game species to those intended to protect all of biodiversity both within a nation, and across borders. To illustrate this progression, we will describe changes in the nature of conservation in the U.S.

Conservation in the United States

Europeans colonizing America found a landscape that, by comparison with a highly exploited Europe, must have seemed pristine. Aboriginal peoples had exploited natural resources and driven some species to extinction, but their low population densities and lack of technologies for widespread devastation prevented wholesale destruction. Native Americans apparently made extensive use of fire to manage lands for both agriculture and game. Some historians argue that Atlantic coastal lands cleared by Native Americans became important colonization sites for European settlers and helped them survive their first winters (Russell 1976).

During the colonial period, North American forests were extensively exploited for lumber, ship masts, naval stores (gum and turpentine), and charcoal for heating. Huge tracts were cleared for agriculture. Demand for forest products in Europe and domestic demand by a rapidly growing population were eagerly met by exploiting the seemingly endless forests. Later, forests were again called upon to provide lumber for vast railroad networks and building construction as the nation expanded westward. In coastal areas, salt marshes were harvested for salt hay (*Spartina*) to feed cattle before the opening of the prairies to grain farming.

The value of forests as an economic resource was not the only philosophical perspective held by the colonists, however. Religious attitudes of some groups, especially the Puritans, held that the forest was the abode of the devil. This is perhaps not an unfamiliar attitude even today, for many children's stories place witches, trolls, and goblins in deep, dark forests, and many otherwise reasonable adults are more frightened in a forest than in the heart of a large city with high crime rates.

Thus, the forests were beset by increasing economic demands and were perceived to be endless and vaguely evil—hardly a nourishing environment for conservation. Conservation did, of course, develop in North America, but it required several centuries after initial European colonization to become firmly established. Perhaps it was necessary first to develop a significant population whose livelihood was not intimately tied to forest exploitation.

American conservation efforts can be traced to three philosophical movements, two of the nineteenth century and one of the twentieth (Callicott 1990). The **Romantic-Transcendental Conservation Ethic** was derived from the writings of Ralph Waldo Emerson and Henry David Thoreau in the East, and John Muir in the West. Emerson and Thoreau were the first prominent North American writers to argue, in the mid-1800s, that nature has uses other than human economic gain. Specifically, they spoke of nature in a quasi-religious sense, as a temple in which to commune with and appreciate the works of God. Nature was seen as a place to cleanse and refresh the human soul, away from the tarnishings of civilization. This was the philosophical and aesthetic position that Muir used as he argued for a national movement to preserve nature in its wild and pristine state, and condemned its destruction for material and economic gain. John Muir's movement flourishes today in the form of many citizen conservation groups; his direct organizational legacy is the Sierra Club.

This noneconomic view was countered by the so-called **Resource Conservation Ethic**, made popular by the forester Gifford Pinchot at the turn of the twentieth century. His was an approach to nature based in the popular utilitarian philosophy of John Stuart Mill and his followers. Pinchot saw only "natural resources" in nature and adopted the motto, "the greatest good of the greatest number for the longest time" (Pinchot 1947). Nature, to Pinchot, was an assortment of components that were either useful, useless, or noxious to people. Note the **anthropocentric** valuing of nature, not because it is part of "God's design" (as per the Romantic-Transcendentalists), but because natural resources feed the economic machine and contribute to the material quality of life. Pinchot (1947) once stated that "the first great fact about conservation is that it stands for development."

Pinchot's approach to conservation stressed equity—a fair distribution of resources among consumers, both present and future—and efficiency, or lack of waste. This led to adoption of the **multiple-use** concept for the nation's lands and waters, which remains the mandate of the U.S. Forest Service and Bureau of Land Management. Under multiple use, many different uses of the land are attempted simultaneously, such as logging, grazing, wilderness preservation, recreation, and watershed protection. Because a market economy may or may not be efficient and has little to do with equity, government regulation or outright public ownership of resources was deemed necessary to develop and enforce conservation policy.

These two movements thus created a schism, with the preservationists (Muir, Emerson, Thoreau) advocating pure wilderness and a spiritual appreciation for nature, and conservationists (Pinchot) adopting a resource-based, utilitarian view of the world. A third movement, born of this century, emerged with the development of evolutionary ecology. This **Evolutionary-Ecological Land Ethic** was developed by Aldo Leopold in his classic essays, published shortly after his death in *A Sand County Almanac* (1949), and in other writings. Leopold was educated in the Pinchot tradition of resource-based conservation, but later saw it as inadequate and scientifically inaccurate. The development of ecology and evolution as scholarly disciplines conclusively demonstrated that nature was not a simple collection of independent parts, some useful and others to be discarded, but a complicated and integrated system of interdependent processes and components, something like a fine Swiss watch. There are really only a few parts of a watch that appear to be of direct utility to its owner, namely, the hour, second, and minute hands (back when watches had hands). However, proper functioning of these parts depends on dozens of unseen components that must all function well and together. Leopold saw ecosystems in this context, and this is the context in which modern ecology first developed. This **equilibrium** view was subsequently replaced by a dynamic, **nonequilibrium** ecological perspective, discussed later in this chapter. Nevertheless, the Leopold land ethic remains as the philosophical foundation for conservation biology.

Much of modern conservation is based on various mixtures of these three philosophies. The Resource Conservation Ethic of the late nineteenth century is still a dominant paradigm followed by public resource agencies such as the U.S. Forest Service, under which U.S. forest tracts are seen as economic resources to be managed for multiple human uses. The Romantic-Transcendental Conservation Ethic, though more typically without the overt religious rationale of its early proponents, is the basis for activism by many private conservation organizations throughout the world, whose goals are to save natural areas in a pristine state for their inherent value. This difference has resulted in repeated confrontations among so-called "special interest groups."

Leopold's Evolutionary-Ecological Land Ethic is the most biologically sensible and comprehensive of any approach to nature and should serve as the philosophical basis for most decisions affecting biodiversity. It is the only system that can provide even moderately useful predictions about our effects on the natural world, but it is still only part of the total decision-making process; the economic, spiritual, and social needs of people must also be met. It is curious that management decisions concerning natural areas can be made without recourse to evolutionary ecology, yet this still routinely happens in many resource agencies. Similarly, it would be a fruitless, counterproductive, and ethically suspect exercise to base comprehensive land use decisions solely on evolutionary ecology without regard to the people who will be affected.

Most natural areas today are remnant patches of formerly contiguous habitats in landscapes dominated by human economic endeavors (Figure 1.6). The biological activity within any one of these natural areas is strongly dependent on what happens outside its boundaries. Any long-term security for a natural area will come about only when it is accepted as an integral and contributing part of broader economic and development planning. Just as the Evolutionary-Ecological Land Ethic grew out of traditional disciplines to meet the emerging crises in biodiversity, so also are the traditional disciplines of resource economics and anthropology giving rise to new interdisciplinary views, sometimes called "ecological economics" and "ecological anthropology," views that stress long-term environmental sustainability.

Modern conservation biology: A synthesis

Modern conservation biology has sought to replace both the extreme Romantic Preservationist and the exploitative utilitarian philosophies of the nineteenth century with a balanced approach that looks to an ethic of stewardship for philosophical guidance, and a melding of natural and social sciences for theory and practice. This interdisciplinary context is necessary for conservation biology to flourish and make contributions to a sustainable biosphere.

By the 1960s and into the 1980s, it was becoming painfully obvious to many ecologists that prime ecosystems throughout the world, including their favorite study sites, were disappearing rapidly. Biodiversity, the outcome of millions of years of the evolutionary process, was being carelessly discarded, and, in some cases, willfully destroyed. Previous conservation efforts, while focusing on important components of nature such as large vertebrates, soils, or water, still had not embraced the intricacies of complex ecosystem function and the importance of all the "minor," less charismatic, biotic components such as insects, nematodes, fungi, and bacteria. It was time to change this attitude, and many people began writing on these subjects (e.g., Dasmann 1959, Ehrenfeld 1970, Soulé and Wilcox 1980, Frankel and Soulé 1981, and Schonewald-Cox et al. 1983). These books helped to lay the groundwork for today's conser-

Figure 1.6 An aerial photograph showing a mixed natural and human-dominated landscape in South Carolina. Lighter areas are argicultural fields and human housing developments, darker patches are forests, fields, and streams. (Photograph courtesy of Savannah River Ecological Laboratory.)

ESSAY 1.2

Working with U.S. Government Agencies in Biodiversity Conservation

Jamie Rappaport Clark, *Executive Vice President, Defenders of Wildlife, and Former Director, U.S. Fish and Wildlife Service*

Over the years, biology has furthered our understanding of the interconnectedness and interdependencies that keep ecosystems functioning. This increased understanding has validated the inherent value of nature and supported the realization that a vibrant economy ultimately depends on a healthy environment. Public awareness and support of environmental protection led to the passage of important environmental laws such as the Endangered Species Act, the National Environmental Policy Act, the Clean Water Act, and the Clean Air Act.

Protecting the environment remains a tricky balancing act. Most people want economic development to be compatible with environmental protection and they expect government to reconcile conflicts between the two.

In many situations, however, government actually causes this conflict through contradictory mandates of their environmental and land management agencies. The U.S. Forest Service conserves our nation's forest resources, but also allows for the harvesting of timber. The National Marine Fisheries Service conserves living marine resources off America's shores, but is also charged with maintaining viable commercial fisheries. The National Park Service's mission includes not only preserving the ecological and historical integrity of parks, but also offering quality public recreational opportunities. How do you balance the beauty and diversity of these public lands while at the same time ensuring a safe and memorable experience for the nearly three hundred million visitors to our national parks?

To cope with the duality of these mandates, many government agencies have explored the practical implementation of concepts like sustainability and ecosystem management. Both of these concepts, however, are still only vaguely defined. From the resource manager's perspective, they need to be able to say authoritatively with the support of sound science that they have identified the limit on how much human interaction an ecosystem can sustain. To date, such limits still have not been defined for most cases.

Conservation biology can help us identify those thresholds. Presently, academicians in this fast evolving field are discussing what constitutes a sustainable level of human resource interaction and whether we can recognize it and manage for it. Similar discussions are taking place with respect to ecosystem management. Meanwhile, natural resource managers, through the process of adaptive management, are doing their best to put these ideas into practice. While doing so, they are confronted with real-world, real-life constraints. Limited funding, staffing, and resources are some of the most challenging obstacles affecting all natural resource management agencies. The politicization of natural resources decision-making is causing increasing conflicts at all levels of government. Additionally, each agency is also faced with a set of constraints unique to the resources under its care.

The U.S. Fish and Wildlife Service's (USFWS) mission is to manage fish, wildlife, and plants and their habitats. To carry out this mission, the agency is often guided by statutory deadlines. For example, under the Endangered Species Act, the USFWS must make decisions (listing determinations, consultation decisions) based on the best *available* science. For practical and statutory compliance reasons, the USFWS does not have the luxury of waiting for better science or more science to become available. There is often inherent internal conflict regarding what constitutes the best available science and whether it is complete enough to make informed decisions.

Wildlife trade issues, for instance, require the USFWS to examine not only the status of a species like the African elephant (*Loxodonta africana*), its habitat, and its interaction with other species, but also to determine who wants to trade ivory, and the social and economic situations that drive the ivory trade. Decisions to list a species as threatened or endangered take into account not only population size, but also the degree of threat, based on factors like disease, habitat loss, and commercial use. We need to understand all these factors if we are to make smart choices about how to best conserve species and their habitats.

To achieve conservation success, natural resource managers must forge partnerships with all segments of society that are in play in a given region. This point was clearly brought home in the Pacific Northwest with the Northern Spotted Owl controversy of the early 1990s. A landscape challenge as complex as conserving resources in forested lands across the Pacific Northwest can be accomplished only with the participation of local communities, industry, private groups, and other government agencies at all levels, including internationally.

Throughout the country, the USFWS is exploring innovative ways to fulfill their conservation mission. They partner with the timber industry to provide habitat for Red-cockaded woodpeckers (*Picoides borealis*) in the southeast, work with ranchers and farmers to restore natural habitat while ensuring continued economic viability for landowners, and they strategize with expanding municipalities like San Diego to make sure their development plans remain consistent with the conservation of imperiled species. In forging such partnerships, the USFWS faces two real-world constraints: (1) the incomplete knowledge of ecosystem functions and processes, and (2) the ever increasing societal demands on the landscape that cannot be ignored.

Enter the conservation biologist, who will have a significant role in the future direction and management of our nation's natural heritage. To make the best decisions possible, resource managers require solid, dependable information and sound, science-based approaches to guide them on decisions on everything from local planning and zoning initiatives to state and national environmental laws and compliance. As government agencies experiment more with approaches to ecosystem management, they will need more options to explore. Managers will need a better understanding of metapopulation dynamics. They will require an understanding of the scientific principles and practical concepts for designing future refuges. To connect protected lands, resource managers will need to better understand the theories and application of linking fragmented habitats. All of these challenges are the very issues that the science of conservation biology seeks to address.

Many of the resource agencies will use this evolving science to help in prioritizing research needs. Conservation biologists can help decide where to focus limited resources by identifying the circumstances and the species that most need research initiatives such as genetic or behavioral studies, or population viability analyses. Such tactical research is essential to everyday decision making. Vital to this is the link between ongoing activities, important conservation initiatives, and specific research needs. Conservation biologists can and should play a pivotal role in creating that link.

Providing resource managers the information to make sound decisions is only the beginning. The task of conserving biodiversity is too large and important for just one agency. That is why partnerships are crucial, especially with private landowners. Because private lands are increasingly important for maintenance of biological diversity, we need to do a better job of engaging landowners in conservation issues and opportunities. We need to identify all the stakeholders and invite them to help find a solution that can protect both biodiversity and a sustainable economy. We need to provide our partners with flexibility and certainty in the face of uncertainty about biological processes and human activities.

With this in mind, the USFWS developed a suite of management tools to accomplish this task, including Habitat Conservation Plans, Candidate Conservation Agreements, and Safe Harbor Agreements. In each case, an agreement takes some of the risk of proactive conservation efforts away from the landowner and offers them some degree of security and certainty. Central to all is the concept of adaptive management, which acknowledges the evolving nature of scientific knowledge.

The USFWS often relies on conservation biologists to identify the areas of uncertainty and to help address them by devising a range of actions along with a feedback loop to monitor progress. As more public–private partnerships take wing, conservation biologists will need to help natural resource managers further develop and implement adaptive management principles, and to devise other means to achieve conservation goals. Collaborative, comprehensive efforts, with a focus on the concepts of basic ecology, landscape conservation, and restoration, are the only way we are going to successfully tackle the challenges facing us in this new century.

Biodiversity conservation requires everyone to assume some of the responsibility. The overwhelming challenge of invasive alien species is a case in point. According to a Cornell University study, invasive species inflict damages of $138 billion annually on the U.S. Further, they are contributing to the decline of 35 percent of threatened and endangered species. These biological invaders have infested more than 100 million acres of the U.S. and are spreading across the nation at a rate of 3 million acres per year.

To address this challenge, we need to broaden awareness of the ecological consequences of foreign species. We need to enlist a broader constituency. Boaters can help prevent the spread of zebra mussels (*Dreissena polymorpha*) from one body of water to another by checking for biological hitchhikers whenever they take their vessels out of the water. To stem nonnative species invasions, increased efforts toward prevention, eradication, and control mechanisms are essential. We are currently relying mostly on biological controls and pesticides, both of which can be problematic. The next generation of conservation biologists must help find better ways. Further, as global trade increases, we need sound science-based risk analysis to identify the potential problems caused by new species invading our borders.

Conservation biologists are also finding themselves increasingly involved with captive propagation. This wildlife recovery method has proven useful as an emergency tool where the original threats to a species in the wild are also being mitigated. The USFWS has worked with partners to restore populations of California Condors, Mexican gray wolves, Puerto Rican Parrots, and black-footed ferrets.

For some species, wild populations have fallen so low that the remaining animals are in danger of becoming extremely inbred, a real challenge in addressing the potential for genetic bottlenecks. For the Florida panther (*Puma concolor coryi*), the population had been so reduced that the rate of inbreeding has increased significantly over natural levels. The closest related subspecies, cougars from Texas (*P. c. stanleyana*), were introduced into south Florida to inject diversity into the population's gene pool, with careful attention given to avoid swamping the locally adapted Florida panther genome. This is an area requiring further study and conservation biology is the science best suited to deliver the information wildlife managers need in making the right call in these difficult situations.

The twenty-first century presents formidable challenges. Some scientists believe that the pressures put on ecosystems by society are already causing a new wave of mass extinctions. In many ways we stand at a crossroads. In the final chapter of *Silent Spring*, Rachel Carson wrote "The road we have been traveling is deceptively easy, a smooth superhighway on which we progress with great speed, but at its end lies disaster. The other fork on the road . . . offers our last, our only chance to reach a destination that assures the preservation of our earth." She penned those words in 1962. I believe we still have a chance to change the path we are on. Conservation biologists will play a significant role in determining our success along that path.

As this new century gets underway, conservation biologists have the opportunity to help natural resource managers make a strong case for the preservation of biological diversity and to provide policy makers with the scientific basis and the tools to change the course we're on. I believe we will ultimately be successful and that history will remember this time not for a catastrophic loss of biodiversity but for a heroic choice made by humankind: to value what we leave of the land more than what we build on it.

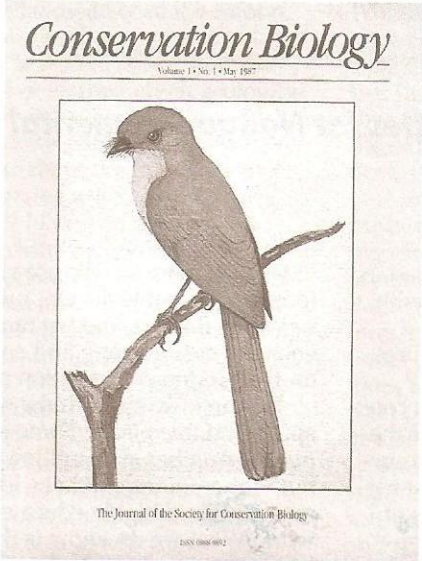

Figure 1.7 The first issue of the journal *Conservation Biology*, published in May 1987. (Photograph courtesy of E. P. Pister.)

vation biology by melding good evolutionary ecology with human resource use, and providing a vision of where modern conservation should go, and they motivated a large cadre of scientists to put conservation at the forefront of their research and personal agendas.

In 1985, the Society for Conservation Biology was formed, a large membership rapidly grew, and a new journal, *Conservation Biology* (Figure 1.7), was developed to complement existing journals such as *Biological Conservation* and *The Journal of Wildlife Management*. More recently, the Society for Conservation Biology launched *Conservation in Practice* in 1999, with the goal of putting conservation science into practice, and conservation practice into science. Thus, in the past two decades, the thrust and outlook of conservation dramatically changed, and continues to change as conservation science matures. From this point forward the field has continued to develop rapidly. Many textbooks and many more professional books on diverse aspects of conservation biology have been produced. The Society for Conservation Biology has grown from a fledgling organization with a small journal to a major international scientific society with multiple publications. And graduate and undergraduate programs in conservation biology have developed in colleges and universities throughout the world.

Students of conservation biology today should be excited to know that the science of conservation is still developing, and needs many bright minds to determine its future directions. Anyone who thinks that much of the work has already been done, and that there is little room left for contributions, does not yet understand the many challenges of conservation biology; hopefully, the following chapters will set that record straight.

A large number of international conservation organizations are active today, as well as numerous national and local organizations, and government organizations at all levels. These conservation groups are responsible for directing public and government attention to particular places and species in need of our help, and developing major approaches to effecting conservation across the globe. Beyond these organizations, groups of citizens are increasingly taking on conservation issues and working to improve the future for their children and grandchildren.

Conservation is undertaken at all levels: by citizens working to restore degraded lands or stop overexploitation of wild species, by local governments regulating land and water uses, by NGOs working toward opportunities for conservation that support local communities, by state and national governments enacting legislation to prevent extinction, and by international agreements designed to curb climate change and the loss of biodiversity worldwide. By knowing more about these activities, we can help push for new actions at levels higher than ourselves, while working within our own communities for positive change.

Guiding Principles for Conservation Biology

Three principles or themes that serve as working **paradigms** for conservation biology will appear repeatedly throughout this book (Table 1.1). A paradigm is "the world view shared by a scientific discipline or community" (Kuhn 1972), or "the family of theories that undergird a discipline" (Pickett et al. 1992). A paradigm underlies, in a very basic way, the approach taken to a discipline, and guides the practitioners of that discipline. We believe these three principles are so basic to conservation practice that they should permeate all aspects of

TABLE 1.1 ***Three Guiding Principles of Conservation Biology***

Principle 1:	Evolution is the basic axiom that unites all of biology. (The evolutionary play)
Principle 2:	The ecological world is dynamic and largely nonequilibrial. (The ecological theater)
Principle 3:	Human presence must be included in conservation planning. (Humans are part of the play)

ESSAY 1.3

The Role of Science in Defining Conservation Priorities for Nongovernmental Organizations (NGOs)

Kathryn S. Fuller, *World Wildlife Fund*

The proposition that science should play a key role in setting conservation priorities seems self-evident: After all, where would conservation *be* without the sciences of biology and ecology? Isn't science the foundation of the environmental movement?

Science indeed lies at the heart of conservation, but the relationship is complex. Understanding how science contributes to conservation requires us to examine a range of disciplines that would once have seemed completely alien to it. Today conservation science increasingly incorporates economics, social science, geography, and knowledge management into the planning process.

A crucial part of that process has been the emergence of the field of conservation biology. The professional membership organization, the Society for Conservation Biology, is now 20 years old, with over 5,000 active members, and the competition to publish in its journal has grown dramatically.

How has science, through the maturing study of conservation biology, influenced the setting of conservation priorities, as practiced by nongovernmental institutions, which are increasingly responsible for moving conservation initiatives forward?

Biological science no longer exclusively sets the boundaries of conservation. This is due in part to the uniquely multidisciplinary nature of modern conservation, which is the product of years of evolving philosophy and practice. My own organization, World Wildlife Fund (WWF), is a useful case study in this evolution. When we began in 1961, we concentrated our efforts on individual species, animals like the Arabian oryx, the rhinoceros, and the giant panda, our organization's symbol. We emphasized scientific research and hands-on fieldwork. The application of the broader principles of conservation biology have forced us to look beyond individual species' requirements, to incorporate ecological processes, environmental change, and most importantly, to protect viable and representative areas of all natural habitats.

The focus on habitats, in turn, led us toward the humans who interact with those habitats and the connection between human poverty and resource destruction. Now, every day, WWF addresses itself to what is perhaps conservation's bitterest irony: Some of the world's poorest people struggle to survive alongside the world's greatest natural treasures. Beyond the borders of parks live people desperate for cropland and firewood. Adjacent to herds of wildlife in Africa are villagers without an adequate source of protein. And around the world is a vastly increasing new category of refugees, fleeing not tyrants but a deteriorating environment.

Clearly, unless we consider economic and social realities we will fail in our efforts to preserve biodiversity in the long term. So WWF seeks ways to marry the preservation of biological diversity with environmentally sound economic development. This transition from "pure" conservation to one that considers both conservation and development means we can no longer closet ourselves behind laboratory doors. We must delve into areas unfamiliar to conservationists, like anthropology, sociology, economics, and political science. And recognizing that the best-designed projects will fail without ongoing funding, we must take on the role of conservation financiers, brokering debt-for-nature swaps and creating new financial mechanisms to leverage our limited resources into lasting change. What we do know from experience in places as different as Nepal, Bhutan, New Guinea, the Guianas, and South Africa is that it is simply a myth that only developed nations can afford to undertake, or are interested in promoting, biodiversity conservation.

Given all this, it might be easy to go on and say that science has less of a claim on today's conservation agenda—fighting for attention as it is with the fields of economics and politics. But that would be a mistake. Because not only does science lie at the heart of conservation, it is now more critical than ever. Science determines our conservation priorities and provides the blueprint. We use various tools—sustainable development, conservation finance, and yet more science—to create strong and enduring on-the-ground conservation networks.

We can only guess at the number of species on this planet. Some estimates put the number at 30 million or more, but with millions still to be identified, most of this is highly educated guesswork. What we do know is that we are losing species at an almost unimaginable rate. The renowned biologist E.O. Wilson says we are on the brink of a catastrophic extinction of species—of a kind unseen since the demise of dinosaurs 65 million years ago.

When confronted with mass extinctions on this scale, the inevitable temptation is to throw up one's hands and ask, "Where to begin?" Science can tell us where to start a path in a rational and comprehensive manner, and equally important, it can help correct our path even as we forge it. Science also provides the kind of foresight that every conservation organization desperately needs—the ability to look ten and twenty years into the future and envision where we need to be.

Of course, setting conservation priorities for our planet will never be simple or straightforward. As a start, we know that tropical moist forests contain at least half of all Earth's species. Tropical forests, especially on islands, are in fact the crucible of modern conservation. Knowing this only takes us so far, however, since it still leaves us with a range of other habitats to incorporate into our planning: tropical dry forests, temperate, Mediterranean, and boreal forests, grasslands, and of course, marine and freshwater systems. But scientists at WWF and elsewhere are working to identify key natural areas featuring exceptional concentrations of endemic species and unique ecological phenomena that are representative of the full measure of biodiversity. By concentrating efforts in these areas where the potential payoffs are greatest, conservationists can respond in a more informed and systematic way to the challenge of preserving biodiversity.

We have learned about the importance of examining ecosystems at large spatial and temporal scales, and the more we have learned about ecological systems, the more we have learned how interconnected they are. We have also learned about the importance of events occurring at large time scales, including El Niño and other natural large-scale disturbances such as fire. Conservation biology has forced us to examine food webs and the far-reaching effects of large predators in ecological systems, and in the case of marine systems, the removal of top predators and the resulting effects on other trophic levels. The combined effect has caused most conservation organizations to think at larger scales beyond the boundaries of individual protected areas—the scales at which most ecological systems operate.

Science can and must contribute to the fruitful mélange of ideas currently circulating in the conservation field. Without the help of science, we cannot hope to tackle the truly foreboding problems facing our planet today—problems that in fact were first identified by scientists: climate change, fragmentation and degradation of habitat, and their result, the loss of biological diversity.

Already, we are seeing exciting and promising new sustainable-use techniques at work: sustainable harvesting of nontimber products like fruits, seeds, medicinal plants, and wild game; agroforestry methods that combine traditional crops with multiple-purpose trees; restoration ecology and watershed protection. Scientific methodologies such as geographic information systems (GIS), remote sensing, decision support systems, and high technology solutions to tracking the movements and dispersal of endangered species continue to revolutionize the field of conservation biology.

Science anchors the economic and political exigencies of modern conservation in intellectual bedrock. Conservation biology has forced us to expand our temporal and spatial reach to fully incorporate today's conservation challenges. Although foundations and endowments encourage scientists to think in small and discrete terms, the problems confronting the world are so massive that scientists must scale their thinking accordingly. The need for solid science to inform decisive action by regional, national, and international nongovernmental organizations and other groups has never been so great. If conservation biologists fail to come up with a long-term vision for what success looks like in all of the biologically important places in the world, surely others who wish to exploit the resources of those regions for short-term gain have their own blueprint for development. Doing good conservation science has never been a more urgent occupation.

---

conservation efforts and should be a presence in any endeavor in the field.

PRINCIPLE 1: EVOLUTIONARY CHANGE The population geneticist Theodosius Dobzhansky once said, "Nothing in biology makes sense except in the light of evolution." Evolution is indeed the single principle that unites all of biology; it is the common tie across all areas of biological thought. Evolution is the only reasonable mechanism able to explain the patterns of biodiversity that we see in the world today; it offers a historical perspective on the dynamics of life. The processes of evolutionary change are the "ground rules" for how the living world operates.

Conservationists would do well to repeatedly recall Hutchinson's metaphor, "the ecological theater and the evolutionary play," discussed earlier. Because conservation issues all lie within the biological arena, evolution should guide their solution. Answers to conservation problems must be developed within an evolutionary framework; to do otherwise would be to fight natural laws (Meffe 1993), a foolish approach that could eventually destroy the endeavor.

The genetic composition of most populations is likely to change over time, whether due to drift in small populations, immigration from other populations, or natural selection (discussed in Chapter 11). From the perspective of conservation biology, the goal is not to stop genetic (and thus evolutionary) change, not to try and conserve the *status quo*, but rather to ensure that populations may continue to respond to environmental change in an adaptive manner.

PRINCIPLE 2: DYNAMIC ECOLOGY The ecological world, the "theater" of evolution, is dynamic and largely nonequilibrial. The classic paradigm in ecology for many years was the "equilibrium paradigm," the idea that ecological systems are in equilibrium, with a definable stable point such as a "climax community." This paradigm implies closed systems with self-regulating structure and function, and embraces the popular "balance of nature" concept. Conservation under this paradigm would be relatively easy: Select pieces of nature for protection, leave them undisturbed, and they will retain their species composition and function indefinitely and in balance. Would that it were so simple!

The past several decades of ecological research have taught us that nature is dynamic (Pickett et al. 1992). The "balance of nature" concept may be aesthetically pleasing, but it is inaccurate and misleading; ecosystems or populations or gene frequencies may appear constant and balanced on some temporal and spatial scales, but other scales soon reveal their dynamic character. This principle applies to ecological structure, such as the number of species in a community, as well as to evolutionary structure, such as characteristics of a particular species. Conservation actions based on a static view of ecology or evolution will misrepresent nature and be less effective than those based on a more dynamic perspective.

The contemporary dominant paradigm in ecology recognizes that ecological systems are generally not in dynamic equilibrium, at least not indefinitely, and have no long-term stable points (Botkin 1990). Regulation of ecological structure and function is often not internally generated; external processes, in the form of natural disturbances such as fires, floods, droughts, storms, earth movement, and outbreaks of diseases or parasites are frequently of overriding importance. Indeed, we now know that biodiversity in ecosystems as different as prairies, temperate and tropical forests, and the intertidal zone are maintained by nonequilibrial processes (Figure 1.8). Ecosystems consist of patches and mosaics of habitat types, not of uniform and clearly categorized communities.

It is important to understand that our emphasis on nonequilibrial processes does not imply that species interactions are ephemeral or unpredictable, and therefore unimportant. Communities are not chaotic assemblages of species; they do have structure. Embedded within all communities are clusters of species that have strong interactions, and in many cases, these interactions have a long evolutionary legacy. Nevertheless, this does not mean that community structure is invariant and that species composition does not change at some scale of space and time. Change at some scale is a universal feature of ecological communities.

Conservation within this paradigm focuses on dynamic processes and physical contexts. An important research goal for conservation biologists is to understand how the interplay between nonequilibrial processes and the hierarchy of species interactions determines commu-

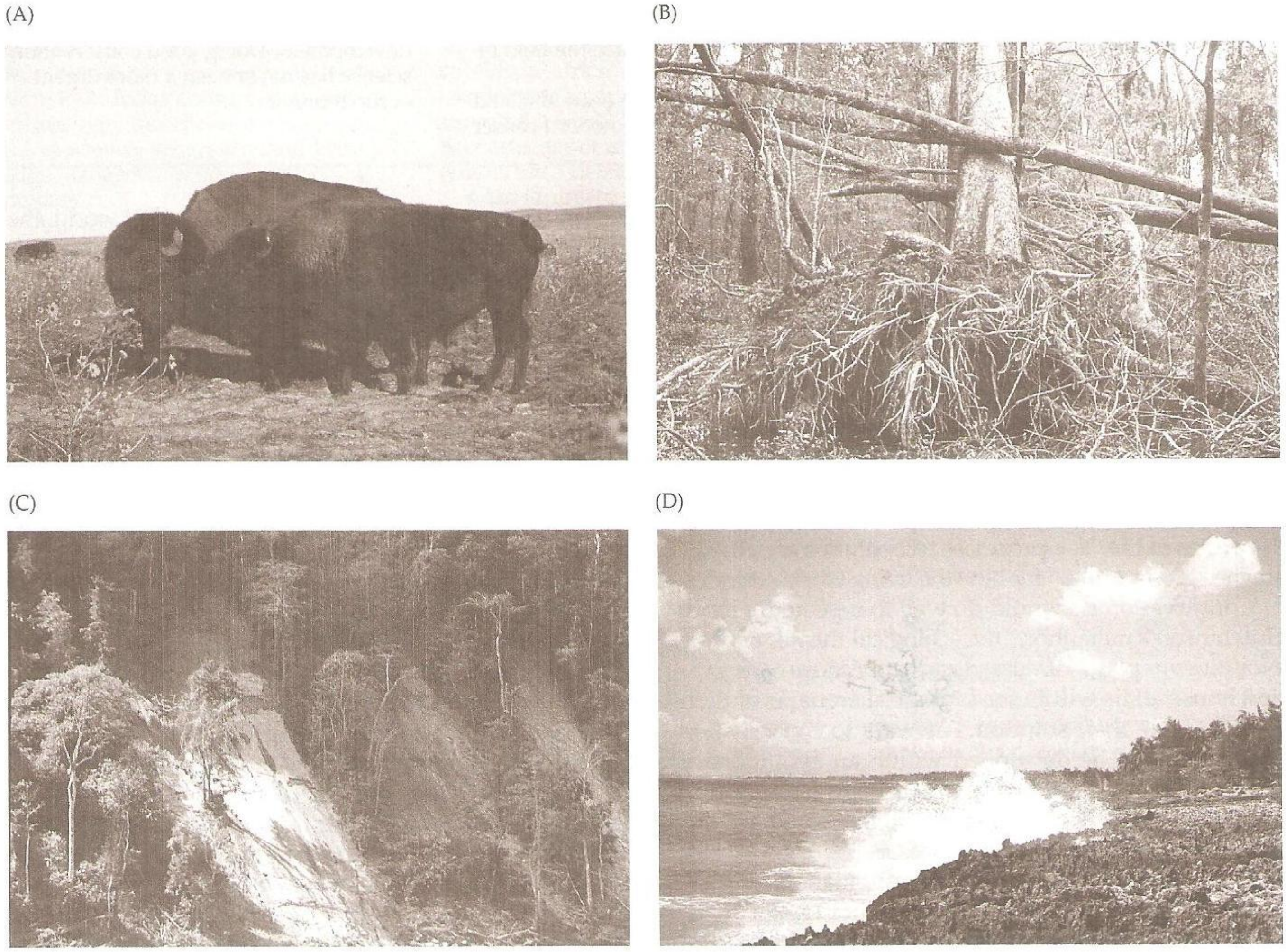

Figure 1.8 Nonequilibrial processes play a major role in most ecosystems. Surface disturbances by bison create openings or "wallows" in prairies (A). Hurricanes and other storms open gaps in both temperate (B) and tropical (C) forests. Wave action (D) and tidal changes on rocky shorelines open up disturbance patches. (A, photograph courtesy of J. Wolfe; B, Congaree Swamp, South Carolina after Hurricane Hugo, 1989, by R. Sharitz; C, lower montane forest in Costa Rica, by C. R. Carroll; D, coral rock in the Dominican Republic, Caribbean Sea, by M. C. Newman.)

nity structure and biodiversity. Ecosystems are open systems with fluxes of species, materials, and energy, and must be understood in the context of their surroundings (Pickett et al. 1992). A further implication is that conservation reserves cannot be treated in isolation, but must be part of larger conservation plans whose design recognizes and accounts for spatial and temporal change (Petraitis et al. 1989; Pickett and Ostfeld 1995).

PRINCIPLE 3: HUMAN PRESENCE Humans are and will continue to be a part of both natural and degraded ecological systems, and their presence must be included in conservation planning. Conservation efforts that attempt to wall off nature and safeguard it from humans will ultimately fail. As discussed in principle 2, ecosystems are open to the exchange of materials and species, and to the flux of energy. Because protected areas are typically surrounded by lands and waters intensively used by humans, it will be impossible to isolate them completely from these outside influences. There is simply no way to "protect" nature from human influences, and those influences must be taken into account in planning efforts. Indeed, isolating protected areas may carry its own liability in terms of increased extinction probabilities for many species.

On the positive side, there are benefits to be gained by explicitly integrating humans into the equation for conservation. First, people who have been longtime residents in the region of a protected area often know a great deal about local natural history. This "indigenous knowledge" can be useful in developing protected area management plans, and local residents can play important roles as staff (for example, as guards or environmental educators). Second, protected areas should be "user friendly" to build public support. Two ways to achieve this are through zoning that allows limited public access to portions of the protected areas with established nature trails, and through bringing ecological knowledge about the protected area into formal and informal educational programs. Most cultures take pride in their natural heritage, and a critical mission for all conservation biologists is to build upon that pride through public education. If people do not perceive that the protected area has any value to them, they will not support it.

Finally, native human cultures are a historical part of the ecological landscape and have an ethical right to the areas where they live. Aboriginal and tribal peoples from alpine to tropical regions have existed for millennia in their local systems, and to displace them in the name of conservation is simply unethical. Furthermore, they themselves add other types of diversity—cultural and linguistic diversity—which Earth is rapidly losing. Impoverishment of indigenous human cultures and languages is as large a problem as is impoverishment of other levels of biological diversity. What's more, some of these cultures have developed sustainable methods of existence that can serve as models for modern sustainable development.

We must equally recognize that indigenous cultures have the right to control their destiny. We would be hopelessly naive to imagine that indigenous cultures can remain unchanged and unaffected by outside influences. What we can do is understand their internal systems of values and their knowledge of local natural resources, and then try to work with them toward the twin goals of conservation of biodiversity and sustainable economic development.

We must also incorporate problems of modern cultures into conservation, for they will have the largest influences on resource use. Many conservationists feel that the only realistic path to conservation in the long term is to ensure a reasonable standard of living for all people. Of course, this involves achieving greater equity among peoples, with less disparity between the "haves" and the "have-nots." In part, this will involve convincing some to accept lower standards of living so that others may climb out of desperate poverty, with the result that all will have lesser impact on biodiversity. This will not be an easy task. It will also involve attention to a number of other issues, including birth control, revised concepts of land ownership and use, education, health care, and empowerment of women.

Some postulates of conservation biology

Of course, the foundation of conservation biology is much broader than these three principles. For example, Michael Soulé, a cofounder of the Society for Conservation Biology, lists four postulates and their corollaries that characterize value statements relevant to conservation biology (Soulé 1985). Like the principles listed above, these postulates help to define the ethical and philosophical foundations for this field. Soulé's first postulate is that *diversity of organisms is good*. Humans seem to inherently enjoy diversity of life forms (called **biophilia** by E. O. Wilson [1984]), and seem to understand that natural diversity is good for our well-being and that of nature. A corollary of this postulate is that untimely extinction (that is, extinction caused by human activities) is bad. His second postulate, *ecological complexity is good*, is an extension of the first, and "expresses a preference for nature over artifice, for wilderness over gardens" (Soulé 1985). It also carries the corollary that simplification of ecosystems by humans is bad. The third postulate, *evolution is good*, has already been discussed above, and carries the corollary that interference with evolutionary patterns is bad. The final postulate is that *biotic diversity has intrinsic value*, regardless of its utilitarian value. This postulate recognizes inherent value in nonhuman life, regardless of its utility to humans, and carries the corollary that destruction of diversity by humans is bad. This is perhaps the most fundamental motivation for conservation of biodiversity.

These postulates can be, and have been debated, as can any philosophical position that by definition cannot be founded on an entirely objective, scientific basis. Nevertheless, they are explicitly or implicitly accepted by many, both in and out of the conservation profession. Aspects of these arguments will be pursued further in Chapter 4.

Pervasive Aspects of Conservation Biology Efforts

Conservation biologists seek solutions to a daunting problem: how to preserve the evolutionary potential and ecological viability of a vast array of biodiversity, preserving the complexity, dynamics, and interrelationships of natural systems, in the face of humankind's propensity to try to control, simplify, and conquer those systems. To accomplish this, conservation biology has evolved into a complex multidisciplinary field that is united by the need to respond swiftly to the unfolding biodiversity crisis despite considerable uncertainty.

A discipline responding to an immense crisis

In crises, action must often be taken without complete knowledge, because to wait to collect the necessary data could mean inaction that would destroy the effort at hand. Such immediate action requires working with available information with the best intuition and creativity one can muster, while tolerating a great deal of uncertainty. This, of course, runs counter to the way that scientists are trained, but is nonetheless necessary given the practical matters at hand.

Conservation biologists are often asked for advice and input by government and private agencies regarding such issues as design of nature reserves, potential effects of introduced species, propagation of rare and endangered species, or ecological effects of development. These decisions are usually politically and economically charged and cannot wait for detailed studies that take months or even years. The "expert" is expected to provide quick, clear, and unambiguous answers (which is, of course, generally impossible), and is looked upon askance if such answers are not there, or seem counterproductive to short-term economic gain. This is a major challenge for conservation biologists, who must walk a fine line between strict scientific credibility, and thus conservatism and possibly inaction, versus taking action and providing advice based on general and perhaps incomplete knowledge, thereby risking their scientific reputations.

A multidisciplinary science

No single field of study prepares one to be a conservation biologist, and the field does not focus on input from any single area of expertise. It is an eclectic, broad discipline, to which contributions are needed from fields as different as molecular genetics, biogeography, philosophy, landscape ecology, policy development, sociology, population biology, and anthropology. This multidisciplinary nature is illustrated in Figure 1.9, in which the overlapping fields of natural and social sciences contribute to the special interdisciplinary identity of conservation biology.

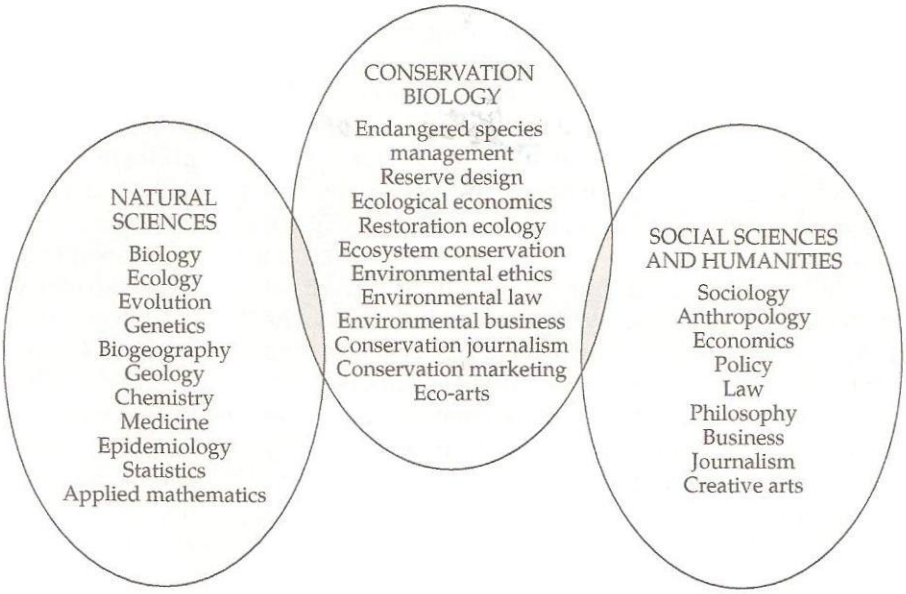

Figure 1.9 The interdisciplinary nature of conservation biology merges many traditional fields of natural and social sciences, and the humanities. This list of relevant subdisciplines and interactions is not exhaustive. Many connections have been made, and more could productively be created in the future.

ESSAY 1.4

A Private Landowner's Perspective

Conservation Biology and the Rural Landowner

Bill McDonald, *Malpai Borderlands Group*

To this rural private landowner, who leases public land for livestock grazing, the emerging discipline of conservation biology embodies both my greatest hopes for the future and my worst fears. Hope—that the best scientific minds will work with the best managerial minds to help us come to grips with the fallout from the remarkable changes of this past century, and help chart a sustainable course to the future. Fear—that the tendency to use big government, in the mistaken belief that government alone can tackle massive issues such as biodiversity loss, will add conservation biology to the growing list of buzzwords abhorred by many rural landowners, and thus make it an impediment to the very effort it represents.

The complexity of our ecosystems, on whatever scale you wish to define the term, simply defies our complete comprehension. Yet, as human beings, we are the only species with the intellectual capacity to recognize the consequences of our collective actions and consciously attempt change for the better. As the dominant species on Earth, to strive to do better is both our responsibility and our hope for survival. It is not easy work. A popular way to attempt to effect positive change is through government edict. In some very clear black and white cases (direct pollution of waters, for instance), this can be a successful approach. When we get to more complex situations, however, this approach results in partial success at best, and often in complete failure. This is particularly true when those who will be most directly affected by the "chosen course of action" are not involved in determining and implementing that course.

I am involved in a different approach. The Malpai Borderlands is a term used to describe a million-acre region in southeastern Arizona and southwestern New Mexico. The region is open space, mountains, and valleys, and its use by people is almost exclusively for cattle grazing. My family has maintained our ranch here for 98 years. Of the families who live here, many like mine are descended from the area's original homesteaders. This region is habitat to many species of plants and animals, some considered rare or endangered.

The Malpai Borderlands Group is composed of area landowners, scientists, and other stakeholders, the latter defined as anyone who has an interest in the future of the place and is willing to work to make it happen. At our invitation, federal and state land agency personnel are included in our effort; federal and state land makes up 47% of the ownership. The goal statement of our group reads as follows:

> Our goal is to restore and maintain the natural processes that create and protect a healthy, unfragmented landscape to support a diverse, flourishing community of human, plant and animal life in our Borderlands Region. Together, we will accomplish this by working to encourage profitable ranching and other traditional livelihoods that will sustain the open space nature of our lands for generations to come.

Early on, we identified two major threats to the natural diversity and health of our lands. First, is the historical suppression of fire, which is leading to a landscape dominated by woody shrub species at the expense of grasses. Second, is the threat of commercial and residential development. Both are also threats to the future of ranching livelihoods, which require both open space and healthy grasses.

While acknowledging that mistakes have been made in the past, and that there is still much to be learned about the effects of grazing on semiarid grasslands, we believe that ranching livelihoods—which depend directly on this large open space resource for its survival—are the best hope for future sustainability of that resource. To date, after ten years of existence, our group has some impressive results to show for our efforts, not the least of which is improved coordination and communication between government agencies and private landowners and between the different agencies themselves.

We have completed four prescribed burns, the first in the history of the area. The burn plans have involved wilderness study areas, two states, multiple private landowners, offices of five different government agencies in both states, coordination with Mexico, and adherence to regulations of the National Environmental Policy Act and the National Antiquities Act. Most challenging was addressing the issue of how fire would impact endangered species. While the burns were successful, with some 70,000 acres improved, the effort required to plan and implement them, one burn at a time, was expensive and exhausting. We therefore embarked on a search for a more comprehensive way to allow fire to beneficially affect the landscape. Working with the appropriate agencies, we came up with a plan that addresses all the issues in advance and we are now on the verge of getting approval from the U.S. Fish and Wildlife Service, whose office of Ecological Services has enforcement responsibility for endangered species, the source of the most contentious issues.

Our group has supported a cattle ranching family in their effort to protect a population of Chiricahua leopard frogs (*Rana chiracahuaensis*), a federally listed species that resides in stock tanks on their ranch. This effort blossomed into a joint commitment with the state wildlife department that has resulted in improved habitat for the frog and an enhanced cattle operation for the rancher. The effort eventually expanded to include the public schools of the nearby community of Douglas, Arizona, where interest in the leopard frog from teachers and students alike resulted in the construction of ponds that have become a temporary sanctuary for the frogs until they can be dispersed to natural habitats on ranches. The recent signing of a Safe Harbor Agreement between the Malpai Borderlands Group and the Fish and Wildlife Service will facilitate expansion of leopard frog habitats, while protecting rights of the private property owners.

We initiated a unique program of grassbanking, where ranchers have access to grass on another ranch in exchange for conservation action of value equal to the value of the grass. For the first users of the grassbank, this meant conveyance of conservation easements to the Malpai Borderlands Group. That means that the private lands on those ranches will never be subdivided. The group now holds conservation easements on a dozen area ranches containing over 75,000 acres of private land permanently protected from commercial or residential development.

There have been a number of other actions taken or facilitated by the group that, while perhaps not as dramatic, have nudged the land a little closer to a long lasting, healthy, and sustainable open space future. Most important of all, we are working together, creating as we go a structure of support for actions that promote the biological diversity of our area and the long-term viability of our ranching livelihoods.

This grassroots alternative to traditional land management approaches is based on the voluntary actions of individuals. Our approach does not, and will never, involve coercion or the force of law. Our approach has been embraced by government agencies, politicians from both major parties, and by most of the news media. It is not, however, completely without its critics. A few landowners remain suspicious of an effort that welcomes the involvement of agency personnel and other stakeholders, particularly The Nature Conservancy. There are also those in the environmental community who do not believe that cattle grazing and healthy semiarid grasslands can coexist, period. We find ourselves between these two poles, in what we call the "radical center." We believe our approach is the one that brings results.

Where does conservation biology fit into such an effort? The role of conservation biology should be informational, certainly. Sound scientific information is crucial to helping us understand what actions to take that will be beneficial to biological diversity, and to be able to analyze the effects of actions already taken. Equally important, conservation biology's role must be supportive. It is important to champion and communicate to others those efforts that are showing results.

Will results come fast enough? Conservation biology has been called a crisis science, which certainly suggests an urgency for its application. The question of how fast, however, becomes irrelevant when we are struggling for something that works at all. The idea that you can artificially speed up a process and then inflict that approach upon all the relevant habitats of the world will ensure failure by changing the very dynamics that made the process initially successful. The continued failure of grand schemes is the real threat to the future diversity of the planet, not the pace or scope of the truly successful efforts. As our effort in the Malpai Borderlands shows, it takes time and hard work to build the trust relationships necessary to achieve real success, and it takes time and hard work to maintain them. This crisis does not call for a few broad strokes, but for millions of little ones.

Several features of this conceptualization of conservation biology are of note. First is the melding of the formerly "pure" fields of population biology and ecology with the "applied" fields that encompass natural resource management. The historical distinction between these disciplines is beginning to blur, and practitioners in these areas are working together toward a common goal. Second is the need for a strong philosophical basis and input from the social sciences. Because the need for conservation in the first place is the direct result of human intervention into natural systems, concern for humanistic viewpoints is vital for reducing present and future confrontations between human expansion and the natural world. Finally, this conceptualization illustrates that conservation biology is a holistic field because protection involves entire ecosystems, and multidisciplinary approaches and cooperation among disparate groups will be the most successful approach.

A strong cross-disciplinary perspective is desirable and necessary for success in conservation. The interests of natural resource agencies for their conservation employees have been expressed as being less in narrow, disciplinary skills than in "real-world" problem-solving abilities. These include "(1) cross-disciplinary breadth as well as disciplinary depth; (2) field experience; (3) language and communications skills; and (4) leadership skills, especially a mix of diplomacy and humility" (Jacobson 1990). Cannon et al. (1996) also indicated the strong need for development of human interaction skills in conservation biologists. A broad, liberal education and an ability to communicate across disciplines, combined with strength within a specialized area, is probably an ideal combination for success and real contributions in conservation biology.

An inexact science

Ecological systems are complex, often individualistic, and currently unpredictable beyond limited generalities. The public, and even other scientists, often do not appreciate this and cannot understand why conservation biologists rarely provide a simple answer to an environmental problem. The reason is, of course, that there usually *is* no simple answer. Ecological systems are complex, their dynamics are expressed in probabilities, **stochastic** influences may be strong, and many significant processes are nonlinear. *Uncertainty is inherently part of ecology and conservation, and probabilistic, rather than prescriptive answers to problems are the norm.*

Conservation biologists increasingly employ modeling techniques and statistical analyses (particularly likelihood and Bayesian approaches) to define an envelope of likely scenarios that may answer a given question.

Thus, a critical area for conservation biologists to become familiar with are such quantitative approaches to problem solving and definition. It is beyond the scope of this book to teach these approaches, but you will see examples of their use in most chapters. Used in efforts to understand the workings of a relatively undisturbed ecosystem, the effect of a threat to that ecosystem, or the effect of a management intervention, these statistical and mathematical approaches can help us to find where the answers are most likely to lie, or at the least, to better define where we need more information to find the answers. While we often cannot know a single answer to a problem, we often may be able to define which answers are most likely to be wrong or right, and work within the range of probable answers.

Thus, the conservation biologist often faces a credibility gap, not because he or she is incompetent, or because the field is poorly developed, but because even the simplest of ecosystems is far more complicated than the most complex of human inventions, and most people have not the slightest notion that this is the case. This gap can easily be exploited by representatives of special interest groups, such as lawyers, engineers, and developers, all of whom are used to dealing with concrete situations that can be easily quantified, and for which a "bottom line" can be extracted. There is never an easy bottom line in ecology, and we can only hope to educate others to that fact, rather than be forced to develop meaningless and dangerous answers that have no basis in reality. The conservation biologist must think "probabilistically" and understand the nature of scientific uncertainty. Consequently, conservationists should include safety margins in the design of management and recovery strategies, as does an engineer in the design of a bridge or an aircraft.

A primary "safety net" that conservation biologists advocate is the adoption of the **precautionary principle**. The environmental equivalent of the Hippocratic oath, "First, do no harm," the precautionary principle exhorts us to avoid practices that could lead to irrevocable harm or serious environmental degradation in the absence of scientific certainty about whether such harm will occur. If an ongoing practice is suspect, then it should be suspended until and unless it is shown not to be harmful. Beyond this, it also calls on people to search for alternatives to potentially damaging practices. Essentially, this is the ultimate safety margin that prevents us from taking potentially damaging actions unless and until we are reasonably sure they will cause no serious harm.

Not only conservationists hold fast to the precautionary principle; many politicians see the wisdom of acting with care when the environmental or human welfare stakes are high. The precautionary principle is a core part of the environmental policies of the European Union. Although less prevalent in U.S. politics, many have pushed for its widespread adoption to protect human health, as well as biodiversity. Former U.S. Environmental Protection Agency director Christine Todd Whitman held the position that "policymakers need to take a precautionary approach to environmental protection. . . . We must acknowledge that uncertainty is inherent in managing natural resources, recognize it is usually easier to prevent environmental damage than to repair it later, and shift the burden of proof away from those advocating protection toward those proposing an action that may be harmful."

One of the strongest statements suggesting extensive use of the precautionary principle is the Wingspread Agreement, formulated at an international meeting of government officials, scientists, lawyers, and environmental and labor activists (Box 1.1), although this wording has not been adopted as policy by any government. Although not explicitly written into many U.S. laws, precaution is implicit in the U.S. **Endangered Species Act**, as well as a number of other important pieces of environmental legislation.

The precautionary principle is imbedded in many laws and international agreements. One of the most important for biodiversity conservation comes in the preamble to the 1992 Convention on Biological Diversity and the Framework for Convention on Climate Change: "Where there is a threat of significant reduction or loss of biological diversity, lack of full, scientific certainty should not be used as a reason for postponing cost-effective measures to avoid or minimize such a threat."

Peru, Costa Rica, and Australia all have recently enacted legislation to protect biodiversity that envokes the precautionary principle. Increasingly, conservation biologists are working to define when and how the precautionary principle should be included in strategies to protect biodiversity (Cooney 2004).

A value-laden science

Science is supposed to be value-free. It is presumably completely objective and free from such human frailties as opinions, goals, and desires. Because science is done by humans, however, it is never value-free, but is influenced by the experiences and goals of the scientists, although they often will not admit that. "Too many teachers, managers, and researchers are trapped by the Western positivist image of science as value-free; . . . Biologists must realize that science, like everything else, is shot through with values. Sorting out the norms behind positions is the initial step of critical thinking" (Grumbine 1992).

Unlike many other areas of science, conservation biology is "mission-oriented" (Soulé 1986). The goal is clearly to conserve natural ecosystems and biological processes, which are held as intrinsically valuable by conservation biologists.

BOX 1.1 Wingspread Statement on the Precautionary Principle

Recognizing the need for guidance on environmental policy, an international group of scientists, government officials, lawyers and environmentalists met January 23–25, 1998 at the Wingspread Center in Racine, Wisconsin. Following two days of discussion, the group issued the following concensus statement, which has served to guide environmental policy planning.

Statement

The release and use of toxic substances, the exploitation of resources, and physical alterations of the environment have had substantial unintended consequences affecting human health and the environment. Some of these concerns are high rates of learning deficiencies, asthma, cancer, birth defects, and species extinctions, along with global climate change, stratospheric ozone depletion, and worldwide contamination with toxic substances and nuclear materials.

We believe existing environmental regulations and other decisions, particularly those based on risk assessment, have failed to adequately protect human health and the environment, the larger system of which humans are but a part.

We believe there is compelling evidence that damage to humans and the worldwide environment is of such magnitude and seriousness that new principles for conducting human activities are necessary.

While we realize that human activities may involve hazards, people must proceed more carefully than has been the case in recent history. Corporations, government entities, organizations, communities, scientists, and other individuals must adopt a precautionary approach to all human endeavors.

Therefore, it is necessary to implement the Precautionary Principle: When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically. In this context the proponent of an activity, rather than the public, should bear the burden of proof.

The process of applying the Precautionary Principle must be open, informed, and democratic, and must include potentially affected parties. It must also involve an examination of the full range of alternatives, including no action.

The question of values and advocacy in conservation science have been debated in conservation journals and within various scientific societies (e. g. Barry and Oelschlaeger 1996 and associated responses; Meffe 1996). Whether and how conservation scientists should become involved in policy development is a major issue (see Chapter 17). An emerging, consensus answer seems to be that scientists have a clear responsibility to society to lend their knowledge and expertise toward the value-laden goal of biodiversity preservation, but that good, objective science must serve as a foundation for reaching that goal. Objectivity in how science is conducted cannot be compromised to reach predetermined goals, for then all scientific credibility is lost.

A science with an evolutionary time scale

In contrast to traditional resource management, whose currency includes maximum sustained yields, economic feasibility, and immediate public satisfaction with a product, the currency of conservation biology is long-term viability of ecosystems and preservation of biodiversity *in perpetuity*. A conservation biology program is successful not when more deer are harvested this year, or even when more natural areas are protected, but when a system retains the diversity of its structure and function over long time periods, and when the processes of evolutionary adaptation and ecological change are permitted to continue. If there is a common thread running throughout conservation biology, it is the recognition that evolution is *the* central concept in biology, and has played and should continue to play *the* central role in nature.

A science of eternal vigilance

The price of ecosystem protection is eternal vigilance. Even "protected" areas may be destroyed in the future if they contain resources that are deemed desirable enough by powerful groups or individuals. A case in point is the United States' Arctic National Wildlife Refuge, an area set aside for its ecological significance, but repeatedly under pressure (and again as of this writing) to be opened up for oil extraction as world political affairs affect the price and availability of oil. What appears secure today may well be exploited tomorrow for transitory resource use, and the conservation biologist must continually be protective of natural areas and must stay on top of policy developments that affect conservation. Natural ecosystems can easily be destroyed, but they cannot be created, and at best only partially restored.

A Final Word

Ecological systems are complex, and situations are often unique. What makes sense in one system or circumstance will be inapplicable in another. Idiosyncrasies abound, as do conflicting demands. Conservation scenarios need to be defined and pursued individually, not by "prescription." Conservation biology is not easy, but it is not hopelessly complicated either, and much research and application remains to be done, as we emphasize throughout this book. Above all, it can provide exciting and unparalleled career opportunities for people interested in solving real-world problems. The world's biodiversity desperately needs bright, energetic, and imaginative people who will dedicate their work to making a difference. And they certainly can, and must.

Summary

1. Exponential human population growth and consumptive habits in the last few centuries have affected the natural world to the extent that massive alteration of habitats and associated biological changes threaten the existence of thousands of species and basic ecosystem processes. The field of conservation biology developed over the last 40 years as a response of the scientific community to this crisis. Conservation biology differs from traditional resource conservation in being motivated not by utilitarian, single-species issues, but by the need for conservation of entire systems and all their biological components and processes.
2. Conservation practices have a varied history around the world, but generally have focused on human use of resources. In the U.S., two value systems dominated resource conservation early in the twentieth century. The Romantic-Transcendental Conservation Ethic of Emerson, Thoreau, and Muir recognized that nature has inherent value and should not simply be used for human gain. The Resource Conservation Ethic of Pinchot was based on a utilitarian philosophy of the greatest good for the greatest number of people; many resource agencies in the U.S. and elsewhere follow this view. Aldo Leopold's Evolutionary-Ecological Land Ethic developed later, and is the most biologically relevant perspective, recognizing the importance of ecological and evolutionary processes in producing and controlling the natural resources we use. Much of modern conservation biology has grown from and is guided by Leopold's land ethic.
3. Three overriding principles guide all of conservation biology. First, evolution is the basis for understanding all of biology, and should be a central focus of conservation action. Second, ecological systems are dynamic and nonequilibrial; change must be a part of conservation. Finally, humans are a part of the natural world and must be included in conservation actions.
4. Conservation biology has some unusual characteristics not always found in other sciences. It is a crisis discipline that requires multidisciplinary approaches. It is an inexact science that operates on an evolutionary time scale. It is a value-laden science that requires long-term vigilance to succeed. It also requires of its practitioners innovation, flexibility, multiple talents, and an understanding of the idiosyncrasies of ecological systems, but offers outstanding career challenges and rewards.

Please refer to the website www.sinauer.com/groom for Suggested Readings, Web links, additional questions, and supplementary resources.

Questions for Discussion

1. How would you explain the significance of human population growth and the human ecological footprint for biodiversity conservation?
2. What would conservation practice be like if we primarily followed the principles of Pinchot's Resource Conservation Ethic? How would it differ from the present day focus of Conservation Biology? Is the present focus of conservation biology preferable to the Romantic-Transcendental Conservation Ethic of Emerson, Thoreau and Muir? How?
3. How would you answer a conservation skeptic who asserted that because ecological processes are nonequilibrial, conservation of current communities is misguided since they are destined to change?
4. Why are multiple disciplinary perspectives important in conservation biology?
5. How are the views of conservation biology and conservation practice similar among the four essayists (Erica Fleishman, Jamie Rappaport Clark, Kathryn Fuller, and Bill McDonald) featured in this chapter? How are they different?