1 Introduction

Aldo Leopold is generally accepted as providing the philosophical basis for wildlife management in the United States. Leopold was trained and employed initially as a forester, and the academic and disciplinary home of wildlife management in the early years was aligned with forestry. But over time, due to the need to be recognized as a discipline in its own right, wildlife biology and management diverged from the forestry profession and in recent years the views of some wildlife professionals have been at odds with views expressed among some forestry professionals. This book is an attempt to bridge the disciplines of wildlife habitat management and forest management. It provides the conceptual bases for stand and landscape management so as to achieve habitat objectives for various species and communities and also provides case studies from across the United States to illustrate how these concepts can be applied. By providing the foresters with an explanation of concepts of habitat selection, habitat relationships, habitat elements, element dynamics in stands and landscapes, habitat permeability, connectivity, and exogenous pressures (climate change, invasive species, development), they can understand how these factors would influence the decisions made during stand and forest management. Further, biologists are provided with explanations of stand and forest landscape dynamics, silvicultural approaches to providing habitat elements, and harvest planning. Case studies in each section of the book provide examples of how these concepts can be applied to achieve habitat goals at stand, landscape, and regional spatial scales. Finally, the information culminates in stand prescription development and forest planning—key prerequisites to sustainable management practices. In addition, this planning process must include the concerns and objectives of various stakeholders. Foresters and wildlife biologists MUST work together, cooperatively, with these concerned publics to ensure that management approaches are adaptable to the inevitable social changes and to the competing demands for ecosystem services and aesthetic qualities of forests while also ensuring that current decisions are not likely to forgo future options.

WHAT IS HABITAT?

Despite the need to work together to achieve mutual goals across forested landscapes, the language of disciplines can simply interfere with success. Throughout this chapter I will try to define terms that could be confusing or misinterpreted between the disciplines. For instance, a brief search of the web using the search terms "forest wildlife habitat" produced 356,000 hits, including the following quotes from resource professionals: "In recent years, an increasing number of landowners have realized the economic importance of timber management as a way to enhance wildlife habitat." Moreover, another quote states that "Several practices have damaged the wildlife habitat, including habitat fragmentation; past roads, excessive logging and development all worked to fragment large areas of intact habitat." So who is correct? All 356,000? Well, yes and no. We cannot understand how to manage the forests to provide habitat for wildlife species, or more generally for biodiversity, unless we understand what habitat is and is not. But first, what is wildlife? It is important to first recognize that it is not a singular noun, but rather a plural one. Wildlife encompasses many species. To think of wildlife as one thing is making the mistake of considering us (humans) and them (all other species) as two separate groups—we are all in this together, we people and other species. Biodiversity goes beyond the collection of animals that we often perceive as wildlife to include all forms of life—plants, animals, microbes, and all the bits of the Earth that support them. Leopold (1949, p. 147) suggested that "…to keep every cog and wheel is the first precaution of intelligent tinkering." Save the pieces. In our efforts to manage forests to meet wildlife and biodiversity goals, the pieces are the species and the resources are what those species need to survive and reproduce. So let us think about what a species needs as habitat.

Habitat is the place where a species lives. It includes the physical and biological resources necessary to support a self-sustaining population. Each species and each population has its own habitat requirements (Krausman 1999). References to "wildlife habitat" are meaningless, therefore, unless a particular wildlife species is identified because everything is habitat for something. Krausman (1999), Hall et al. (1997), and Garshelis (2000) have made compelling arguments for clarifying the confusion that results from using the term "habitat" to mean the vegetation types or other classes of the environment that are not directly related to a particular species.

Although habitat has been defined in many ways, I define habitat as the set of resources necessary to support a population over space and through time. Hence every species has its own habitat needs, and the term "wildlife habitat" has little real meaning. Further, this definition focuses on populations and not simply individuals. *Populations* are self-sustaining assemblages of individuals of a species over space and through time. Communities, by contrast, are assemblages of populations over space and through time. This definition of habitat is consistent with the approach taken by Hall et al. (1997), but Garshelis (2000) makes the point that quite often foresters and wildlife biologists both will refer to vegetation types or other discrete classes of the environment as habitats. More accurately these are *habitat types* or *cover types* in that some species can be associated with some vegetation types and not with others. But these associations occur only because some or all of the resources needed by the species occur in those types. Consequently, it is important to think about how habitat functions to provide those resources to each species.

Habitat Function

It is useful to think of habitat meeting not only an individual's needs but also a population's needs. It is, after all, the population that can be sustained. Individuals, though clearly essential to population maintenance, just come and go in the process. Just as you and I come and go in the process of maintaining a human population. A number of things drive the success of a population, especially energy. Although nutrients, water, and other factors clearly have a role in maintaining the fitness of individuals and populations (e.g., Jones 1992), the lion's share of the system is driven by energy. A population gains energy from food resources and conserves energy by exploiting cover resources (Figure 1.1).

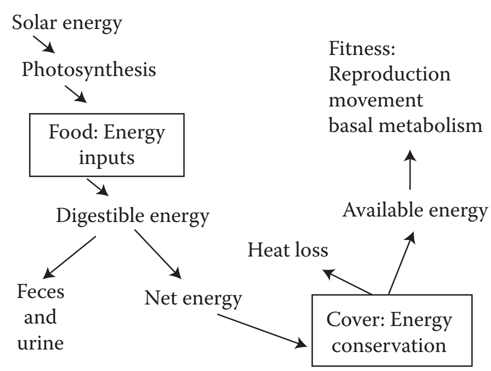

FIGURE 1.1 The concept of energy flow through individuals to influence individual and population fitness. (Based on Mautz, W.W. 1978. *Big Game of North America, Ecology and Management*. Stackpole Books, Harrisburg, PA, pp. 321–348; adapted from McComb, W.C. 2001. *Wildlife Habitat Relationships in Oregon and Washington*. OSU Press, Corvallis, OR.)

Energy is the currency for population sustainability. Give it more and the population will grow; give it less and the population will decline. When an individual goes energetically bankrupt, he dies. When a population goes energetically bankrupt, it goes extinct.

Food provides the source of energy (and nutrients) for individuals and populations. Food quality matters. Tree species vary in their ability to provide protein and carbohydrates to herbivores. Some parts of plants are more digestible than others and some plant species are more digestible than others (Mautz et al. 1976). It is this digestible energy and the net energy remaining after digestion and metabolism that influences the fitness of individuals and populations. But fitness, the ability to survive and reproduce, is also influenced by cover quality.

It is advantageous for an animal to conserve any energy that it acquires. Mammals and birds maintain a constant body temperature and expend a large amount of energy to maintain that temperature. Cover provides a mechanism for conserving energy. The *thermal neutral zone* is the range of ambient temperatures where an animal has to expend the least amount of energy maintaining a constant body temperature. Thermal cover places the animal closer to the thermal neutral zone. Energy expenditures are minimized in an animal's thermal neutral zone to maintain body temperature (Figure 1.2, e.g., Mautz et al. 1992).

Any departure from the thermal neutral zone results in increased expenditure of energy; so animals often select habitat that reduces climatic extremes. There are upper and lower critical temperatures beyond which exposure for a prolonged period would be lethal. Cover from overheating is especially important to large animals with a low surface-area-to-body-mass ratio because they may find it particularly difficult to release excess heat unless water is available to aid in evaporative cooling. Cover from severe cold is especially important to a species with a high surface-area-to-body-mass ratio (e.g., small birds and mammals). Cover that allows an animal to stay within an acceptable range of temperatures (particularly those that approach the thermal neutral zone) is important to maintaining a positive balance of net energy and hence influences animal fitness. For instance, imagine yourself standing in a field wearing summer clothes in mid-January in Minnesota. Without any measurements, you know that you are expending a significant amount of energy to stay warm. Now imagine you are in a field in Arizona in August at noon. You must expend energy to stay cool and not let your body temperature rise too high (e.g., heat stroke). In either case, moving into a building where the temperature is 18°C (65°F) allows you to spend less energy keeping your body at the appropriate temperature. Refer to Figure 1.2 and plot the metabolic rate for a small mammal or bird at a low temperature and then the metabolic rate for a temperature near the thermal neutral

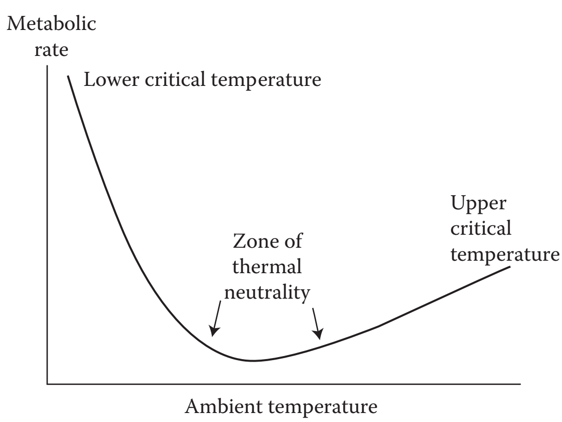

FIGURE 1.2 Relationship between metabolic rate and ambient temperature in a hypothetical mammal. (Based on Gordon, M.S. 1972. *Animal Physiology: Principles and Adaptations*, 2nd ed. The MacMillan Co., New York, 591 pp.; adapted from McComb, W.C. 2001. *Wildlife Habitat Relationships in Oregon and Washington*. OSU Press, Corvallis, OR.)

zone. The difference in metabolic rates along the *y*-axis is an index to the amount of energy that the individual can conserve by staying closer to the thermal neutral zone. For a small animal with a high metabolic rate and high surface area to body mass that conserved energy can mean the difference between life and death on a cold winter night. But there are both behavioral and physiological adaptations that some species have to further conserve energy. Southern flying squirrels (see Appendix 1 for a list of scientific names of all plants and animals used in this book) and some species of cave-dwelling bats often will use communal roosts in winter to collectively maintain a lower surface-area-to-body ratio. Flying squirrels pack many small bodies together to make one bigger, more energetically efficient big body by huddling (Merritt et al. 2001). Other species such as eastern chipmunks hibernate or, as in the case of striped skunks, enter a state of torpor where metabolic rates are reduced and energy is conserved. Black-capped chickadees, a small, 10-g bird that spends winters in very cold climates, will cache food, roost in cavities, and alter their metabolic rates seasonally to cope with temperature extremes (Cooper and Swanson 1994). So the effects of conserving energy through use of thermal cover can be improved even more by these physiological and behavioral mechanisms.

But the relationship portrayed in Figure 1.2 is different for species that do not maintain a constant body temperature. Most reptiles, amphibians, and some nestling birds (birds that have not yet fledged) do not use large amounts of energy to maintain a constant body temperature. They are *ectotherms*—they receive most of their body heat from the surrounding environment, unlike *endotherms* that generate their own body heat. For ectotherms, metabolic rates and food requirements vary as ambient temperature varies. The evolutionary advantage of such an approach is that these ectotherms require less food to survive, but they can be restricted from extreme environments that otherwise would be inhabitable by endotherms (some bird and mammal species). Hence, reptiles and amphibians often use cover to adjust the ambient temperature to allow them to survive, reproduce, and move in places and times when they otherwise would be unable to (Forsman 2000). Consequently, cover is an important component of habitat for these species, to both conserve energy and place them at a temperature where they can be active.

Cover can also refer to the portion of habitat that an animal uses for nesting and escaping from predators. The most significant loss of energy by an animal is conversion of its energy into the energy of its predator! Hiding cover protects an animal from predation. Cottontail rabbits often spend resting hours in dense shrubby cover adjacent to grassy fields and meadows (Bond et al. 2001). The dense shrub cover protects them from predation by red-tailed hawks whose body size and wing spread do not allow them to penetrate dense vegetation. Simple modifications to habitat such as allowing shrubs to proliferate along field edges can lead to increased survival and increased population growth for cottontails in this example.

Nesting cover provides the conditions necessary for raising young—appropriate temperature and protection from predators and competitors. The effectiveness of nest box programs for wood ducks, eastern bluebirds, and other cavity-using species demonstrates that manipulation of the quantity, quality, and availability of nesting cover resources can be an effective management technique (McComb and Lindenmayer 1999). Forest managers can influence habitat for a species by altering food quality, quantity, and/or availability while also altering the quality, quantity, and/or availability of cover. This strategy can lead to drastic changes in habitat quality for the species.

Water is differentially important to animal species. Some species require free water or high humidity (mountain beaver, e.g., have a primitive uretic system) (Schmidt-Neilsen and Pfeiffer 1970). Others species obtain most of their water from their food (e.g., pocket gophers). Some species use water as a form of cover to enhance evaporative cooling (e.g., elk) or to escape predators (e.g., white-tailed deer). Still others such as amphibians require free water or moist environments for reproduction.

The size of habitat is also an important determinant of its suitability for a species. A patch of habitat must be sufficiently large to provide energy inputs and energy conservation features to sustain a population. Habitat may occur in one large unit, but more commonly it is distributed in patches embedded in other less suitable patches. If these habitat patches are too widely distributed, then the animal expends more energy moving among patches than it receives from those patches. The amount of habitat and its quality and distribution are therefore interrelated. Increasing any one or all of these attributes of habitat increases the net energy available to animals that use this energy to maintain body temperature, move to food and cover, and reproduce.

Habitat for Humans

When trying to understand the concept of habitat, it may be helpful to think of your habitat. You are an individual of a species, a mammal that maintains a constant body temperature, and you have your own set of resources that you need to survive and reproduce. Think about your food requirements. You eat a certain number of calories per day and this energy is converted to adenosine-tri-phosphate (ATP) or stored for future use. You use this energy to maintain your body temperature and support your physical being, to move throughout the day from place to place, to raise your children, and to buy or harvest food. Generally human food is rather digestible and high in energy, though in some societies digestible energy can limit not only human health but also survival.

Humans, like most other mammals, also use cover. We have homes where we attempt to keep the ambient temperature as close to our thermal neutral zone as possible. We raise our children there and we use these homes at times as a place of refuge during inclement weather or catastrophic disturbances. We need clean water in adequate quantities so as not to become dehydrated. All of these things must be in close proximity so that we do not spend more energy-acquiring resources than we receive. Substitute nearly any other animal species and we can similarly define the food, cover, and water requirements for that species as we can for our own species. But for each species those requirements differ. No two species are likely to coexist and have the same habitat requirements for very long if resources are limited and species are competing for them. There are instances however when predation pressure on two prey species can allow them to coexist using the same resources, but if predation pressure changes or resource availability changes, then one species will likely outcompete the other (McPeek 1998). Because we humans are so adaptable and because we usurp energy and other resources that could be used by other species, we have a profound effect on the number of species and individuals with which we share this planet. “Saving all the pieces” comes at a price. And it is not a price that society is willing to pay in all instances. There are 7 billion people, which represents 455 million tons of human biomass that must be supported daily on this planet. And two more people are added every second. Saving all the pieces may be a noble goal, but human self-preservation and preservation of life styles can trump that goal quickly, unless we give more thought to our own habitat needs within the context of the needs of the other species with which we share this planet.

FORESTS AS HABITAT

How we manage forests to partition energy among various forms of life is the essence of the challenge facing foresters and wildlife biologists. It is a challenge because the rate of primary production is fixed over large areas and times, because there is a solar constant, and because climate changes are relatively slow (the current climate change crisis not withstanding). Further, although herbivores in forests exist in a sea of plant energy, little of it is available for those herbivores to use. Food quantity is often not as important as food quality in a forest (Mautz 1978). Most of the energy in a forest is in cellulose, the wood that society demands, and for many species this wood is not very digestible. Animals can only use the *digestible energy* in food (Figure 1.1); so indigestible portions of food (e.g., cellulose, lignin, chiton, or bones) or compounds in the plants that inhibit digestion (tannins and other phenols) reduce food quality (Robbins et al. 1991). These indigestible portions of a forest can become available as energy to many species if they are made available through decomposing organisms (Figure 1.3). Without the decomposers being available as digestible food for other

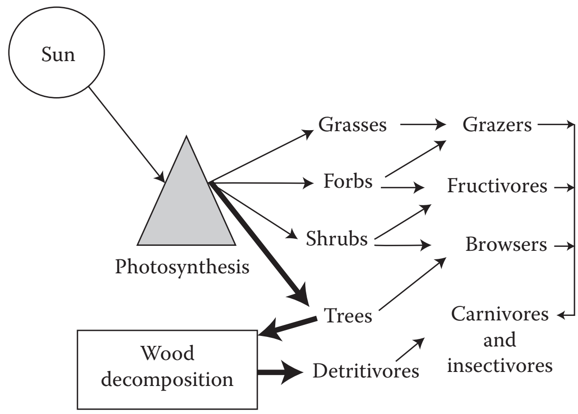

FIGURE 1.3 Energy pathways through a forest. Arrow sizes reflect relative differences in energy availability. (Adapted from Harris, L.D., 1984. *The Fragmented Forest: Island Biogeography Theory and the Preservation of Biotic Diversity*. University of Chicago Press, Chicago, IL, 211 pp.)

species in forests, most of the energy would go unused. Indeed, without decomposers, animal diversity would be reduced to a relatively few species specialized to eating twigs, leaves, fruits, or the nonwoody portions of the forest. The *decomposition pathway* is quite important in maintaining a diverse animal community in many forests. Further, for those species that rely on plant fruits for food, providing plants with adequate sunlight and water to grow and produce flowers and fruits is a key to meeting these food needs.

Historical Approaches to Managing Forests as Habitat

Management of forests as habitat for wildlife has been conducted for centuries in many cultures. Native Americans used fire to at least move animals during hunts if not to provide better forage for them (Boag 1992). But it was not until Leopold completed his *Game and Fish Handbook* for the Forest Service in 1915 and the subsequent publication of *Game Management* (Leopold 1933) that active management efforts began on many public and some private forest lands to promote selected species. There have been two common approaches to management of forests as habitat for species: management of individual species and management for biodiversity. Only recently has the focus of land managers shifted from utilitarian goals to protection of rare species to conservation of entire ecosystems. Indeed, the evolution of wildlife management as a discipline was driven largely by the philosophies underpinning forest management and both disciplines have evolved in parallel with regard to the focus of their management efforts.

Both foresters and wildlife biologists viewed that there is a way to manage species to provide the desired plants or animals in a non-declining, sustained yield manner. Harvest scheduling works for black oaks and black bears—we just need to provide the correct habitat, manage the density of the organisms to provide sufficient resources for the remaining individuals, and the system can go on and on and on. Right? Well, maybe, but by taking this approach there is the risk of losing other species that might be of value to society. Managers began to focus management on indicator species (species that are surrogates for other species) or guilds of species (groups of species with similar habitat needs) in order to meet the needs for many other species. These approaches also produced problems for exactly the reasons described in the previous section: each species has its own habitat requirements and each will respond differently to management activities (Mannan et al. 1984).

But some approach is needed to produce the desired species of plants and animals while minimizing the risk of losing some pieces that we may need later. The most recent approach to managing to meet societal goals of aesthetics, game, biodiversity, recreation, and timber fall within the realm of *ecosystem management*—an approach designed to minimize risk to species and maximize the likelihood that the approach will be sustainable (Meffe et al. 2002). One basis for this approach recognizes that forest disturbances change the abundance of individuals in many populations, and those changes also influence the composition of plant and animal communities. Before technologically advanced humans began managing forests, natural disturbances caused the localized extinction of some species and opportunities for recolonization by others. Communities changed as forests regrew following these disturbances. Species tended to be adapted to the range of conditions that occurred under these natural disturbance conditions. Understanding how species respond to these conditions and how management might replicate or depart from those conditions can be useful in understanding the effects of management on a suite of other resources (Landres et al. 1999). In addition, consider that the management of an individual species has consequences for other species in its community. Forest disturbances that benefit black-tailed deer, for example, probably would benefit creeping voles and orange-crowned warblers, two species found in early successional forests, but not Douglas squirrels or pileated woodpeckers, two late-successional forest species.

Natural disturbances such as fires, insect defoliation, and hurricanes notwithstanding, vegetation management by forest-land managers is probably the greatest factor influencing the abundance and distribution of animals in our forests today. By understanding the concepts of habitat function, population change, and habitat patterning, managers can make decisions that can find the appropriate societal balance among commodities, species, and ecosystems.

Why Manage Habitat?

We manage habitat for various reasons such as personal goals, corporate objectives, and legal requirements. Policies in the United States, such as the Endangered Species Act and National Forest Management Act, require people in various agencies to manage habitat. Why do we have these policies? Why should we spend time and money managing habitat for species that occur in our forests? Quite simply we do or do not manage habitat because society either cares about these resources or they do not, respectively. Wild animals are public resources that occur on both public and private lands. If society placed no value on a species or group of species, then we would not manage their habitat. Values that society places on animals evolve over time and from culture to culture. Take the beaver for example (Figure 1.4). Clearly, there are many reasons to manage habitat for beaver,

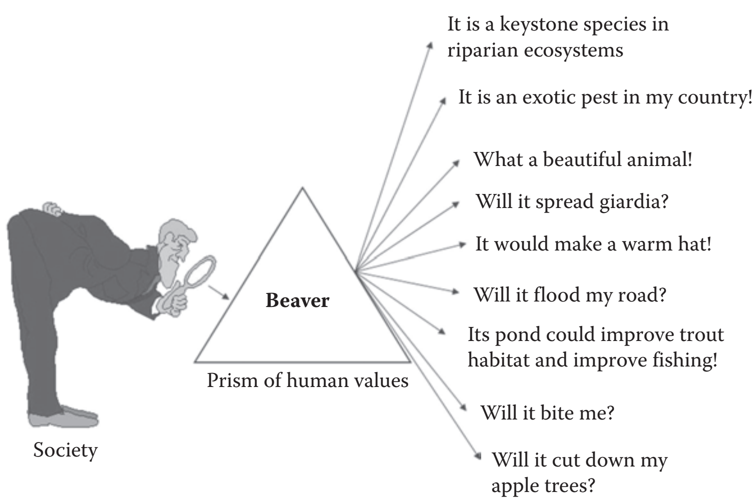

FIGURE 1.4 Society views natural resources through a prism of values. (Based on discussions with R.M. Muth, University of Massachusetts, Amherst, MA.)

though some segments of society would like to ensure that there are fewer animals and some would like more of them. To complicate matters further, oftentimes people with differing values are neighbors and the beavers do not care where the property line falls!

These values placed on a resource usually change slowly as other aspects of our society change. In some cultures, the species may be viewed as an important economic or otherwise subsistence resource that would be harvested and used for survival. As society becomes less reliant on or less engaged with native species, people may begin to place greater intrinsic value on them or fear them because they are unknown. Finally, the relative importance of a species may change markedly and rapidly as unexpected events occur, leading to rapid changes in societal values that have unanticipated impacts on our ability to manage natural resources. On September 11, 2001, on a west-bound United flight from Hartford to Denver, I was somewhere over Lake Erie at 9:15 a.m. eastern time. I was fortunate to have spent a week in Chicago rather than other alternatives that morning. Those events changed our society's priorities suddenly. They certainly changed mine. Although it did not necessarily diminish the importance that people placed on environmental values, it raised human safety and welfare to a much higher priority than previous to that event. Human and financial resources once used to provide natural resource values for our society were diverted to these higher priorities. We saw a similar response following hurricanes Rita and Katrina in 2005. One can argue that the political decisions were made at the time to achieve ideological as well as humanitarian goals, but changes did occur that impacted many aspects of our ability to meet natural resource and environmental quality goals for society. We are not alone in these struggles.

Overwhelming economic pressures face many parts of the world. Huge loans have been provided by the International Monetary Fund (IMF) to countries such as Argentina. These debts to the IMF, combined with the overwhelming pressure to ensure that people survive on a limited and often declining natural resource base, significantly limit options to maintain environmental values. Forest reserves, popular approaches to biodiversity conservation in wealthy countries and recognized as important by developing countries, are usually an untenable option in much of the world unless significant foreign monetary support is provided. Even so, reserves become only one approach to protecting biodiversity. Indeed, the majority of the land and water resources that could support some components of natural systems are not within reserves and never will be. Social pressures force managers to consider options that are both economically feasible and ecologically sound. If large tracts of forest are managed in a manner that considers the structure and function of the habitat for valued species, while still allowing some economic value to the landowner, then there is a greater likelihood that it will remain as a forest or field. Once the value of a forest falls below that of other land uses, then there is a risk of conversion to a new use (e.g., industrial agriculture, grazing, or housing).

If the forest is managed to consider structure and function to valued organisms, then it may support these species, which otherwise would be found primarily in reserves, thereby complementing effectiveness of the reserve system. For instance, actions that maintain a forest rather than a pasture that likely would be overgrazed will decrease the probability that the site would be lost to desertification in the dry tropics. Active forest management to achieve multiple objectives such as grazing lands (Figure 1.5a), wood products (Figure 1.5b), and habitat for valued wildlife (Figure 1.5c) may be one step toward maintaining economic and ecological values.

We do not know with certainty how to manage all or even most forests to achieve multiple values. But we do understand vegetation dynamics, disturbance ecology, habitat selection, and population dynamics as well as the influence of local, regional, and global economies, cultural mores, and social value systems. If we use this information in a thoughtful manner, then we should be able to develop reasonable management plans to achieve multiple objectives. However, we will need to monitor the effectiveness of the plans to ensure that we are meeting our goals. This *adaptive management* process (listen, synthesize, plan, implement, monitor, learn, listen, etc.) is an integral part of habitat management (Baskerville 1985). My objective is to provide the concepts, processes, and tools that you can use to develop resource management plans that will help you achieve landowner goals now and into the future.

FIGURE 1.5 In northern Argentina an effort is being made at Salta Forestal to manage native dry tropical forests for grazing (a), wood products (b), and habitat for various species of wildlife (in this case, one of several species of armadillos found in the region) (c) in a manner that helps to support local economies while conserving biodiversity.

CASE STUDY: THE FORESTS OF BRITISH COLUMBIA

Society directs the way that forests are managed. Over the past 100 years, we have seen marked changes in the principal values associated with forests in nearly every technologically advanced culture. Changes in values and beliefs associated with forest management have followed somewhat parallel courses in the United States, Canada, New Zealand, and Australia, though at different times. The following example is extracted from a paper by Kremaster and Bunnell (1998) and reflects those changing values associated with forest management in British Columbia (BC). Forests in BC extend from the subalpine region of the Canadian Rockies to the boreal forest in the north and south through temperate rainforests along the Pacific Coast to pine forests of the Interior. BC's forests cover an area twice the size of all of the New England states and New York State combined. The forest products industry has been and continues to be very important to the provincial and national economy.

The remaining text in this case study is paraphrased from Kremaster and Bunnell (1998) to illustrate these social changes. "Until the 1940s, forests in British Columbia were seen as inexhaustible suppliers of timber. It was not until after World War II that attention is focused on sustainable forestry, and the public began to expect foresters to grow trees and continuously provide timber over the long term. Major concerns at that time were fire protection and the decline in timber volume as old growth was converted to managed stands. Foresters were expected to manage economically valuable tree species to ages well short of the potential life span of the species.

Wildlife concerns in the first half of the 1900s focused primarily on game species and fish. During the late 1960s and in the 1970s, foresters began to embrace the paradigm of 'multiple use' or managing for many values on each piece of land. In BC, legislation that was passed recognized that many resources were provided by forests and all were important to its citizens. This idea of multiple use remained in place through the mid-1980s. Wildlife concerns expanded to include nongame species, but attention was still focused mainly on game and fish species. Forest guidelines protected unstable soil and some streams, but growing trees and protecting live trees from insect and fire were the main concerns reflected in management guidelines.

During the late 1960s and in the 1970s, silvicultural systems focused on producing and recovering the maximum amount of economic fiber from the forest. Along the Pacific coast, clearcutting was the dominant practice, even as interest in forests expanded beyond trees alone (Figure 1.6).

FIGURE 1.6 Example of timber harvest in a watershed commonly seen in BC and Alaska in the 1970s.

Typical rotations (the interval between harvests) increased the area of early stages of natural succession and truncated succession well short of tree ages in historical forests. Research began to document changes to wildlife species assemblages associated with various stages of forest development. It was recognized that managed and unmanaged forests change over time in response to natural and human-induced disturbances, and that different vertebrate species were more abundant in different stages of forest development.

Products and values desired from forests have continued to change. Although many people still embrace the notion of multiple use, there is general realization that a given piece of land, unless enormously large, cannot provide all desired, and sometimes competing resources. The current scientific perception is that all parts of the ecosystem are linked and activities that affect one aspect of the system will likely affect others. The current management focus is on managing ecosystems, sustaining biodiversity, and maintaining forests more like historical ones. These approaches are in response to current public concerns, which include loss of species, productivity, future options, and economic opportunities. Sustaining biodiversity has become a fundamental goal. Forest practices and policies have continued to change. Scientists and managers have translated public concerns and their own improved understanding of forest systems into new approaches. Social concerns as well as long time periods and large areas were incorporated into the concept of 'ecosystem management.' Concerns about losing species and productivity impelled policy makers to create legislation (e.g., BC Forest Practices Code [FPC]), integrate recent scientific knowledge (e.g., Scientific Panel for Sustainable Forest Practices in Clayoquot Sound [CSP]), and initiate new approaches to planning (e.g., Innovative Forestry Practices Agreements). Legislation and planning try to include recent knowledge but policy continues to precede reliable knowledge.

Legislation and planning processes have been enacted to translate public and scientific concerns into different forest practices. With the advent of the FPC in BC, foresters have a legislated responsibility for sustaining biological diversity when compared with other natural resource managers. Regulations governing agricultural and urban development do not reflect the same concern for maintaining ecosystems, even though these activities have had a greater impact on biological diversity.

The FPC has encouraged less clear-cutting and promoted a range of retention during even and uneven-aged management. Retention of older stages of forest development, maintaining connectivity, and protecting buffers around several stream classes are now legislated. The levers used in FPC regulations reflect forest features that we believe are related to biodiversity and ecosystem productivity. Managers are limited to practical approaches—for example, remove snags or let them stand, and leave live trees to grow old or harvest them at an economic rotation. As a result, these levers include stand structures such as snags, downed wood, species mixtures, and large old trees, and forest-level measures such as seral stage distribution, amount of edge, forest interior, patch size, and corridors. Fortunately, these attributes link to public concerns and to species richness. To evaluate the effectiveness of these approaches, forest managers need to know 'How much is enough of specific forest elements?', 'What spatial patterns are important?', and 'Which species are likely to need more individualized approaches?'"

This example from BC has been repeated in many parts of the United States, Canada, New Zealand, Australia, and elsewhere. And now in BC, as well as in many other parts of the world, climates are changing as are increases in insect defoliators and risk of fire. Saving all the pieces may take considerable effort and active management on at least part of the landscape if species are to persist in landscapes structured by recent timber harvest and facing new environmental conditions. Clearly, social values have shifted to concerns regarding biodiversity conservation, and the management concepts and approaches used by biologists and foresters should reflect those concerns.

SUMMARY

Habitat is the set of resources necessary to support a population over space and through time. It is a species-specific concept and is different from a habitat type or cover type, which is often a classification of the environment that may or may not be related to the resources necessary to maintain fitness or an individual, a population, or a species. Food represents the inputs of energy and nutrients. Digestible energy is not as available to many vertebrates in forests unless indigestible cellulose is broken down through decomposition. Energy is conserved by a species use of cover. Energy expenditure to maintain a constant body temperature is minimized in the thermal neutral zone; thermal cover allows an animal to provide an ambient temperature closer to the thermal neutral zone. Escape and nesting cover protect an animal from risks of predation or competition.

Habitat was historically managed to increase populations of game species. The focus for habitat management has changed from primarily utilitarian in the mid-1940s in the United States to considering a broad suite of organisms, including endangered species and species enjoyed for their aesthetics. Biodiversity conservation has become the most recent social goal in forest management. Indeed, we manage forests to achieve human needs and desires. Wood products are clearly one reason for managing forests, but providing habitat for desired species, clean water, recreation, and rangeland resources is also paramount. The challenge to private forest landowners is that they are charged with meeting societal goals for a public resource (wildlife) on their private lands. To be effective at meeting both individual and public goals for forests, foresters must work collaboratively with wildlife biologists, conservation biologists, and other resource professionals to develop innovative approaches to forest management. That is the focus of this book.

REFERENCES

Baskerville, G. 1985. Adaptive management—Wood availability and habitat availability. *Forestry Chronicle* 61(2):171–175.

Boag, P.G. 1992. *Environment and Experience: Settlement Culture in Nineteenth-Century Oregon*. University of California Press, Berkeley, CA.

Bond, B.T., B.D. Leopold, L.W. Burger, and D.L. Godwin. 2001. Movements and home range dynamics of cottontail rabbits in Mississippi. *Journal of Wildlife Management* 65:1004–1013.

Cooper, S.J., and D.L. Swanson. 1994. Seasonal acclimatization of thermoregulation in the black-capped chickadee. *Condor* 96:638–646.

Forsman, A. 2000. Some like it hot: Intrapopulation variation in behavioral thermoregulation. *Evolutionary Ecology* 14:25–38.

Garshelis, D.L. 2000. Delusions in habitat evaluation: Measuring use, selection, and importance. Pages 111–164 in L. Boitani and T.K. Fuller (eds.). *Research Techniques in Animal Ecology: Controversies and Consequences*. Columbia University Press, New York.

Gordon, M.S. 1972. *Animal Physiology: Principles and Adaptations*, 2nd ed. The MacMillan Co., New York, 591 pp.

Hall, L.S., P.R. Krausman, and M.L. Morrison. 1997. The habitat concept and a plea for standard terminology. *Wildlife Society Bulletin* 25:173–182.

Harris, L.D. 1984. *The Fragmented Forest: Island Biogeography Theory and the Preservation of Biotic Diversity*. University of Chicago Press, Chicago, IL, 211pp.

Jones, R.L. 1992. Relationship of pheasant occurrence to barium in Illinois soils. *Environmental Geochemistry and Health* 14:27–30.

Krausman, P.R. 1999. Some basic principles of habitat use. In K. L. Launchbaugh, K. D. Sanders, and J.C. Mosley (eds.). *Grazing Behavior of Livestock and Wildlife*. Idaho Forest, Wildlife and Range Exp. Sta. Bull No. 70. University of Idaho, Moscow, pp. 85–90.

Kremaster, L.L., and F.L. Bunnell. 1988. Changing forests, shifting values, and chronosequence research. *Northwest Science* 72(Special issue No. 2):9–17.

Landres, P.B., P. Morgan, and F. J. Swanson. 1999. Overview of the use of natural variability concepts in managing ecological systems. *Ecological Applications* 9:1179–1188.

Leopold, A. 1933. *Game Management*. Charles Scribner's Sons, New York, NY, 481pp.

Leopold, A. 1949. *A Sand County Almanac*, *and Sketches Here and There*. Oxford University Press, New York.

Mannan, R.W., M.L. Morrison, and E.C. Meslow. 1984. Comment: The use of guilds in forest bird management. *Wildlife Society Bulletin* 12:426–430.

Mautz, W.W. 1978. Nutrition and carrying capacity. Pages 321–348 in J.L. Schmidt and D.L. Gilbert (eds.). *Big Game of North America*, *Ecology and Management*. Stackpole Books, Harrisburg, PA.

Mautz, W.W., J. Kanter, and P.J. Pekins. 1992. Seasonal metabolic rhythms of captive female white-tailed deer: A reexamination. *Journal of Wildlife Management* 56:656–661.

Mautz, W.W., H. Silver, J.B. Holter, H.H. Hayes, and W.E. Urban, Jr. 1976. Digestibility and related nutritional data for seven northern deer browse species. *Journal of Wildlife Management* 40:630–638.

McComb, W.C. 2001. Management of within-stand features in forested habitats. Pages 140–153 in D.H. Johnson and T.A. O'Neill (eds.). *Wildlife Habitat Relationships in Oregon and Washington*. OSU Press, Corvallis, OR.

McComb, W.C., and D. Lindenmayer. 1999. Dying, dead and down trees. Pages 335–372 in M.L. Hunter Jr. (ed.). *Maintaining Biodiversity in Forest Ecosystems*. Cambridge University Press, New York.

McPeek, M.A. 1998. The consequences of changing the top predator in a food web: A comparative experimental approach. *Ecological Monographs* 68:1–23.

Meffe, G.K., L.A. Nielsen, R.L. Knight, and D.A. Schenborn. 2002. *Ecosystem Management*: *Adaptive*, *Community-Based Conservation*. Island Press, Washington, DC.

Merritt, J.F., D.A. Zegers, and L. Rose. 2001. Seasonal thermogenesis of southern flying squirrels (*Glaucomys volans*). *Journal of Mammalogy* 82:51–64.

Robbins, C.T., A.E. Hagerman, P.J. Austin, C. McArthur, and T.A. Hanley. 1991. Variation in mammalian physiological responses to a condensed tannin and its ecological implications. *Journal of Mammalogy* 72:480–486.

Schmidt-Nielsen, B., and E.W. Pfeiffer. 1970. Urea and urinary concentrating ability in the mountain beaver, *Aplodontia rufa*. *American Journal of Physiology* 218:1370–1375.