Herpetology
An Introductory Biology of Amphibians and Reptiles

Fourth Edition

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Academic Press is an Imprint of Elsevier

Chapter 14

Conservation Biology

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It's nature's way of telling you, summer breeze
It's nature's way of telling you, dying trees
It's nature's way of receiving you
It's nature's way of retrieving you
It's nature's way of telling you
Something's wrong
It's nature's way, it's nature's way

Spirit, 1970
Twelve Dreams of Dr. Sardonicus, Epic Records

Conservation science has become a successful and innovative field of study with many practitioners and extensive numbers of research articles in high-quality journals dedicated to the field. However, much of the research in the field is not leading to actions that translate to saving species and their habitats. Local success stories can of course be found and should be celebrated, but the overall picture for most groups of plants and animals is a steady decline in the number of individuals and populations, and, ultimately, species. These facts have led scientists to take a hard look at why most conservation assessments and recommendations have gone unheeded. Conservationists strongly believe they are doing work relevant to the needs and betterment of society.

Many factors contribute to this lack of success. It cannot be overlooked that the resources allocated to conservation activities are insignificant compared to those allocated to economic growth and development in most countries around the world. At present, governments of most countries believe that economies based on continued growth are the only pathway to economic prosperity. Short-term objectives for monetary gain often outweigh conservation priorities. Aside from these truths about global politics and the human tendency to have a short-term view of the world, other long-held conventions prevent the work of academic conservationists from translating into real-world action. Many conservationists are university researchers, and promotion in their careers is based on their production of innovative, often theoretical, research articles. They usually do not have the time or funding to carry out the work that would result in actually saving populations and species. Practitioners who do attempt to carry out this work often do not have ready access to conservation-oriented scientific journals and publications. Journal subscriptions are typically bundled and sold to university libraries for a substantial price, and the public does not have ready access to university libraries.

Solutions to this dilemma are not easily formulated. Universities seem unlikely to change their priorities for evaluation of faculty research to allow for involvement in political or community work that might result in conservation of species or areas. However, in an attempt to influence the type of research done and to foster collaboration among conservation scientists and conservation practitioners, researchers in various countries (i.e., Canada, Australia, Switzerland, Germany, United States) have recently attempted to identify conservation research priorities that would best lead to

Herpetology. http://dx.doi.org/10.1016/B978-0-12-386919-7.00014-9
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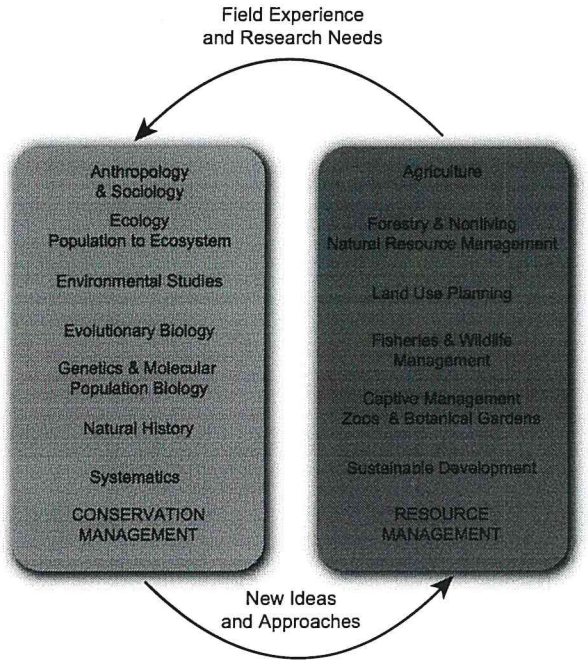

FIGURE 14.1 Conservation biology encompasses a broad range of biological and social studies to address issues and problems arising from and recognized through the use and management of natural resources. *Adapted from Temple, 1991.*

effective policies and management strategies. This work has generally focused on asking policy advisors, government and nongovernment agency conservationists, social scientists, and others involved in conservation to supply questions regarding the type of research that would best help them with their conservation needs. Workshops have been held to consolidate lists of questions in various areas, including populations and species, ecosystem functions, environmental change, and many other areas critical to conservation. With the formulating of specific questions as guidance, researchers hope to encourage communication among decision makers and scientists and to enhance evidence-based conservation that will lead to positive outcomes.

Complicating these efforts even further, we have seen an ever-increasing disconnect between people and nature as the human population expands and technology becomes more pervasive. Children no longer play outside with abandon and make natural history discoveries on their own; instead, television, computers, cell phones, tablets, and other devices compete for leisure time. Another reason for this disconnect is that an estimated 48% of all people worldwide now live in cities, and the diversity of plants and animals with which they interact is homogenized in the sense that the same city-adapted species are seen day after day.

Solutions to these problems are badly needed at a time when adults are busy with fast-paced lives and outdoor activities of children are structured at local parks and ball fields. Children especially must be reconnected with the natural world. Children naturally love nature, and, if given the chance, they will make discoveries on their own. Research has shown that children who are exposed to wild areas appreciate and value these areas as adults. But urban parks and outdoor playgrounds do not supply the appropriate habitats because of their structured settings and typically low diversity of plants and animals. One successful model in helping to reverse this trend is Chicago Wilderness, which is a regional reserve of 225,000 acres encompassing three states and overseen by a consortium of more than 260 federal, state, and private organizations. The reserve consists of wild areas that are encompassed in federal lands, state parks, county preserves, and many other locales that include prairies, wetlands, woods, and other habitats. A great number of volunteers have made this enormously successful project work, and people are learning about their biodiversity, restoration ecology, and how best to educate children and others about conservation. Efforts such as these are necessary at a global level to provide a connection with the natural world and to educate children and adults about the need to save natural habitats and the biodiversity contained within them. With the current rapid conversion of farmland and natural areas to urban settings in the United States and other parts of the world, the time to set aside these natural lands is running out.

The relationship between economics, resource use, and conservation is only beginning to be explored and debated (Fig. 14.1). Without consideration of how our consumption

of material goods drives our economy and how we can make changes that affect the world, we will not be able to save our wild areas and their tremendous diversity. We must also consider the size of the human population and begin to deal openly with this subject. We explore these areas in the sections of this chapter.

GENERAL PRINCIPLES

A major focus of conservation biology is the maintenance of the world's biodiversity. Biological diversity is the product of organic evolution, and biological processes from the molecular level involving DNA to the biosphere are not intelligible without reference to organic evolution. Organisms continually interact with their abiotic and biotic environments; intraspecific and interspecific interactions create the numerous local ecological theaters. Nowhere is the ecological play the same; players and conditions constantly change, bringing about a dynamic and evolving ecological world. Species and species interactions that we observe today often have a deep and complex evolutionary history, and virtually all biological communities have a history involving drifting continents, diversification events, dispersals, and climatic change. Nevertheless, the impact of a single species, *Homo sapiens*, may prove to be greater than all historic and biological interaction effects combined in terms of causing dramatic change on a global scale.

Humans have impacted natural landscapes and their living components from the time that they became organized as hunter–gatherers. More recently, human impact has increased dramatically as the population continues to grow (Fig. 14.2). From the year 1000 to 1800, the human population increased from 310 million to 970 million (net increase of 660 million in 800 years). From 1800 to 1900, the population grew from 970 million to one billion 650 million (net increase of 680 million in 100 years). From 1900 to 1950, the population grew from one billion 650 million to two billion 519 million (net increase of 869 million in 50 years). From 1950 to 2000, the population grew from two billion 519 million to six billion 70 million (net increase of three billion 557 million in 50 years). As of September 30, 2012, the human population reached seven billion 70 million. Because the growth has been exponential, the time required to add another billion people to the world is now about 11 years. The Earth's human population is currently increasing by 211,090 people *per day*. Conservative estimates predict that although the fertility rate is declining worldwide, the population will continue to grow until 2050, when it will reach 9.2 billion. This figure is dependent on the continued decline of the fertility rate; should this rate cease to decline by only a small amount, the world population could reach 10.8 billion by 2050. Other estimates put the figure much higher.

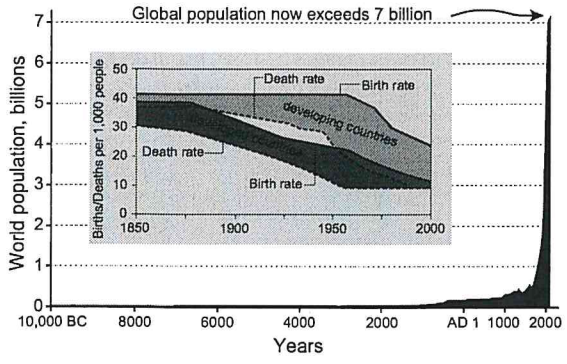

FIGURE 14.2 World population growth during the last 12,000 years. The insert depicts the natural population increase for developing (blue) and developed (orange) countries defined as the difference between birth rate and death rate. *Based on figures from the World Bank.*

The fertility rate is not the same throughout the world; developing countries have a higher fertility rate, and much of the growth of the population will be in these regions. The fertility rate of the United States is typically 2.13, although a downturn to 1.9 occurred in 2008, apparently in response to a severe economic recession. In the United States, much of the increase in population is due to immigration. Analyses by the United State Census Bureau indicate that 10,501,000 people became legal permanent residents in the decade from 2001 to 2010. By its nature, the number of current illegal immigrants is difficult to know with certainty; the estimates range from seven million to a high of 20 million. The population of the United States was 296 million in 2005 and is predicted to reach 438 million by 2050, with 82% of the increase due to immigration. The consequences of this population size will be an increase in the loss of biodiversity, more urban sprawl, and more pressure on stressed social systems.

As for all species on the planet, maintenance of human populations requires, at minimum, food, potable water, and a place to live. Unlike nearly all species that have ever lived, we have extended our ecological footprint on a per capita basis in an attempt to extend our micro-environments to extremes only dreamed about a thousand years ago. The effect of increased human populations on the biosphere is multiplied by the increased rate of technological development, extraction of natural resources for energy production, conversion of natural lands, and the resulting environmental pollution from these activities. To believe that science and technology will allow us to continue current rates of population growth and maintain or increase our standard of living is naïve at best. Loss of amphibian and reptile species and habitats are just one symptom of a much larger problem, human population growth, and addressing this problem requires engaging all political, religious, cultural, and educational leaders throughout the world. This issue is not one that should deeply concern only Americans; it is a global issue that should concern citizens of all countries.

Biodiversity

What is biodiversity, and how does the biodiversity crisis impact the field of herpetology? At its simplest, biodiversity is the wealth of life throughout the world, including the smallest viruses and microbes to the giant whales and redwoods. Biodiversity includes the genetic diversity embodied in these organisms, and the interactions among them that form unique communities and ecosystems. The history of life on Earth is recorded in the DNA of organisms; this too is an important component of biodiversity. The study of biodiversity and its conservation require addressing diversity at several levels and in several ways (Table 14.1). Species richness, often called species diversity (see Chapter 12), is easiest to recognize conceptually simply by noting how many different species exist in a given area. Species richness is typically reported by taxonomic group. For example, 19 species of snakes occur in the metropolitan Washington area; 54 species of native frogs and salamanders occur in the state of Oklahoma; and 7021 amphibian species occur in the world. These regions are arbitrarily defined, and the numbers offer a sense of a region's diversity but have little biological utility. A biologist or resource manager needs more precise data and asks for species-diversity metrics relative to habitats or natural plant–animal associations. The number of species in a given area is termed alpha diversity (Table 14.1). A biologist may also wish to know how species diversity changes along an environmental gradient (beta diversity) or the differences in number and kinds of species among climatically and structurally similar habitats in different geographic areas (gamma diversity). Such diversity has long fascinated herpetologists. For example, Ronald Heyer's study in 1967 of herpetofaunal change along an altitudinal gradient in Costa Rica represents a study of beta diversity, and Eric Pianka's studies in 1986 and 1994 of lizard assemblages in the deserts of Africa, Australia, and North America represent studies of gamma diversity. The fascination, however, extends beyond the number and kinds of species that occur in a region to what these occurrences reveal about the origin and interactions of an assemblage or community and the ecology of the individual species. Subsequently, these studies provide historical "snapshots" by informing us about how a locality and its fauna have changed through time. It is the multitude of such biological studies and the presence of voucher specimens in the world's museums that allow scientific assessments of changing diversity and species abundance.

The numerous assessments of diversity are few relative to the number of habitats and ecosystems throughout the world. Additionally, many studies may have been scientifically rigorous for their time, but they lack either the scope of data or the appropriate sampling regime to rigorously examine current conservation issues. Their proportionately small numbers highlight the necessity of continuing biodiversity inventories in order to obtain an accurate and thorough knowledge of the world's flora and fauna. Another critical aspect of these inventories is the collection of specimens and the prompt study of these voucher specimens. Good science relies on repeating and verifying observations. Verification of species occurrence relies on actual specimens because most plant and animal species cannot be reliably identified in-hand, from photographs, or from a small set of recorded measurements. Biodiversity inventories regularly identify new species, and these discoveries include amphibians and reptiles. Often these new species are common faunal members, but their uniqueness has not been recognized because they were not carefully examined. Close study of numerous groups of amphibians and reptiles, particularly using modern molecular

TABLE 14.1 Types or Levels of Biological Diversity

Type	Definition
Genetic diversity	The gene pool or genetic composition of a population or set of populations.
Species diversity	The number of species in an area.
Alpha diversity	The number of species in a community or habitat.
Beta diversity	The difference or change in species number along an environmental gradient.
Phylobetadiversity	How phylogenetic relatedness of communities changes across a landscape.
Gamma diversity	The difference or change in species composition among similar communities or habitats in different areas.
Community ecosystem diversity	The number of plant–animal associations or communities throughout an entire naturally or artificially defined region.

Sources: Caughley and Gunn, 1996; Graham and Fine, 2008; Primack, 1995.

methods, is revealing that the true diversity is masked by not distinguishing among cryptic and closely related species. Moreover, the use of phylogenetic relationships among populations provides the opportunity to determine genetic changes across landscapes, both within individual species and among communities (e.g., phylobetadiversity; Table 14.1). The biodiversity crisis has imposed urgency on the documentation of the world's biota, and the rate of discovery of new organisms seemingly has accelerated. For example, Brazil has the richest amphibian fauna in the world with 776 species, 50% of which have been described in the last 40 years; in addition, many species are undiscovered or undescribed.

The biodiversity crisis is characterized by the loss and reduction of diversity within all three levels previously described. The most extreme loss is the extinction of a species. Extinction is a natural process and occurs continuously; however, the crisis we now face is occurring because the rate of extinction, that is the number of species lost per unit time, has greatly exceeded the normal rate. In addition, the breadth of extinctions has broadened, encompassing all sizes and types of organisms. Normally, extinction occurs at a slow pace and the number of species that disappear equals or is slightly fewer than the number of new species that appear. This gradual accumulation of species through time results in increasing diversity. The current phenomenon of rapid decline of the world's biodiversity has characteristics of a geologically ancient mass extinction event, where thousands of species are lost in a short period of time. Mass extinction is a catastrophic event; those documented from the fossil record have losses of more than 30% of the species. An estimate of 96% loss of species has been proposed for the mass extinction event at the end of the Permian. Although that estimate may be high, a 50% loss is not a high estimate for that event. If one of every two species disappears, species interactions and ecosystems change drastically. Conservationists are concerned about the loss of diversity because a high rate of extinction might lead to a cascading extinction event in which the loss of one species causes the loss of multiple species. No matter how resourceful we humans are, the human species cannot be assured that it will survive a mass extinction because the complex interactions among species that support our global food supply are at risk.

Genetic Studies in Conservation

The use of modern molecular methods in the study of conservation has advanced considerably in the last decade. These methods have revolutionized many aspects of assessment of the health of amphibian and reptile populations. Certain methods are applicable for the determination of population- and species-level genetic diversity, whereas other methods are suitable for understanding causes of declines, including habitat loss and disease or pollution. The most common type of DNA sequencing used today for amphibian and reptile studies is PCR-based sequencing. The number of base pairs that can be read on gene sequences depends on the size of the DNA fragment sequenced, the number of individual sequences, and the number of samples that are sequenced. Consequently, the instruments used have a huge impact on the number of base pairs read. PCR-based sequencing is limited to about 1000 base pairs. However, next-generation sequencing, including pyrosequencing and sequencing-by-synthesis that are beginning to be used in genomic studies can generate as much as 80–120 billion base pairs of data in a single run. Thus, use of next-generation sequencing could greatly increase the amount of genetic data available for diversity studies, and the costs have come down enormously.

In recent years, genetic studies have become increasingly common for assessing new species and species complexes, leading to a much better understanding of diversity. Numerous cryptic species have been revealed with the use of genetic techniques. In addition, large studies using genetic methods to reveal phylogenetic relationships have led to the recognition of 44 families of frogs, compared to 17 families a decade ago. In his 1993 herpetology textbook, George Zug recognized 16 lizard families, four amphisbaenian families, and 15 snake families. Not only have phylogenetic relationships of squamates changed radically as the result of molecular analyses, 43 recognized families of lizards (with amphisbaenians included) and 23 families of snakes are now recognized. As an example of how rapidly new taxa are being discovered, a recent paper by Blair Hedges and Caitlin Conn describes an entire skink fauna from the Caribbean islands that included 61 species in 16 genera. Thirteen of the genera are new! Molecular data contributed considerably to the ability to discern these taxa. A much better understanding of the number of species and their relationships will be invaluable for conservation decisions.

Landscape genetics is a relatively new field that attempts to understand how landscape variables influence genetic variation. Some topics addressed by landscape genetics include identification of barriers to gene flow, determination of source–sink populations and movement corridors, and examination of spatial scales (Table 14.2). The most commonly used molecular markers in amphibian and reptile studies are microsatellites. Much emphasis has been placed on amphibians, partly because the reliance of most species on water for breeding makes it relatively easy to identify discreet populations. In most studies, amphibian populations vary in genetic structure from place to place. In many instances, topographic features act as barriers to gene flow. For example, mountain ridges and elevation affect gene flow in Columbia spotted frogs (*Rana luteiventris*). Some other amphibians do not

TABLE 14.2 Examples of Use of Landscape Genetics in Amphibian and Reptile Conservation Biology

Taxon	Focus of study	Sources
Salamanders		
Ambystoma macrodactylum	Effective population size	Funk et al., 1999
Ambystoma macrodactylum	Altitude and topography	Giodano et al., 2007
Ambystoma macrodactylum sigillatum	Topography	Savage et al., 2010
Ambystoma maculatum	Dispersal, connectivity	Zamudio and Wieczorek, 2007
Ambystoma tigrinum melanostictum	Landscape genetics	Spear et al., 2005
Frogs		
Rana luteiventris	Population structure	Funk et al., 2005
Rana temporaria	Landscape structure	Johannson et al., 2008
Rana chensinensis	Topography	Zhan et al., 2009
Ascaphus truei	Protected vs. managed forests	Spear and Storfer, 2008
Ascaphus truei	Disturbance	Spear and Storfer, 2010
Epidalea calamita	Connectivity	Stevens et al., 2004, 2006a,b
Rhynchocephalians		
Sphenodon punctatus	Effects of habitat modification	Moore et al., 2008
Squamates		
Uta stansburiana	Habitat	Delaney et al., 2010
Sceloporus occidentalis	Habitat	Delaney et al., 2010
Plestiodon skiltonianus	Habitat	Delaney et al., 2010

appear affected by even fairly major topographic features. The Chinese wood frog *Rana chensinensis* lives in steep mountain ranges that would appear to serve as major barriers to gene flow. Aibin Zhan, Cheng Li, and Jinzhong Fu found relatively low genetic variation among populations from 10 central sites in the Tsinling and Daba Mountains over a distance of more than 300 km. Most of the variation was within sites. In this case, the mountains do not present significant barriers to gene flow. Apparently, production of large numbers of offspring (up to 2000 eggs), high availability and connectivity of breeding sites (small streams), and high mobility of frogs account for the low variation among sites, creating sufficient gene flow to counter population differentiation.

The tuatara *Sphenodon* is restricted to islands off New Zealand, and is the only remaining genus of a once diverse reptile clade, the Rhynchocephalia. Its habitat has become fragmented into remnant forest, regenerating forest, and grassland pasture sites. Fine-scale genetic structuring exists within an island population and is driven by recent habitat modification. Because these reptiles are extremely long-lived, maintain a large population size, have a simple social structure, and disperse randomly, fine-scale genetic structuring would seem unlikely. Nevertheless, these factors do not appear strong enough to counteract the genetic structure caused by a sedentary lifestyle. Fragmentation may have similar effects on other species that are highly sedentary.

Genetic studies are valuable for understanding the spread of infectious diseases as well. Knowing whether spread of a virus is recent or occurred long ago has conservation implications in that the source agent spreading a recent virus might be controlled. As one example, *Ranavirus* is one of two genera of Iridoviridae known to cause an emerging disease in amphibians. J. K. Jancovich and colleagues isolated and amplified DNA fragments from 17 sites where salamander (*Ambystoma* of several species) die-offs had occurred; an isolate from a bait shop salamander was also used. From these samples, a gene genealogy of iridoviruses was obtained, showing that the salamander ranaviruses were monophyletic and probably the result of a single introduction that recently spread. Human involvement was suggested because the salamander ranaviruses were more closely related to those found in sport fish than to

other amphibians and may have resulted from a host switch from fish to salamanders. In addition, the isolate from the bait salamander was nearly identical to a strain found in salamanders near a Colorado state park. The use of tiger salamanders as fish bait, a multi-million dollar industry, is prohibited in some but not all western states and could have been responsible for spreading the ranavirus. Additional studies using genetic techniques and other experiments are needed to distinguish between these hypotheses.

HUMAN IMPACT ON AMPHIBIAN AND REPTILE COMMUNITIES

Humans have modified the environment everywhere. Such a comment may seem to be an exaggeration, but it is not an overstatement (Fig. 14.3). Globally, our activities have resulted in a rising average annual temperature and in a rise in ultraviolet radiation at the Earth's surface. These climatic effects are only one facet of our environmental alteration, which ranges from global climatic changes to the local loss of a marsh or a patch of forest. All alterations, even those occurring in polar regions, can affect amphibians and reptiles. Scientists are currently alarmed at the increasing melting rate of polar ice sheets as the result of human activity. The resultant rising sea levels will affect amphibians and reptiles in coastal and low-lying areas.

Habitat Modification, Fragmentation, and Loss

Habitat alteration and loss is the most visible human-mediated environmental change. Prehistoric human populations began the process by setting fires to catch game, thereby expanding grasslands and savannas at the expense of forest. The rise of agriculture converted grassland and forest into farms and gardens. The conversion of natural landscapes continues. At the end of the twentieth century, the world had 24 megacities, defined as urban areas with

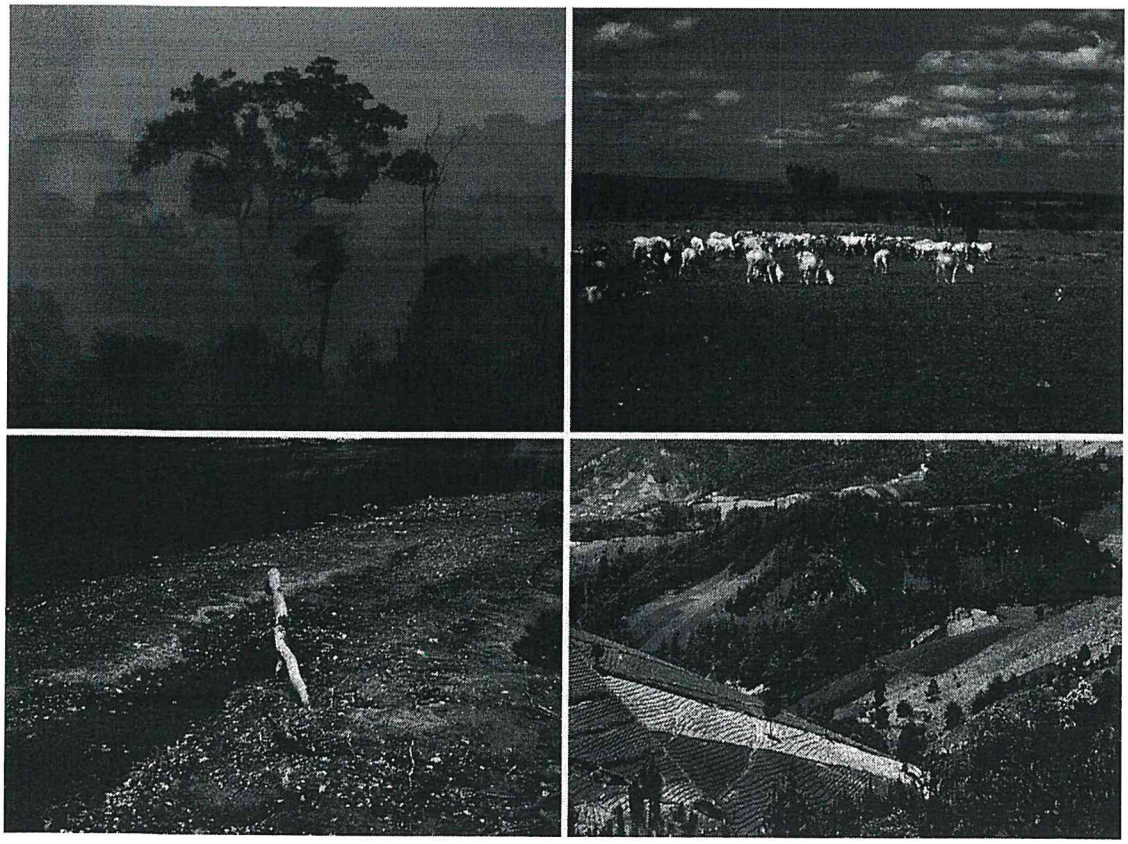

FIGURE 14.3 Disturbed and fragmented habitats. Clockwise from upper left: Tropical Amazon rainforest during the burning season (August) of 1987 in central Rondônia, Brazil—no rainforest remains in this area today (*L. J. Vitt*); desertification in progress due to overgrazing by goats in northern Kenya (*C. K. Dodd, Jr.*); former Guatamalan cloud forest (ca. 2000 feet elevation) converted to agriculture (*C. K. Dodd, Jr.*); stream (Lost Creek) in Alabama degraded from coal mine runoff. The federally protected flattened musk turtle lived in the stream (*C. K. Dodd, Jr.*).