Figure 1.5 The first issue of the journal *Conservation Biology*, published in May 1987. (Photograph courtesy of E. P. Pister.)

tions. Anyone who thinks that much of the science 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.

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 that these three principles are so basic to conservation practice that they should permeate all aspects of 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 recall repeatedly Hutchinson's metaphor, "the ecological theater and the evolutionary play," discussed above. Answers to biological 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 6). 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 a dynamic, largely nonequilibrial world. 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 struc-

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:	The human presence must be included in conservation planning. (Humans are part of the play.)

ture and function, and embraces the popular "balance of nature" concept. Conservation under this paradigm would be relatively easy: simply 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 old "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 to as evolutionary structure, such as the 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 (Botkin 1990) recognizes that ecological systems are generally not in dynamic equilibrium, at least not indefinitely, and have no stable point. Regulation of ecological structure and function is often not internally generated; external processes, in the form of

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ESSAY 1D

A Nongovernmental Organization Perspective

The Role of Science in Defining Conservation Priorities for Nongovernmental Organizations

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 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 reexamine our notions of both endeavors, to reconcile ecology with disciplines that would once have seemed completely alien to it.

A crucial part of that process has been the emergence of conservation biology. As might be expected, this effort to conserve biological diversity by wedding the disciplines of ecology, genetics, and practical wildlife management has prompted dissent, some of it from wildlife managers who have worked for years without benefit—or, many of them would argue, *need*—of scientific oversight. It is clear that conservationists need to build more bridges between these managers and the scientists now entering the field, simply because both sides have much to learn from each other.

Some dissenters claim that conservation biology is simply the latest in a series of gimmicky cross-disciplines, aimed at dazzling foundations with gaudy new academic packages. Nothing could be further from the truth. Conservation biology is here to stay because it looks at long-standing fieldwork through the prisms of new theoretical frameworks, and thus creates a synergy of enormous potential power. The proper question is not whether conservation biology is just a passing fad, but rather, what do we *do* with this new hybrid? How do we tap its potential?

There are two answers to this question. First, 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.

Achieving genuine long-term conservation, however, requires a broader approach. Initially, that meant looking not just at species but at their habitats. That, 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 can help ease the economic burdens that drive people to overexploit their natural resources, we can never hope to arrest the environmental degradation of the developing world. So WWF seeks ways to marry the preservation of biological diversity with environmentally sound economic development.

This transition from "pure" conservation to one that integrates conservation and development means we can no longer closet ourselves behind laboratory doors. We must delve into areas unfamiliar to conservationists, such as 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.

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 the second answer to the question of science's role in conservation is this: science is more critical than ever. If we posit ourselves as architects, then science is the foundation of our edifice, the base from which we use various tools—sustainable development, conservation finance—to structure something strong and enduring.

In a way, science is not just foundation but continuing illumination, telling us where we need to go and how to get there. How, for instance, do we help people in the developing world improve their quality of life in sustainable ways unless we give them viable models of development? This is where science plays a role. Already, we are seeing exciting and promising new sustainable-use techniques at work in our tropical forests: harvesting of non-timber products like fruits, seeds, medicinal plants, and wild game; agroforestry methods that combine traditional crops with multiple-purpose trees; restoration ecology and watershed protection.

Science can and must contribute to the fruitful mélange of ideas currently circulating in the field. Without science's help, we cannot hope to tackle the truly forbidding problems facing our planet today—problems that in fact were first identified by scientists: global warming, ozone depletion, fragmentation and degradation of habitat, and perhaps foremost of all, the loss of biological diversity.

We can only guess at the number of species on this planet. Some estimates put the number at 50 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?" Again, this is where science comes in. Science can tell us where to begin our path, and equally important, it can help correct our path while we forge it. Science also provides the kind of foresight that every conservation organization desperately needs—the ability to look ten, twenty years in the future and figure out 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 most of today's mass extinctions are taking place in the tropical forests, which contain at least half of all earth's species and are being depleted faster than any other ecological community. Tropical forests are in fact the crucible of modern conservation. Knowing this only takes us so far, however, since it still leaves us with billions of acres of forest to somehow incorporate into our planning. But scientists at WWF and elsewhere are working to identify key natural areas featuring exceptional concentrations of endemic species and facing exceptional degrees of threat. By concentrating efforts in those areas where the needs and the potential payoffs are greatest, conservationists can respond in a more informed and systematic way to the challenge of preserving biodiversity.

Science can be a partner in that effort, anchoring the economic and political exigencies of modern conservation in intellectual bedrock. Conservation biology can rise to the moment, expanding its 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 us are so massive that scientists must scale their thinking accordingly. The need for solid science to inform decisive action by nongovernmental organizations and other groups has never been so great.

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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 is maintained by nonequilibrial processes (Figure 1.6). 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.

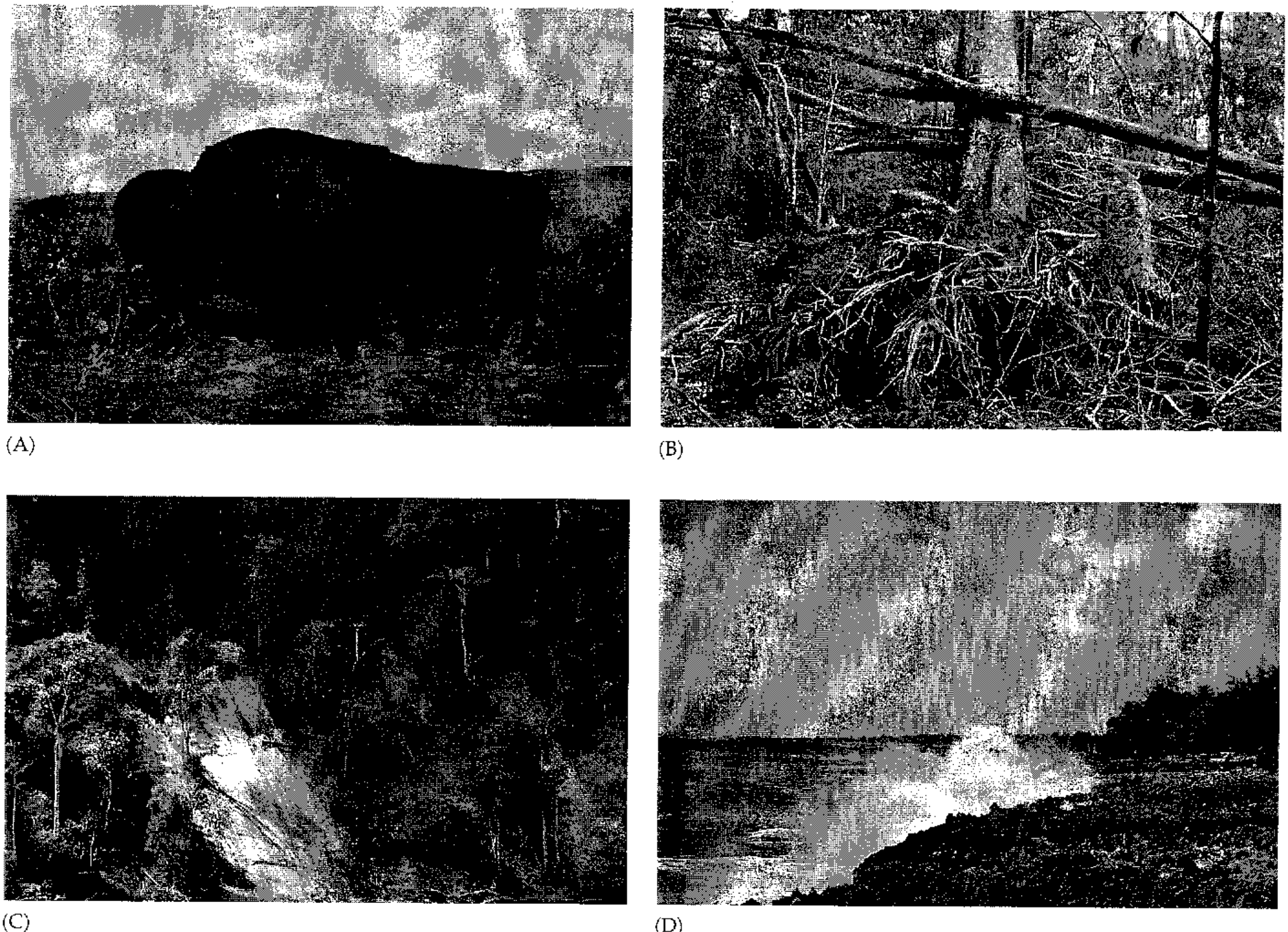

Figure 1.6 Nonequilibrial processes play a major role in most ecosystems. Surface disturbances by bison create openings or "wallows" in prairies (A). Hurricanes and other storms open gaps in both temperate (B) and tropical (C) forests. Wave action (D) and tidal changes on rocky shorelines open up disturbance patches. (A, photograph courtesy of Jerry Wolfe; B, Congaree Swamp, South Carolina after Hurricane Hugo, 1989, by Rebecca Sharitz; C, lower montane forest in Costa Rica, by C. R. Carroll; D, coral rock in the Dominican Republic, Caribbean Sea, by Michael C. Newman.)

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 community structure and biodiversity. Ecosystems are open systems with fluxes of species, materials, and energy, and must be understood in the context of their surroundings. A further implication is that nature reserves cannot be treated in isolation, but must be part of larger conservation plans whose design recognizes and accounts for spatial and temporal change. This principle is further developed by Petraitis et al. (1989), Botkin (1990), Pickett et al. (1992) and Pickett and Ostfeld (1995).

Principle 3: The 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 under principle 2, ecosystems are open to the exchange of materials and species, and to the flux of energy. Because nature reserves are typically surrounded by lands and waters intensively used by humans, it is impossible to isolate reserves 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 reserves carries its own liability in terms of increased extinction probabilities and gene losses 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 reserve often know a great deal about local natural history. This "indigenous knowledge" can be useful in developing reserve management plans (see Essay 11B), and local residents can play important roles on reserve staffs as, for example, guards and environmental educators. Second, reserves should be "user-friendly" in order to build public support. Two ways to achieve this are by allowing limited public access to those portions of the reserve with established nature trails, and by bringing ecological knowledge about the reserve into formal and informal educational programs. Most people take pride in their natural heritage, and a critical mission for all conservation ecologists is to build upon that pride through public education. If people do not perceive that the reserve 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 the earth is rapidly losing. The loss of indigenous human cultures and languages is as large a problem as is the loss 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 requires greater equity among peoples, with less disparity between the "haves" and the "have-nots." Achieving equity 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 a lesser impact on biodiversity. This will not be an easy task. It will also involve attention to a number of other issues, such as birth control, revised concepts of land ownership and use, education, health care, empowerment of women, and so forth.

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, listed 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 of the 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." 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.

ESSAY 1E

A Private Landowner's Perspective

Conservation Biology and the Rural Landowner

Bill McDonald, Malpai Borderlands Group

To this rural private landowner, who also leases public land for livestock grazing, the emerging discipline of conservation biology embodies both my greatest hope for the future and my worst fear. Hope—that the best scientific minds will work with the best managerial minds to help us to come to grips with the fallout from the remarkable changes of this past century, and to chart a sustainable course to the future. Fear—that a 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, we must strive to do better; it is both our responsibility and our hope for survival. It is not easy work. A popular way to attempt to effect such positive change is through governmental edict. In some very clear-cut cases (direct pollution of waters, for instance), this can be a successful approach. In 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 million-acre region in southeastern Arizona and southwestern New Mexico. It contains open space, mountains, and valleys, and its use by people is almost exclusively for cattle grazing. My family has maintained our ranch here for 90 years. Of the families who live here, many, like mine, are descended from the area's original homesteaders. The region is home to many species of plants and animals, some considered rare and/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 land 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 goal by working to encourage 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 landscape. 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 development—a distant threat at the moment, which is the best time to address it. 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 much remains to be learned about the effects of grazing on semiarid grasslands, we believe that ranching livelihoods, which depend directly on the open space resource for their survival, are the best hope for the future sustainability of that resource.

To date, after just three 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 the first prescribed burn in the history of the area. The burn plan involved a wilderness study area, two states, four private landowners, five different government agencies in both states, coordination with Mexico, and adherence to the regulations of the National Environmental Policy Act and the National Antiquities Act. While the burn itself was successful, the effort to make it happen was exhausting. We have now embarked on a search for a less bureaucratic way to bring the beneficial effects of fire to the landscape.

Our group has supported a cattle ranching family in their efforts to protect a population of Chiricahuan leopard frogs (*Rana chiracahuaensis*) that reside in stock tanks on their ranch. This project has blossomed into a joint effort with the state wildlife department that will result in improved habitat for the frog and an enhanced cattle operation for the ranchers.

We have begun a unique program of grassbanking, in which ranchers gain access to grass on another ranch in exchange for conservation action of value equal to the value of the grass. For the initial users of the grassbank, this has meant conveyance of conservation easements to the Malpai Borderlands Group, which will result in the private lands on those ranches never being subdivided.

A number of other actions have been taken or facilitated by the group that, while perhaps not as dramatic, have nudged the land a little closer to a long-lasting, healthy, sustainable 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 sustainability 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 parties, and most of the news media. It is not, however, without its critics. Some of the landowners remain suspicious of an effort that welcomes the involvement of government agency personnel and other stakeholders, particularly The Nature Conservancy. There are also those in the environmental community who simply do not believe that cattle grazing and healthy semiarid grasslands can coexist. We find ourselves between these two poles, in what we call the "radical center." We believe that 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 to understand what actions will be beneficial to biological diversity, and to analyze the effects of actions already taken. Equally important, conservation biology's role must be supportive. It is important to champion those efforts that are showing results.

Will the 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 still 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 trusting 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.

These postulates can be, and have been, debated, as can any philosophical position, which, 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 further pursued in the next chapter.

Some Characteristics of Conservation Biology

Conservation biology has some unusual characteristics not associated with many other sciences. These result partly from the daunting nature of the problem of how to preserve the evolutionary potential and ecological viability of a vast array of biodiversity. Some of the uniqueness of conservation biology also stems from basic conflicts between the complexity, dynamics, and interrelatedness of natural systems and humankind's propensity to try to control, simplify, and conquer those systems.

A Crisis Discipline

Soulé (1985) labeled conservation biology a "crisis discipline," with a relationship to the larger field of biology analogous to surgery's relationship to physiology, or that of war to political science (or, we suppose, AIDS to epidemiology). In such crisis disciplines, action often must be taken without complete knowledge, because waiting 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 nonetheless is necessary given the practical matters at hand. These problems are discussed further in Chapters 16 and 17.

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 issues are usually politically and economically charged, and decisions 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 contrary 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 possible 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 diagrammed in Figure 1.7, which shows how the overlapping fields of natural and social sciences contribute to the special interdisciplinary identity of conservation biology.

This conceptualization of conservation biology has several important features. 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 common goals. Second is the need for a strong philosophical foundation and input from the social sciences. Because the need for conservation in the first place is the direct result of human intervention in natural systems, an understanding of humanistic viewpoints is vital for reducing present and future confrontations between human expansion and the natural world. Finally, conservation biol-

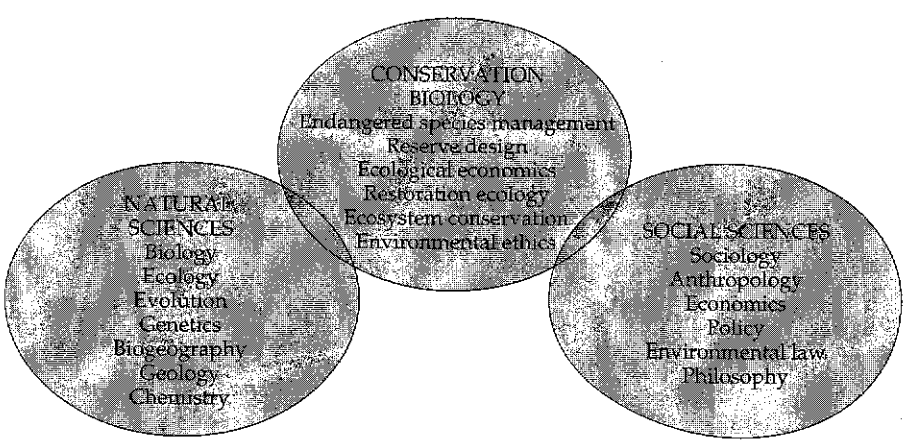

Figure 1.7 The interdisciplinary nature of conservation biology merges many traditional fields of natural and social sciences. The list of relevant subdisciplines and interactions shown is not meant to be exhaustive.

ogy is a holistic field because conservation 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. A conference held in 1989 that included several global resource agencies outlined their collective vision of the training necessary for their future conservation employees (Jacobson 1990). The interests of these agencies were less in narrow, disciplinary skills than in "real-world" problem-solving abilities. These included "(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 achieving success and making real contributions in conservation biology.

An Inexact Science

Ecological systems are complex, often unique, and currently unpredictable beyond limited generalities. The public, and even other scientists, often do not appreciate this and cannot understand why ecologists are such uncertain folks who hedge their bets and will not 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.*

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 a "bottom line" 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 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). This recognition of value-laden science has been called "post-modern science" and is discussed in depth in Chapter 16 and Essay 19A.

Unlike many other areas of science, conservation biology is "mission-oriented" (Soulé 1986); its goal clearly is to conserve natural ecosystems and biological processes, and there is nothing value-free about it. However, the methodology used to obtain information and put it to use must be good, objective science; if not, all credibility will quickly be lost. Nevertheless, conservation biologists should not delude themselves into thinking that their science is value-neutral. Its values are clearly defined: natural systems and biological diversity are good and should be conserved.

The question of values and advocacy in conservation science has been debated recently in conservation journals and within various scientific societies (Barry and Oelschlaeger 1996 and associated responses; Meffe 1996). Whether and how conservation scientists should become involved in policy development is a major issue; the emerging consensus seems to be that scientists have a clear responsibility to society to lend their knowledge and expertise to the value-laden goal of biodiversity preservation, but that good, objective science must serve as the 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 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 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 can be only partially restored.

A Final Word

Throughout this book you may find cases of seeming opposites or contradictions in our messages. It may seem that at one point we advise letting natural processes occur and at another suggest interventionist management. We will recognize nonequilibrial processes in general, but then discuss deterministic processes that can reach equilibrium in particular cases. This is not done to confuse you. Ecological systems are complex, and their 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, and not be part of an automatic, "cookbook" approach.

Conservation biology is not easy, but it is not hopelessly complicated either, and much research and application remains to be done. Above all, it can provide exciting and unparalleled career opportunities for students interested in solving real-world problems. The world's biodiversity desperately needs bright, energetic, and imaginative students who feel they can make a difference. And they certainly can, and must.

Summary

Exponential human population growth in the last few centuries has affected the natural world to the extent that massive alteration of habitats and associated biological changes threaten the existence of millions of species and basic ecosystem processes. The field of conservation biology developed over the last 20 years as a response of the scientific community to this crisis. The "new" 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.

Conservation practices have a varied history around the world, but generally have focused on human use of resources. In the United States, two value systems dominated resource conservation early in the 20th 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 United States 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.

Three overriding principles should 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, and therefore change must be a part of conservation. Finally, humans are a part of the natural world and must be included in conservation concerns.

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.

Suggestions for Further Reading

Gore, A., Jr. 1992. *Earth in the Balance: Ecology and the Human Spirit.* Penguin Books, New York. A stunningly good grasp of global environmental crises is shown by the Vice President of the United States. A better account of biodiversity problems and potential solutions written by a nonscientist cannot be found.

Grumbine, R. E. 1992. *Ghost Bears: Exploring the Biodiversity Crisis.* Island Press, Washington, D.C. An outstanding summary of the biodiversity crisis written in the context of old-growth forests of the Pacific Northwest, and encompassing ethics, law, environmental policy, and activism. A very broad, "real-world" perspective of the challenges facing biodiversity conservation.

Soulé, M. E. (ed.). 1986. *Conservation Biology: The Science of Scarcity and Diversity.* Sinauer Associates, Sunderland, MA. Already a classic, this book laid much of the groundwork for the science of conservation biology. It contains 25 chapters written by scientists who helped define modern conservation biology.

Western, D. and M. Pearl (eds.). 1989. *Conservation for the Twenty-First Century.* Oxford University Press, New York. An outstanding follow-up to the Soulé text that presents a broader perspective of conservation. In addition to biological issues, it includes much information on management of parklands, global issues, human value systems, and planning and legislation in conservation.

Wilson, E. O. 1992. *The Diversity of Life.* Belknap Press of Harvard University Press, Cambridge, MA. This is an excellent overview of the biodiversity crisis, in easily understood terms, spanning the gene to the ecosystem. It also covers basic concepts such as evolutionary change, extinction, and speciation, all described in an engaging style.

In addition, two good introductory textbooks and a more applied text offer broad overviews of conservation biology. These are, respectively, *Fundamentals of Conservation Biology*, by Malcolm L. Hunter, Jr. (1996, Blackwell Science), *Essentials of Conservation Biology*, by Richard B. Primack (1993, Sinauer Associates), and *Saving Nature's Legacy. Protecting and Restoring Biodiversity*, by Reed F. Noss and Allen Y. Cooperrider (1994, Island Press).