18 Approaches to Biodiversity Conservation

So far, we have focused on habitat management for individual species. For some forest wildlife goals, that is an appropriate approach. Oftentimes, especially on public lands, conservation of the full suite of living organisms present on a site, on an ownership, or in a watershed, is an objective, while also meeting other societal objectives such as potable drinking water, recreation, aesthetics and timber production. By now, you must be asking, "How in the world can we possibly manage forests to conserve the hundreds if not thousands of species that occur within a forest with one owner, let alone multiple owners?" Using a species-by-species approach is clearly untenable. But biodiversity is continuing to decline despite widespread efforts at conservation (Rands et al. 2010).

Logging of forest lands is viewed by many as being incompatible with maintenance of biodiversity. Indeed, unsustainable or illegal logging can have a long-lasting adverse effect on conservation of biodiversity (Rands et al. 2010). To mitigate these effects, Rands et al. (2010) suggested managing biodiversity as a public good, integrating biodiversity goals into public and private decision making, and developing conditions that allow implementation of biodiversity conservation policies. Goals are typically set at large spatial and temporal scales and achieved through multiple local actions. These actions are designed to minimize risk of losing a species while considering uncertainty in our decision-making process (Noon et al. 2009, Schultz et al. 2013). Monitoring of focal species and species of conservation concern is a key part of the biodiversity conservation strategies proposed over United States National Forests, in order to lessen the risk of losing species locally or regionally (Schultz 2013).

WHAT IS BIODIVERSITY?

Scientists define biodiversity as the genes, organisms, populations, and species of an area, and the ecosystem processes supporting them (Figure 18.1). Key principles that are often included in the definition of biodiversity are those of ecosystem structure, composition, and function, occurring at various scales of space and time. Most nonscientists view biodiversity as the collage of species, and many equate biodiversity with those species that are rare and wild. Clearly, for scientists and managers to be effective in meeting the expectations that society has for conserving biodiversity, the collage of species must be addressed. Indeed, some of the most challenging aspects of biodiversity conservation are in deciding how to understand ecosystem complexity and the uncertainty of implementing management while protecting both known and unknown species. Due to the complexity of the problem, communicating approaches to the public is challenging. There is a triad of biodiversity perceptions, biodiversity concepts, and biodiversity assessments (Figure 18.1) viewed by the public, scientists, and managers, respectively, that must be interconnected if we are to successfully address the biodiversity issues. Successful conservation of biodiversity must involve the public and adequately meet public expectations.

Species are usually considered the primary currency of biodiversity conservation. But even conservation of species presents challenges. Rare, threatened, and endangered species garner much attention politically, and species that are hunted or are aesthetically appealing (e.g., songbirds, wildflowers) are often used as focal species or as special interest species when making biodiversity decisions. These are just examples of species that could or should be considered during management.

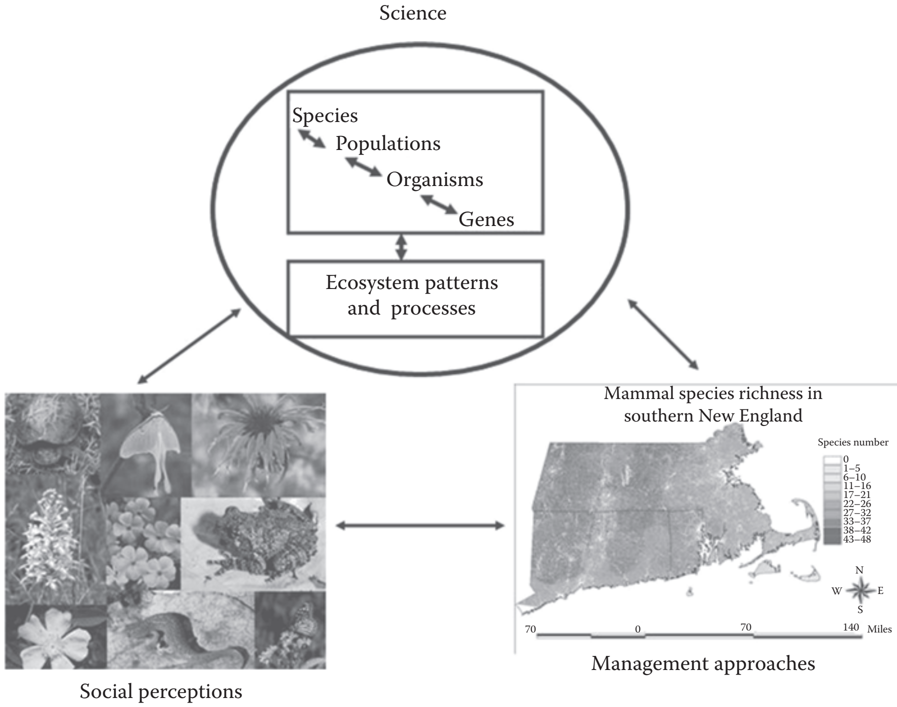

FIGURE 18.1 The scientific concept of biodiversity is a set of processes and conditions that interact to reflect the breadth of life on the planet. Biological complexity is often perceived as a collage of life by nonscientists. (Bottom left; photos by Dr. James Petranka, with permission). Scientific concepts can be used to conserve the collage of life by developing maps of species richness for various groups of organisms. (Bottom right, from Southern New England Gap Program, UMass-Amherst) or by using coarse filter/fine filter approaches (see text).

Mora et al. (2011) estimated that there are 8.7 million species on Earth, of which 6.5 million are terrestrial or found in freshwater systems. Less than 2 million species have been described to date. An approach often proposed, when conserving such a vast array of species, is to use patterns of occurrence for one taxonomic group (e.g., birds) to protect habitat for other taxa (e.g., mammals or amphibians); but this approach does not work very well in many systems (Flather et al. 1997). Of the taxa explored as surrogates for conservation planning, birds, plants, and mammals, seem to hold some promise, but only in certain biomes and only over large areas (Lewandowski et al. 2010, Larsen et al. 2012). There are clear challenges to ensuring that we do not lose biodiversity across the Earth at a rate significantly different from what would be expected if technologically advanced humans did not have such a profound effect on the Earth's resources.

Laikre et al. (2009) found that few nations have biodiversity conservation plans that explicitly consider conservation of genetic diversity, and those nations that did consider genetic diversity were those with a high standard of living. Planners and managers usually assume that genes will be successfully conserved among individuals within a species if we can ensure the long-term viability of populations throughout the geographic range of each species. Policies or actions that eliminate a species from part of its geographic range are assumed to reduce the genetic diversity of the species and increase the risk that the species would be less able to tolerate perturbations to its habitat in the future ultimately leading to extinction (Lomolino and Channell 1995). Two rules of thumb predominate when considering how best to conserve genetic diversity, especially in the face of uncertainty brought on by climate change: (1) maintain large populations and (2) maintain interconnectedness of subpopulations throughout the geographic range of the species (Hendry et al. 2011, Sgrò et al. 2011). We certainly see geographic variation in phenotypes (what an individual looks like), diets, habitat selection, and home range sizes, within many species of vertebrates across their geographic range. A reasonable assumption is that these differences reflect some evolutionary advantage to the species in those places. Very rarely have these assumptions been tested (Lomolino and Channell 1995). But populations fluctuate in size and connections come and go, depending on disturbances and regrowth, so following a precautionary principle of conservation (including active management where and when it is needed) in deference to consumption may be a reasonable strategy for conserving genetic diversity within and among populations.

SETTING BIODIVERSITY GOALS

Most biodiversity objectives reflect the paraphrased text of Aldo Leopold: "…the first rule of intelligent tinkering is to save all the pieces." Indeed, the pieces are the genes, organisms, populations, species, and supporting ecosystem processes (Figure 18.1). These are the very things that are implicitly part of the integrated filter approach to biodiversity conservation. The key word in this quote is "all" and the phrase begs the question, "How much of each?" The answer, obviously, is "Enough!" Saving all the pieces is a noble goal. Indeed, it is a rule of thumb for people who care about seeing the collage of life on this planet persist for future generations to enjoy. But these people are only part of society. Indeed, in some societies, cultures, and places, this group may well be in the minority. Or society may embrace the noble goal of saving all the pieces, but it may follow that by asking how much is enough? And at what price will it be provided? Take for instance the recovery of wild stocks of salmon in the Pacific northwest of the United States. Years of research indicate that there probably are some key factors all working together to cause wild salmon stocks to be at less than 10% of historic levels. If society truly wants salmon to recover to historic levels, then: (1) remove some or all dams to improve passage, (2) do not mix wild genetic stocks with hatchery fish genes, (3) reduce or eliminate sport and commercial fishing, (4) restore freshwater conditions to be acceptable for spawning, and (5) allow all spawning fish to enter the stream and die to provide stream nutrients (Compton et al. 2006). Remove a source of hydropower? Increase electricity bills? Use coal or nuclear fuels for electricity? Do not allow salmon harvest? Will society agree to this? Not likely. And this is in a wealthy society. Consider the overgrazing situation in the dry tropical forests of South America that has led to desertification. Tell the campesino to stop grazing for a few years to allow the rangeland to recover (and it would), and he and his family will starve. So he is not likely to stop grazing. Successful efforts at conserving biodiversity are often more likely to be successful if a social-ecological-systems approach is taken (Ban et al. 2013). Setting biodiversity goals must consider the genetic resources, the species, the ecological processes, and the goals and objectives of the people affected by a decision. And because goals will change over time, plans designed to meet goals now must be adaptable to allow future goals to be met.

HOW DO WE CONCEPTUALIZE "BIODIVERSITY" TO BE ABLE TO CONSERVE IT?

Given the complexity associated with biodiversity and recognizing that it is a resource that society values, what is a scientist, manager, planner, or decision maker to do to ensure that biodiversity is conserved for future generations? How can we hope to understand and consider the needs for all species in a planning area? Generally, a tiered approach to decision making that considers the needs of some species explicitly is used, but this assumes that the needs of others will be met through a more generalized strategy of habitat protection and/or management. So scientists simplify the problem by taking a logical step-wise approach, albeit with significant assumptions. The *filter approach* is often used as a basis for reducing the risk of losing a species from an ecosystem (Hunter 1999, Zenner et al. 2010) (Figure 18.2). In this approach, three management strategies, termed "filters," are used. These "filters" are analogous to management filters designed to "catch" species in each hierarchy of management approaches, and minimize the risk of losing species. The three filters are

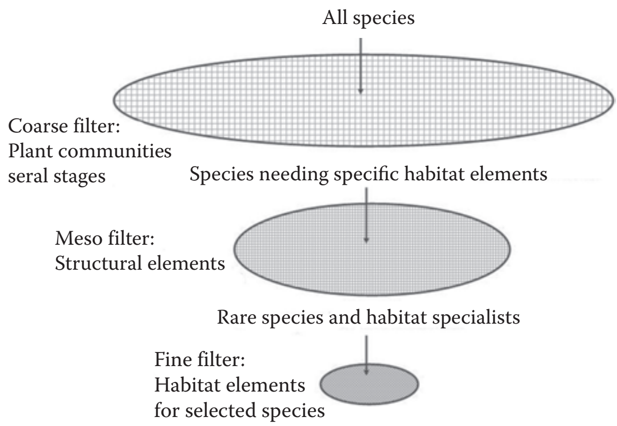

FIGURE 18.2 Coarse filter goals are met using vegetative types and successional stages that are likely to meet the needs for many species in a planning area. Some species require specific habitat elements provided within a meso-filter. For those that are not likely to be met using this approach, a fine filter (single-species) analysis is conducted.

coarse, meso and fine, each with a set of assumptions about how the combination of these three types of filters can be employed to "capture" species in a management strategy.

Coarse-Filter Approaches

The coarse filter is applied to the landscape by describing the distribution of biophysical classes (e.g., vegetation classes, slope classes, stream classes, etc.) that occur in an area of concern and documenting the arrangement and connectivity of these biophysical classes across the landscape. These current conditions may then be projected into the future under various alternative management assumptions or compared to past conditions to see how much they have changed over time. The current and possible future conditions are often compared to some reference condition(s). Recently, that comparison has quite often been to the historical range of variability (HRV) in one or more ecosystem indicators (Landres et al. 1999, Keane et al. 2009) (Figure 18.3).

It is important to understand that, when using the HRV as a reference condition, the objective is *not* to return to a condition that once occurred in the past, but rather to consider the range of

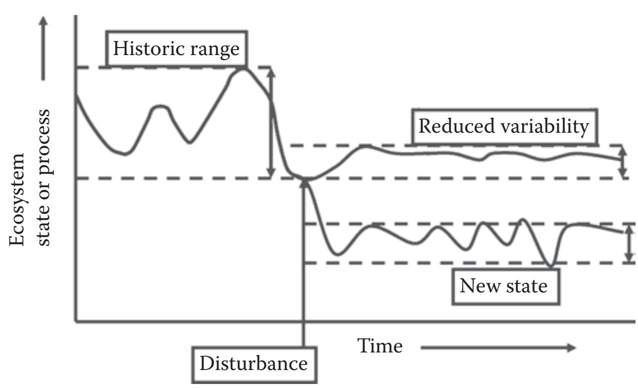

FIGURE 18.3 Use of the historical range of variability allows managers to consider the implications of future conditions following a disturbance on reducing the variability in a system or creating an entirely new state of conditions in an ecosystem.

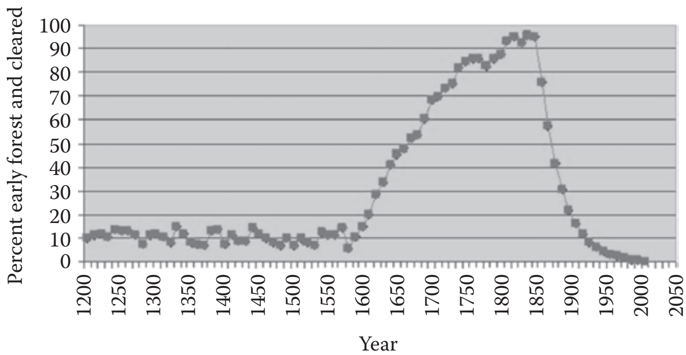

FIGURE 18.4 Generalized changes in open and early-successional forest conditions following European colonization in New England. While increases in this ecosystem state provided habitat for many species others were lost. Now, due to much lower availability of this condition, species associated with this condition are at risk.

conditions that species likely encountered in the past and the process that led to those conditions. Biologists often assume that the species persisted within these ranges of conditions and processes. The more the current and likely future conditions depart from the HRV, the greater the *risk* that genes or species may be lost from the system. For instance, consider the likely distribution of one ecosystem indicator, open and early successional conditions, in New England (Figure 18.4). As European humans introduced new technology and approaches to land management, preEuropean fluctuations in this indicator began to change following forest clearing and, eventually, farm-land establishment and subsequent abandonment (Foster 1992, DeGraaf and Yamasaki 2001). The departure from the historical range of variability was significant with most forest land converted to open land in much of southern New England. What was the risk to biodiversity of this departure? Global extinction of a few species, most notably passenger pigeons. Also, the likely loss of species that we had not identified by the time they were lost and regional extinction of forest-associated species, such as fisher, moose, white-tailed deer, black bear (Figure 18.5), wild turkey, and beaver. As the forest returned and the amount of open land declined, these latter species have occupied the area once again from forests to the north. But now the amount of open grassland and early successional

FIGURE 18.5 Black bears were extirpated from southern New England during the 1800s and did not return to the area for over 100 years. Now they are common and can cause damage to homes, property, and crops in the region. (Photo by Karl J. Martin. With permission.)

conditions is very low, probably lower than it was historically, and we now see species that are considered at risk because we have less of these conditions than we did historically. Bobolinks, eastern meadowlarks, and chestnut-sided warblers are all considered species associated with these open conditions and are species of concern in the region (Vickery et al. 1992) (Figure 18.6).

The organisms and values that currently occur in the forests of a region have persisted through centuries of natural- and human-induced disturbances. Some did not survive past deforestation. Some may only now be recovering. Considering the plan within the context of the historic range of variability is one way to assess the risk of losing species when attempting to achieve a desired future condition (DFC) for a landscape. Consider the likely representation of early-, mid-, and late-seral forests during the early 1600s in the New England region. Proportions of these successional stages are inherently variable annually, decade to decade, and century to century, as hurricanes, ice storms, floods, fires, and other disturbances occurred with varying levels of frequency and severity. But these proportions clearly now depart from historic ranges. Early-seral shrub stage and grassland conditions are now poorly represented in the northeastern landscape. Due to past forest clearing, only a very small proportion of the landscape is now in late-seral condition. Consequently, species associated with any of these conditions may be considered at greater risk than species associated with mid-successional conditions.

Further, it is important to think of the range of variability that once occurred, not just as seral condition, but also plant community representation. What should be a reasonable proportion of representation of vegetation types across the landscape to reflect the conditions with which these species have evolved? Due to recent land uses, some plant communities are very rare. Prairie communities in the Great Plains and in the Willamette Valley of Oregon have been reduced to a tiny fraction of what they were historically. Old-growth forests in New England are less than 1% of historic conditions. Should we restore these systems to historic levels? Can we? Although we may set restoration as a goal, achievement of that goal may not always be possible. But we may wish to focus on recovery of a greater proportion of these types to minimize further losses of species from the region.

Finally, it is important to consider the size and arrangement of the patch types that would be created across the landscape. Within the context of actively managed forests, harvest planning has a direct bearing on the arrangement of plant communities and seral stages across a landscape over time. The range of patch sizes in managed forests often departs from the distribution of patch sizes created by natural disturbances. In many cases, most patches should be of small size, fewer of larger size, and

FIGURE 18.6 Early successional forest is being created on Massachusetts Wildlife Management Area lands and privately owned lands using landowner incentives program (LIP) funds in response to regional declines in species associated with shrublands and grasslands.

very few very large patches (of course, small and large are relative to the sizes represented over time, following disturbances and regrowth). Size matters to some species and so does location. Tailoring patch sizes and arrangements to plant communities, based on the effects of natural disturbances within the constraints set by society, may mean that there is less risk of losing species. Creating edges, small or large patches, and connectivity can all influence the species assemblage occurring in a landscape over time. Connectivity may be especially important in the face of climate change (Nunez et al. 2013).

Now consider which plant communities and successional stages are currently underrepresented in the ecoregion in which your landscape occurs and which of these might be underrepresented in the future following a particular course of management. Of those that are underrepresented in the ecoregion, which could be represented in the landscape that you are managing? Given the contribution of your management actions to improving regional representation of underrepresented types, what should be the desired future representation of these types in your forest? Answering these questions will help to design a coarse-filter strategy for a landscape and can help to guide harvest planning in forested landscapes into the future.

The departure of key ecosystem indicators, especially ecosystem processes, from historical conditions under which the species persisted can be useful in understanding if species are likely to be at risk of local or global extinction. But what indicators do you choose when making this coarse-filter assessment? Whitman and Hagan (2003) evaluated over 2000 biodiversity indicators and "simplified" this list to 137 indicator groups. Even this is an overwhelming number of indicators for managers to address, so Whitman and Hagan (2003) proposed that decision makers and scientists should work together with managers to identify indicators relevant to the values identified by stakeholders. Once the group of indicators is identified, then considering historical conditions may be problematic or not even particularly useful in some instances. If current human values differ markedly from the historical range of conditions and processes, then simply using the indicator without a historical reference may still provide a context for setting coarse-filter goals. There is a tendency to use indicators that are associated with current rare communities or conditions, and there is certainly a political justification for doing so. However, care must be taken in selecting indicators that may reflect rarity, isolation, or high values in the future as well (Hauer et al. 2010).

Meso-Filter Approaches

Although many species may receive adequate protection using a coarse-filter management strategy, some species require certain structural elements that must be present in plant communities and seral stages to ensure that they will likely persist in the management area (Crous et al. 2013). Hence, a meso-filter approach that considers the sizes, distribution, and abundance of structural elements, such as snags, logs, hollow trees, and the other elements presented in Chapter 4, are distributed across the landscape over time at a range of spatial scales (Hunter 2004). These structures are often inventoried and managed at the stand level, but it is the distribution of these habitat elements among stands across a landscape that will influence habitat quality for many species, especially those having home ranges exceeding a stand in size. How many of these elements are needed? Again, approximating a range of conditions that would be expected following historical disturbances and regrowth provides one context for estimating the numbers, especially where habitat relationships studies have not been conducted for a wide range of species. Where data are available, then data-driven habitat relationships can influence decisions regarding how much, what size, and where to provide these elements. An excellent example is the use of DecAID to guide management of dead wood across a landscape based on existing habitat relationships data (Mellen et al. 2002).

Fine-Filter Approaches

But the combination of coarse- and meso-filter management strategies may not provide suitable habitat for all of the species in a landscape. Some species are simply rare enough, have low reproductive rates, have large territories, or have been adversely affected by habitat loss (or other factors) that their populations are low and they require special attention. Consequently, a "fine filter" is constructed that maintains the coarse-filter structure and the meso-filter elements but takes special management actions to conserve the set of species identified for fine-filter consideration. Those species that may need to be considered more carefully to ensure that their needs are met in the coarse-filter approach, might include those based on the following criteria (Figure 18.7):

1. *Risk:* Species that are rare or already at risk of declining in abundance so as to become locally or regionally extinct, or are already designated as threatened, or endangered through a regulatory status, or which might become rare in the future.
2. *Narrow niche breadth:* Species that are restricted to specific successional stages, especially those that are or may become uncommon or disconnected in the future (e.g., due to climate change or land use) or are sensitive to environmental gradients, such as moisture gradients or elevational gradients.
3. *Ecological function:* Keystone species are those whose effects on one or more critical ecological processes or on biological diversity are much greater than would be predicted from their abundance or biomass (Aubry and Raley 2002). Also *link species* that play critical roles in the transfer of matter and energy across trophic levels or provide a critical link for energy transfer in complex food webs (e.g., insectivorous birds) (Cohen 1984).
4. *Management focal species:* Umbrella species, which, because of their large area requirements or use of multiple habitats encompass the habitat requirements of many other species, or species that are representative of certain conditions that are now or are likely to be uncommon in the future on the landscape (Lambeck 1997).
5. *Economic importance:* Game species from which local economies and stakeholder groups derive benefit from hunting, or species that inflict costs on forest owners and managers.

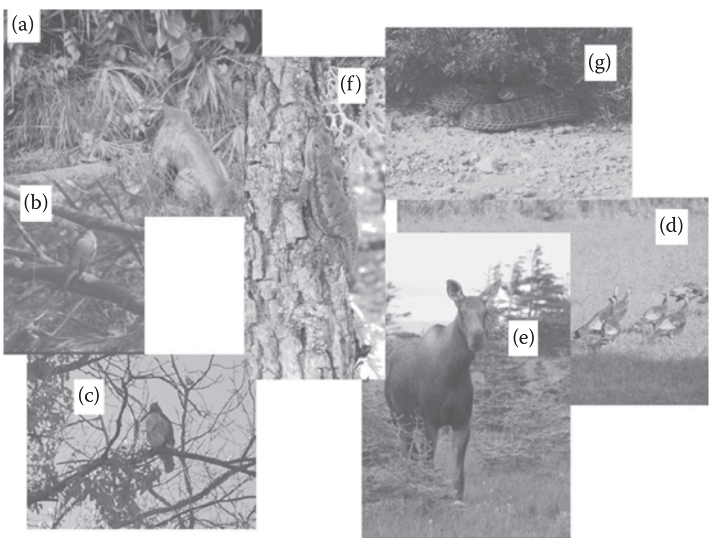

FIGURE 18.7 Examples of species selected as foci for fine-filter analyses based on (a) risk (Florida panther photo from USDI USFWS digital library), (b) narrow niche breadth (many species of neotropical migrant birds such as this hermit thrush are elective of vegetative structural stages), (c) ecological function (raptors such as this red-tailed hawk play a key role in energy transfer among trophic levels), (d) umbrella species (such as wild turkeys, which have large area requirements and use multiple vegetation conditions), (e) species of high economic importance (such as moose), (f) species for which we have limited data or knowledge (such as many species of reptiles, including this western fence lizard), and (g) species that have high public interest due to risks associated with them (such as this prairie rattlesnake).

6. *Cryptic Species:* Those species for which we have limited data or knowledge and need to be explicitly considered during management, often using expert advice.
7. *Public/regulatory interest:* Species in which society has expressed interest because of media events (e.g., rattlesnakes), public policy (e.g., migratory birds), or human health concerns (e.g., carriers of west Nile virus).

These criteria can help managers narrow the list of species that must be explicitly considered in a fine-filter approach. Once identified, then the specific habitat elements needed in appropriate arrangements, sizes, and numbers can be provided in the forest to ensure that these species have their habitat requirements met. Suring et al. (2011) developed a process for implementing a fine-filter strategy on public lands in the northwestern United States. Their process includes identification of species of conservation concern, description of habitats and other important ecological factors, grouping species, selection of focal species, development of focal species assessment models, development of conservation strategies, and designing monitoring, and adaptive management plans (Suring et al. 2011). Occasionally, fine-filter species are grouped into guilds, or an indicator species is used to represent the habitat needs of other species. *Guilds* are groups of species that share common resources such as cavity-nesting birds, bark-foraging birds, or forest-floor insectivores. *Indicator species* are species that are assumed to be surrogates for other species having similar resource needs. In the early ecological literature, however, indicator species were used to indicate certain environmental conditions (e.g., water pollution). Indicator species in forest management are used quite differently. For instance, pileated woodpeckers are often used as a management indicator species for cavity-nesting birds (Landres et al. 1988). But use of both guilds and indicator species as convenient ways to manage for multiple species is fraught with problems. Because each species has its own set of habitat requirements, no species can ever be a perfect surrogate for another. Indeed, tests of individual species responses to forest management indicate that although several species may belong to the same guild, they each respond differently to a forest management treatment (Mannan et al. 1984). Lindenmayer and Likens (2011) outlined a rigorous set of tests that would be needed to assess if indicator species are a reasonable approach to managing habitat for multiple species; rarely have these rigorous tests been conducted. Consequently, it is important to consider management strategies that focus on species, habitat elements, or broad vegetative conditions and not seek “short-cuts” that may lead to misleading management strategies and increase the level of uncertainty in meeting biodiversity goals.

CHALLENGES TO MANAGING BIODIVERSITY

The filter strategy is based on many assumptions. But using this technique, several factors will likely influence the degree to which protection of biodiversity will be effective. The spatial scale over which the decision is made, its context, and the level of spatial detail used in defining the desired future condition (DFC) for the landscape, and the management approaches used to achieve that condition, all contribute to effective management. Similarly, the temporal framework within which the decision is made is critical. Will the DFC meet the concerns of constituents now? Ten years from now? 100 years? What is the appropriate timeframe? All decisions are couched within a number of factors associated with the uncertainty of ecological and sociological processes. How do we effectively consider uncertainties so that the decisions made are effective, yet still reflect the resilience and adaptability needed to address uncertainty? Each of the following factors must be considered in detail.

SPATIAL SCALE

Land ownership implies a certain level of commitment to part of the Earth, and that commitment is expressed through the accumulation of individual landowner behaviors over space and time. It would seem obvious that one landowner making a decision to manage for cavity-nesting birds in a stand on her land is easy. Just leave a certain number of trees or snags of certain sizes, and the goal is reached. Or is it? How will the actions of her neighbors influence the likelihood that these and other biodiversity objectives will be met on her land? And how will her actions influence the achievement of her neighbor's goals to provide a corridor for migrating elk? Can she trust her federal neighbors to follow through on their commitments to follow their plans, even as government policies change? Will her private neighbors sell their land? Subdivide it? Will the state impose restrictions on private land management that inhibit her ability to achieve her goals on her land and those of her neighbors? Will an NGO (nongovernment organization) intervene to offer a conservation easement and purchase development rights? All of these questions, driven by social values, are played out on the patchwork quilt of the landscape occupied by landowners and their neighbors (Figure 18.8). Effective decisions must consider this spatial context for the property or properties being managed or reserved.

Landscape management goals often are formed based on a larger regional plan at a large spatial scale (e.g., the Northwest Forest Plan) and are implemented through cumulative actions made at small spatial scales over time (e.g., stand prescriptions and forest plans). The policy guides the actions (e.g., how many wildlife trees to leave in a clearcut, how wide should a riparian buffer strip be), but decisions must be made locally to determine where and often how these should occur.

Not only must the sociopolitical framework be considered when making biodiversity conservation decisions, but the species and ecological processes must also be considered. Large territory and home-range sizes of some species, combined with the need to ensure that an adequate number of individuals of each must be maintained, may dictate the appropriate spatial scale over which planning should occur. How large an area do we need to consider in order to make effective decisions that include habitat and connections among populations for marbled salamanders? Northern goshawks? Wolverines? Where you draw the line taxonomically in your assessments and decisions will influence the spatial scale associated with the planning and decision-making process. Similarly, the dominant ecological processes that might influence the outcome of a conservation plan should also be considered (Huber et al. 2010). Wildfires, insects, disease, wind, ice, and climate change, all have ranges of frequencies, sizes, and intensities associated with various locations on this Earth. Some managers choose to manage spatial scales such that these natural disturbances are "captured" within the spatial extent of the landscape being managed (Poiani et al. 2000).

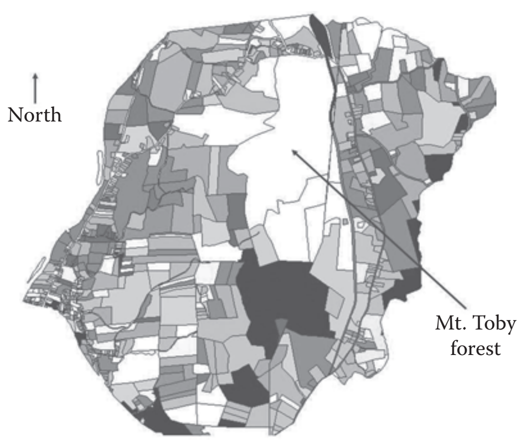

FIGURE 18.8 Management of a 300 ha forest in western Massachusetts is heavily influenced by the goals, objectives, and actions of many adjacent landowners, illustrated here by all tax lots within a few kilometers of the forest.

Time

Stakeholders in the outcome of a landscape management plan often view effective timeframes as days, weeks, maybe years, and sometimes decades. We all at least try to plan for our financial security throughout our lives so we are used to thinking in multiple decades. Most people want to leave a legacy of their values to the next generation. We humans have a more difficult time thinking in terms of multiple lifetimes. Many Native American cultures view sustainability as seven generations (Hansen 2011), although such a view may not be common in other cultures. Yet, some plans made to achieve biodiversity goals may not be fully realized for many decades. The recovery of nesting habitat for northern spotted owls may take 200 years in many locations and even longer for nesting habitat for marbled murrelets (Spies et al. 2007). In these examples, a decision was made to designate a part of the landscape that contains many square kilometers of young plantations as late successional reserves. Many stakeholders are unable to understand how recent decisions are effectively leading to the intended goal. It is important to not just consider human lifetimes when considering the appropriate temporal scale for projecting likely effects of biodiversity decisions. It is equally as important to understand the effects of decisions relative to the multiple generations of key species affected by the decisions. Consider long-lived species such as box turtles and Puerto Rican parrots. These are such long-lived species (40 years or more) that by the time declines in populations are detected, the options for recovery may be very limited. Similarly, recovery, when it is possible, may take multiple generations for these species—hundreds of years. Consequently, the appropriate timeframe for considering effectiveness of biodiversity management over large landscapes is driven by the interface of several key actions:

1. Human schedules for implementing the plan
2. The inherent rates of growth and disturbance affecting the vegetative (and occasionally the physical) components of the environment
3. The potential and realized rate of population growth for key species
4. The rate of movement and colonization of habitat for key species

Consequently, there is not a standard appropriate timeframe associated with all biodiversity management plans. Consider the potential for documenting responses of organisms to management actions. The species in Table 18.1 are ranked by their potential longevity in years. This would be the maximum time needed for a complete turnover in a generation. The number of generations is then portrayed for 40-, 100-, and 200-year rotations in a forest managed using even-aged systems. If a species can reproduce multiple generations on a site before it is harvested, then any single individual

TABLE 18.1
Approximate Longevity in Years and as Expressed in Number of Generations per Rotation under Even-Aged Management for Six Species with Very Different Life Histories

		Rotation Length (Years)		
Species	**Longevity (Years)**	**40**	**100**	**200**
Short-tailed shrew	3	13	33	67
Winter wren	4	10	25	50
Spruce grouse	5	8	20	40
Red-cockaded woodpecker	16	3	6	13
Great-horned owl	27	1	4	8
Box turtle	50	1	2	4

faces less of chance of being displaced to different home ranges. Both the temporal scale associated with the reproductive capacity of the species and the frequency of habitat displacing disturbance must be considered over a spatial scale large enough to allow species to move to available habitat as disturbances displace the species.

Clearly, natural disturbances have probabilities of occurring at a range of frequencies that could lead to displacement for these species. As rotation lengths depart from the historical range of natural disturbance frequencies, the risk to long-lived species (which often have low reproductive rates) increases. In addition, because they are so long-lived, changes in populations can be subtle, making it difficult to detect population declines. Conversely, documenting recovery of these species can also be difficult, requiring long periods of population monitoring.

There are at least two dominant additional factors that must be considered when making biodiversity decisions over large multiowner areas. Land tenure can influence achievement of goals, particularly if the parcels being sold or inherited change owners having one set of core values to another. Rotation lengths also influence the time that a forest will be suitable for a set of species. An understanding of these transition probabilities can be particularly important in understanding the likely trajectory of landscape change over the planning period (Spies et al. 2007).

Uncertainty

One of the greatest uncertainties facing conservation biologists and land planners is development of conservation and management strategies with incomplete information about the suite of species under consideration. Based on past research, we know enough about the habitat used by many species to at least develop reasonable management plans. However, for some species, we know nearly nothing, and then there are all of the species not described that we have yet to discover.

Consequently, it is important that if biodiversity conservation is a primary goal for a management plan, then a reasonable course of action is to follow the precautionary principle and err on the side of conservation rather than resource extraction. This approach places the burden of proof on managers to demonstrate that there is minimal risk to conservation of biodiversity when extracting resources. Then, once the plan is developed, we can monitor using techniques that will add to the information available to make decisions (Schultz et al. 2013). Surveying and managing, formal monitoring protocols, and moving the system toward the HRV while monitoring key resources are approaches that can improve knowledge and reduce uncertainty over time.

Land management planners must define the spatial and temporal grain (finest level of information needed), extent (outer bounds of the planning problem), and context (surrounding landscape conditions). Once the spatial and temporal context for biodiversity decisions has been decided (perhaps one of the most critical first decisions), planners suddenly find themselves faced with a number of uncertainties that influence the likely effectiveness of their plans. One key uncertainty is the continued social commitment to biodiversity values. Societal values change, and planning must be adaptable to that change (Figure 18.9). Values placed on deer in the United States have evolved from largely utilitarian, to protection, to recreation, to nuisance, to public health concerns. How will values change for northern spotted owls? Townsend's big-eared bats? Burying beetles? We tend to think of goals and objectives as being relatively stable. But they will change, and biodiversity protection plans should reflect an ability to adapt to new values.

There also are a number of biophysical uncertainties: fires, floods, invasive plants and animals, disease, and global climate change, to name a few. For many of these factors we have information that can help us understand probabilities of occurrence of these biophysical factors over time at varying spatial scales. Hence the uncertainty, or likelihood, of these events or effects can be quantified. In so doing, we can also assign risks associated with these events. Many forest "health" issues are framed within this risk assessment paradigm. For instance, an "unhealthy" forest is often considered one with a higher than expected chance of wildfire, disease, or insect irruption, and the ensuing ecological and social effects can be predicted. Further, these risks can be expressed as a

FIGURE 18.9 Prescribed burning was used to maintain grasslands and grass–shrub savannahs in pitch pine forests of Massachusetts to maintain conditions important to many species of vertebrates and invertebrates. Over time, public values may shift due to air quality, smoke, and risk of fire escapement, placing systems like these at greater risk.

departure from the historical range of variability (HRV). But in many systems we cannot return many attributes to fall within the HRV. For instance, in the northeastern United States there are no longer passenger pigeons, American chestnuts, and (as far as we know) wolves. Atlantic salmon are effectively gone and society will not likely pay for their restoration to historical levels. Although some aspects of the northeastern hardwood forests and associated streams have recovered, some aspects will never recover. The past may help inform decisions, but the past cannot define a goal for the future; too much has changed. Even the ability for the past to inform decisions is weakened as we see systems develop in ways that they never have developed in the past. Uncertainties proliferate regarding how systems might develop and how aspects of biodiversity might respond, so we become increasingly unable to use history as a guide to development of desired future conditions.

Finally, there are political uncertainties. Although political decisions are (usually) an outcome of societal values, our political system, and those of other countries, can result in decisions being made that result in significant constraints (or freedom) to achieve biodiversity goals. Honoring the Kyoto Agreement, responses to the events of 9/11/2001, economic recovery, and going to war are decisions made by a few individuals that affected many individuals. Once made, these decisions have significant effects on the certainty with which biodiversity decisions will truly achieve the intended objectives.

Further, changes in policy such as modifications to the Endangered Species Act, Clean Water Act, the National Forest Management Act, and others, are not only likely, they are inevitable, given the changes in society and politicians that we can expect over the next seven generations. Even now we are seeing a society that is becoming more and more divided on many issues important to maintaining a balanced and functional social system. As philosophical beliefs of our elected and appointed officials wax and wane, so will the degree to which policies provide the legal framework for biodiversity planning and decision making.

SUMMARY

Biodiversity is represented by the genes, organisms, populations, and species of an area, and the ecosystem processes supporting them. Contemporary approaches to biodiversity conservation typically take a filter approach. Coarse-filter strategies use the proportional representation of plant communities, successional stages and other classes of biophysical conditions as a guide to providing habitat for most species most of the time. Meso-filter strategies further consider the habitat elements present within these biophysical classes in a way that "captures" even more species. Fine-filter strategies consider the needs for a few individual species that are of high social importance. The approach provides the context within which harvest planning can be developed that would minimize risk to biodiversity while allowing resource extraction. This approach is based on numerous assumptions and is influenced greatly by the choice of spatial and temporal scales over which it is employed. Further, uncertainty in the effectiveness of the strategies often leads managers to follow the precautionary principle when conservation of biodiversity is a primary goal for land management.

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