Chapter 2. Selecting Key Habitat Attributes for Monitoring

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2.1 Objective

The success of habitat monitoring programs depends, to a large extent, on carefully selecting key habitat attributes to monitor. The challenge of choosing a limited but sufficient set of attributes will differ depending on the objectives of the monitoring program. In some circumstances, such as managing National Forest System lands for threatened and endangered species, habitat monitoring may focus on tracking habitat for one or a few **emphasis species**. In other settings, such as monitoring the effects of broad-scale land management plans, habitat monitoring may need to address many species. Regardless of scope, similar processes are used to identify attributes for monitoring. The complexity of the organizational and analytical task, however, will differ significantly with scope. In this chapter, we describe steps for choosing habitat attributes for monitoring and for reducing the list of key habitat attributes to those that are affected by management and can be feasibly measured. In this chapter, and throughout this guide, a **habitat attribute** is defined as any living or nonliving feature of the environment that provides resources necessary for a species in a particular setting. Selecting habitat attributes depends on management priorities and whether monitoring habitat for a particular species or species group is useful or necessary. Selecting habitat attributes for monitoring is based on an understanding of threats and limiting factors that influence population growth and the status of each emphasis species, as well as the factors that may limit their distribution based on physiological ecology and thresholds. This understanding is summarized through the development of a **conceptual model** of habitat relationships for each emphasis species, which forms the foundation for the selection process.

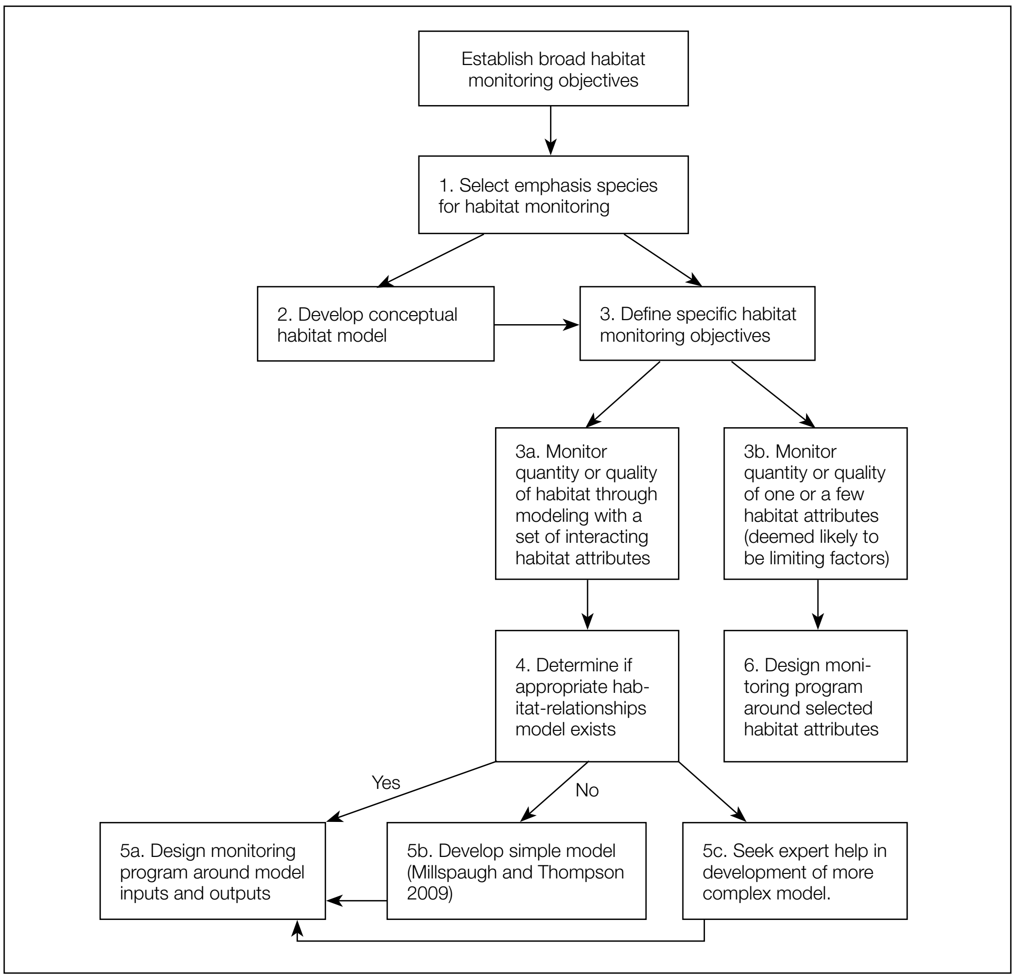
The objective of this chapter is to provide guidance for selecting habitat attributes to monitor that reflect the habitat requirements, limiting factors, and threats of emphasis species at relevant spatial and temporal scales. The chapter also provides guidance on reducing the list of key habitat attributes to those that are affected by management and that can be feasibly measured.

2.2 Key Concepts

2.2.1 Setting Habitat Monitoring Objectives

This chapter focuses on identifying key habitat attributes for monitoring. We assume that broad monitoring objectives have been established and the need to monitor habitat for a species or group of species has been carefully evaluated. The importance of establishing monitoring objectives that will provide knowledge to inform future management decisions cannot be overemphasized (Elzinga et al. 1998, Holthausen et al. 2005). The context for this chapter may be most clearly illustrated using a graphic (figure 2.1). As emphasized in this schematic, setting objectives may occur at two stages of the process. Chapter 3 addresses the establishment of monitoring objectives, including consideration of desired outcomes, **spatial extent**, and precision.

Figure 2.1.—*Considerations in monitoring key habitat attributes.*



2.2.2 Habitat Monitoring Versus Population Monitoring

Numerous published documents describe protocols for monitoring populations of plants and animals (e.g., Elzinga et al. 1998, Manley et al. 2006, McComb et al. 2010). This technical guide describes protocols for monitoring wildlife habitat, which is a need the Forest Service previously recognized (see chapter 1, section 1.2.1). Although the primary objective of habitat monitoring is to provide information on the status of habitats in relation to desired conditions, habitat monitoring is sometimes viewed as a proxy for population monitoring (see chapter 1, section 1.3.2). Using habitat monitoring as a proxy for population monitoring is based on the assumptions that population size is strongly correlated with quality and quantity of habitat and that habitat is the primary driver of population change. The relationship between population size and habitat conditions depends on the life history of the species, the spatial and temporal scale examined, historical legacies, and the specific geographic and ecological context. Evaluating whether a strong relationship exists between habitat and population abundance in any particular situation is difficult. A large body of research, however, demonstrates an association between occupancy by bird species and habitat attributes (reviewed in Wiens 1989a).

Most vegetation attributes measured as habitat are really proxies for the true attribute of interest. For example, prey for insectivorous birds is difficult to accurately quantify, so other attributes that serve as proxies for prey abundance, such as foliage volume, typically are measured (Morrison et al. 2006). In these situations, measurements of vegetation attributes are at least one step removed from the food or other resources used by the organism and are therefore at least two steps removed from evaluating population size. As a result, it is unlikely that vegetation measures can reliably serve as proxies for absolute measures of population abundance, unless the emphasis species is a plant. Consequently, although it is reasonable to monitor vegetation attributes associated with an organism's habitat and make inferences regarding the trends in habitat and, therefore, the capability of the site to support the species, it is inappropriate to assume a one-to-one relationship between habitat amount and population status. Population changes often are the result of factors unrelated to the physical structure of habitat, such as weather, disease, or inter- and intra-species interactions (e.g., predation and competition [Chase et al. 2002]), as well as the recent history of the population.

2.2.3 Considering Management Objectives

Effective monitoring programs reflect specific management objectives. Management objectives and context must influence the rigor and precision of the monitoring program, as well as the habitat attributes monitored. Examining trends in habitat is useful only if that knowledge informs management decisions (e.g., predicts changes that can be encouraged or averted, as appropriate, by management actions) or helps assess the effectiveness of past management actions. In addition, policymakers and resource managers must be able to interpret the implications of monitoring results in the context of management actions for the effort to be effective.

Because of differences in management context, monitoring habitat for a particular species may differ across local management units. Management goals and expectations for environmental change will influence the choice of habitat attributes to examine, the necessary precision required, and the temporal and spatial scales of interest. Forest-to-forest variation in how monitoring is accomplished should represent major differences in context, however, rather than thoughtless inconsistencies.

2.2.4 Emphasis Species

In this guide, *emphasis species* is a generic term for any species that warrants specific attention in planning or analysis. We use this term to convey the breadth of species addressed by this guide and to transcend terminology that may imply special circumstances or definitions beyond our intended focus. Categories such as **focal species** or **umbrella species** have led to much confusion (Caro 2010) and also confer the concept of surrogacy, which is not inherent in our definition of emphasis species.

Emphasis species can be drawn from species with special conservation status, such as federally listed threatened or endangered species, sensitive species, species of high public interest, and **management indicator species**. For purposes of setting monitoring objectives, not all species with special conservation status are emphasis species. Only those species that a planning unit has targeted for additional management or analysis beyond what is prescribed to sustain ecosystem diversity are emphasis species. Emphasis species can also be species that are particularly vulnerable to climate change, species with special habitat requirements, or species that are vulnerable to human presence and activities (chapter 7). Moreover, even if specific management is not needed, sufficient interest in a species or group of species can justify focused evaluation of its habitat.

2.2.5 Grouping Species as an Efficient Way for Monitoring Species' Habitat

Inventory and monitoring of habitat in large areas, such as a single national forest or grassland or multiple management units, may require evaluating 50 or more species and conceivably can include hundreds or even thousands of species (e.g., Groves 2003, Groves et al. 2000, Marcot et al. 1998, Thomas et al. 1993). For land managers, individual attention to such large numbers of species is impractical from logistic and financial perspectives. To address these inefficiencies, various methods have been proposed to eliminate or reduce the number of individual species that are explicitly considered in monitoring or assessment and in subsequent management (Wiens et al. 2008, Wisdom et al. 2005). One shortcut is to select an individual species to represent an entire group of species (e.g., umbrella species, focal species, management indicator species [Noss

1999]). Another approach is to identify and then manage for an entire group of species (e.g., sagebrush [*Artemisia* spp.]-woodland inhabitants) rather than selecting individual species to represent the group, with groups based on criteria such as commonality in habitat associations, life-history traits, or threats to persistence (Andelman et al. 2001, Wiens et al. 2008, Wisdom et al. 2005).

In contrast to relying on individual species, the use of species groups explicitly attempts to address the needs of single and multiple species in a hierarchical fashion. For example, species can be grouped by their use of fine-scale attributes and then grouped at a broader level through vegetation types (Andelman et al. 2001, Wiens et al. 2008, Wisdom et al. 2000). Consequently, the use of species groups in habitat monitoring may be effective if assumptions are tested about how well the species groups represent the needs of individual species, as part of implementing land management plans. The advantages of using species groups compared with other multispecies approaches are that efficiency is increased by analyzing several species as one, yet the habitat requirements of each species is accounted for in the analysis. A disadvantage is that the cross-species relationships must be verified, as described previously, to ensure that the associated group meets the needs of individual emphasis species (Wisdom et al. 2005).

Last, when using species groups, it is important to clearly describe the rationale for using a group, the corresponding habitat attributes of the group, and the process for identifying the group, including critical assumptions and the uncertainty associated with conclusions derived from this approach (USDA Forest Service 2005b).

2.2.6 Spatial and Temporal Scales

Habitats generally must be monitored at several scales because species select and relate to habitat at multiple scales. Many aspects of describing the relationships of wildlife species with their habitat are contingent on the spatial and temporal scales of habitat selection and the spatial context of the management area. Spatial and temporal scales are defined by their **grain**, extent, and hierarchical structure. Each spatial scale identified for each emphasis species should be defined in terms of spatial grain (**resolution**) and extent (Peterson and Parker 1998, Wiens 1989b). Extent refers to the size and boundaries of the area under evaluation. Estimates of habitat attributes across broad spatial extents often reveal different patterns than those derived from smaller spatial extents. Neither estimate is incorrect; patterns revealed at different extents are complementary.

From a statistical perspective, extent is the area of inference and the area from which a sample is drawn (i.e., **sampling frame**; see chapter 3, section 3.3.1). The concept is simple, yet paramount, because it is impossible to make meaningful inferences about monitoring data unless the spatial extent has been clearly established and the sampling points are drawn using an objective process from throughout this extent (see chapter 3). Grain is the resolution at which spatial patterns are measured or the plot size used to measure characteristics (Wiens 1989b). The level of an organism's perception of the landscape is defined according to spatial grain (i.e., the smallest scale at which an organism responds to environmental patterns) and extent (i.e., the largest scale of heterogeneity to which an organism responds) (Kotliar and Wiens 1990, With 1994). Using this approach provides a functional link between selecting the monitoring approach and the species ecology. Ultimately, the match between grain and extent influences what questions to ask and what patterns to observe.

Ecological relationships have hierarchical structures because different processes occur at different spatial and temporal scales. These relationships influence processes occurring at other scales. Within a hierarchy, processes operating across longer timeframes and greater spatial extents serve as constraints on processes occurring across shorter timeframes and smaller extents (O'Neill et al. 1986). This concept has direct bearing on habitat selection because habitat relationships often change across spatial scales, reflecting the hierarchical nature by which animals select resources (Johnson 1980, Mayor et al. 2007, Orians and Wittenberger 1991).

Applying hierarchical structure to habitat selection, Johnson (1980) defined first order (i.e., level) habitat selection as the physical or geographic range of a species. Second order selection determines the home range of individuals within the physical or geographic range of a species. Third order selection is the specific use of sites within a home range, usually for particular functions (e.g., roosting or breeding). Fourth order selection is the choice of individual food items within third order selection sites. Orders of habitat selection are hierarchical because an individual's selection of food items is constrained by what is available at feeding sites, which is constrained by what is available within the home range. The home range must fall within the species' geographic range, which for most species was determined through an evolutionary timeframe.

Hierarchical structure can also apply to limiting factors that may influence the distribution of individuals, populations, and species through the effects of limiting factors on survival, growth, and reproduction (Krebs 2002, Rettie and Messier 2000). Some limiting factors, such as large expanses of undisturbed, high-elevation, mountainous terrain for breeding by wolverines (*Gulo gulo*), operate primarily at broad spatial scales, whereas other factors, such as physical structure for a roost site, come into play only at finer scales. Selecting a particular resource across multiple scales may indicate greater importance of that resource (Bridges 2003, Rettie and Messier 2000). Because of the hierarchical nature of habitat selection, habitats generally must be described and monitored at more than one spatial scale. Work by Knick and Rotenberry (1995), like the previous study by Rotenberry and Wiens (1980), highlighted the multiscaled nature of habitat selection. They reported that nest-site selection by shrub-steppe birds depended on landscape features and local vegetation cover. The previous work (Rotenberry and Wiens 1980) showed that strong patterns of habitat association in grassland and shrub-steppe birds at broad spatial scales disintegrated and were replaced by new patterns at finer scales.

2.2.7 Climate Change and Habitat Monitoring

Habitat monitoring programs are primarily oriented toward evaluating the effects of management actions and providing information to guide changes in management. Managers, however, must also consider the role of climate as a change agent, alone and in concert with management actions. The Intergovernmental Panel on Climate Change (IPCC) has published a number of assessment reports (e.g., IPCC 2007) that provide scientific evidence of global climate change, with the primary indicators of change being increased temperatures, regional changes in precipitation, and an increase in extreme weather events. Numerous researchers have documented environmental consequences of climate change, including changes in hydrologic systems (Bureau of Reclamation 2011, Lettenmaier et al. 2008), vegetation and ecosystems (Harsch et al. 2009, Ryan et al. 2008), and wildlife populations (Morzillo and Alig 2011, NABCI 2010).

The intended consequences of management actions may be thwarted, promoted, or altered in unexpected ways by regional shifts in climate. Become familiar with regional climate change scenarios, especially regarding future water availability, vegetation changes, and wildlife responses, to create monitoring programs that can inform managers about the potential effects of climate in addition to the effects of management actions. For example, if habitat of an emphasis species is likely to shift upslope under a scenario of warmer temperatures, the sampling design could be expanded to include upslope areas that currently are not habitat.

Numerous publications and reports provide guidance for incorporating climate change adaptation into planning, and these resources can provide ideas for monitoring. We recommend Millar et al. (2007) for an overview of managing forested ecosystems under changing climates. We also recommend Glick et al. (2011) because a vulnerability assessment can help identify attributes that may be most susceptible to climate change. Hansen and Hoffman (2011) provide adaptation strategies that also could lead to identifying attributes to monitor. In addition, if you are a Forest Service employee, you should become familiar with the *Forest Service Strategic Framework for Responding to Climate Change* (USDA Forest Service 2008) and the *National Roadmap for Responding to Climate Change* (USDA Forest Service 2010a).

2.3 Process Steps for Selecting Key Habitat Attributes

Identifying habitat attributes to monitor for a species or species group is part of a larger process (figure 2.1). After establishing broad monitoring objectives, initiate a review of emphasis species to determine which species or species group will be the focus of habitat monitoring (figure 2.2). Identify habitat attributes suitable for monitoring by developing conceptual models for each species or species group that focus on habitat requirements, limiting factors, and threats at the spatial scales appropriate for each species or group. Select a subset of priority attributes from the list of habitat attributes identified in conceptual models based on an understanding of monitoring objectives, potential for attributes to respond to management or climate change, feasibility of monitoring, budget, and efficiency. The remainder of this chapter addresses each step more completely, and the case examples in chapter 10 demonstrate the steps.

Figure 2.2.—*Summary of process steps in selecting key habitat attributes for monitoring.*

Step 1
Select emphasis species for which habitat monitoring is appropriate (2.3.1)
- Management considerations (e.g., review laws, regulations, policies, management objectives, and priorities)
- Biological considerations (e.g., document population-habitat links)
- Logistic considerations (e.g., assess monitoring feasibility)
- Assess risk of not monitoring

Step 2
Develop a conceptual model of the emphasis species' habitat (2.3.2)
- Levels of habitat selection
- Habitat requirements, limiting factors, and threats
- Measurable attributes

Step 3
Use/develop species habitat-relationships models (2.3.3)

Step 4
Identify habitat attributes suitable for monitoring (2.3.4)
- Assess the relationship of the attribute to habitat requirements, limiting factors, and threats
- Assess degree of change over time
- Consider geographic scale
- Evaluate ease of measuring and quantifying
- Determine potential response to management activities
- Evaluate environmental context

Step 5
Set monitoring priorities among attributes (2.3.5)
- Determine which attributes are common to many emphasis species
- Determine which attributes best address emphasis species conservation priority
- Evaluate response of attribute to environmental changes over time
- Evaluate the cost of measuring the habitat attributes

2.3.1 Select Emphasis Species for Which Habitat Monitoring Is Appropriate

In most management settings, emphasis species have been identified through a rigorous process reflecting the relevant social, economic, and ecological contexts. Numerous approaches exist for identifying emphasis species (e.g., Bani et al. 2006, Carignan and Villard 2002, Lambeck 1997), and established law and policy may dictate certain criteria for identifying emphasis species (e.g., National Forest Management Act planning regulations). Effective monitoring, however, requires further evaluation to identify a subset of emphasis species that is appropriate and would be effective for monitoring habitat. During the selection process, consider management direction, biological factors, logistical factors, and the risk of not monitoring. This evaluation forms the basis for selecting species and habitat attributes that are to be monitored and should be well documented.

Management Considerations

Management objectives will differ substantially among species and, thus, influence habitat monitoring objectives. Emphasis species for which habitat may be monitored may come from a wide spectrum of conservation categories from taxa listed under the Federal Endangered Species Act to ubiquitous species that may be hunted or trapped.

The process of identifying monitoring priorities begins with a review of pertinent laws, regulations, policies, regional and forest management objectives, and priorities set through partnerships and agreements to determine those emphasis species for which monitoring of populations is required. Recovery plans for threatened or endangered species often require that cooperating agencies monitor population parameters for the species (e.g., red-cockaded woodpecker [*Picoides borealis*] [USDI USFWS 2003]). Others commit the Forest Service to monitor habitat (e.g., Mexican spotted owl [*Strix occidentalis lucida*] [USDI USFWS 1995]). Memoranda of understanding with State wildlife agencies obligate the Forest Service to assist with monitoring populations of important game species (e.g., Sitka black-tailed deer [*Odocoileus hemionus sitkensis*] in the Alaska Region).

Regional and forest management objectives also influence whether habitat is monitored for an emphasis species. If a land and resource management plan specifies management activities in ecological systems that also provide habitat for an emphasis species, it may be advisable to monitor habitat for that species (e.g., woodland caribou [*Rangifer tarandus caribou*] [USDA Forest Service 1987]). Conversely, an emphasis species associated with habitat that is not likely to be influenced by planned management actions may be a poor candidate for habitat monitoring (e.g., gray-crowned rosy finch [*Leucosticte tephrocotis*] in alpine habitats relative to timber management activities).

Biological Considerations

Habitat monitoring should focus primarily on species that are most likely to respond to changes in habitat condition because of management actions, disturbances, or climate change. In particular, management actions may impact systems in ways that are detrimental or positive but remain uncertain and require monitoring. Thus, selecting emphasis species should include not only those that are associated with forest plan objectives or desired conditions, but also those that have the potential to be affected by management actions that modify habitat.

In addition, developing a successful habitat monitoring program requires making a clear distinction between habitat and population monitoring (i.e., habitat monitoring should not be confused with population monitoring) (see chapter 1). In some cases, the monitoring objective for a species at risk will specify the detection of relatively small changes in population size (especially decreases) or occupancy. Depending on the management concern, monitoring objective, detectability, demography, and ecological relationships of a species, it may be prudent to monitor only populations, rather than to also track habitat. Under some limited circumstances, behavioral and spatial relationships may exist that allow populations to be closely linked to specific habitat attributes (e.g., amount of recently burned conifer forest is directly related to populations of black-backed woodpeckers [*Picoides arcticus*] [Hutto 1995]). If strong evidence indicates that habitat features are directly associated with population size of an emphasis species, then habitat monitoring, with the objective of indirectly monitoring populations may be an acceptable approach under a limited range of management circumstances (Haufler et al. 1999, Molina et al. 2006). Species that are difficult to detect and, therefore, difficult to monitor for population abundance are good candidates for habitat monitoring if strong habitat relationships have been documented and if information on annual population fluctuations are not needed. Under these circumstances, compare habitat monitoring results periodically with population data to ensure that the assumed relationship between habitat and population remains (see chapter 1). The indirect nature of the monitoring program relative to the link between habitat and populations must always be considered when the resulting monitoring data are used.

Logistic Considerations

The efficacy of monitoring habitat for some emphasis species depends critically on logistic feasibility. Problems associated with consistently detecting, measuring, and precisely quantifying habitat attributes can prevent adequate monitoring of habitat for even the highest priority species. Conduct a thorough evaluation of logistical constraints early in the development of a habitat monitoring program and again later in the process to ensure that a monitoring program can be initiated and maintained within budget during the identified time horizon.

Determining whether to sample a species or its habitat can also be influenced by species abundance and detectability. Abundant, easily detectable species will generally require less effort to monitor directly rather than to monitor their habitat because individuals of the species will be encountered more frequently during sampling than would individuals of rare species. Subsequent analysis of population data collected on abundant species will be much more robust for easily detectable species than for rare species because fewer sample sites will exist that do not have detections. Consequently, when understanding habitat condition is a priority, monitor the habitat of rare species that are not at risk because it may be less expensive and may provide more rigorous results than attempting to monitor populations directly.

Logistics

Assessing logistic feasibility includes evaluating whether habitat attributes can be monitored effectively with existing technology. For example, spotted salamanders (*Ambystoma maculatum*) are dependent on the presence of vernal pools dispersed through upland forests (Gates and Thompson 1981, Petranka 1998). These vernal pools, however, are difficult to detect with remote sensing techniques in coniferous forests, and they are less detectable in deciduous forests after leaves have appeared in the tree canopy. Field-based sampling of vernal pools would require much time and effort because the pools are relatively rare and are present for only a short time in the spring.

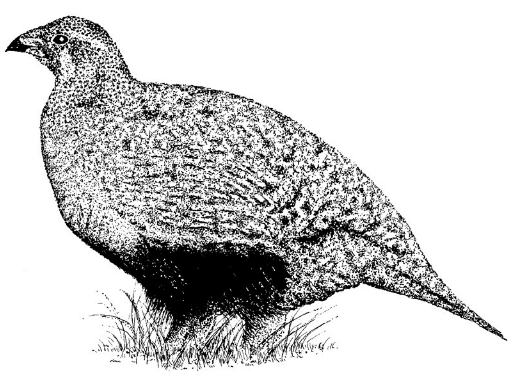
Risk of Not Monitoring

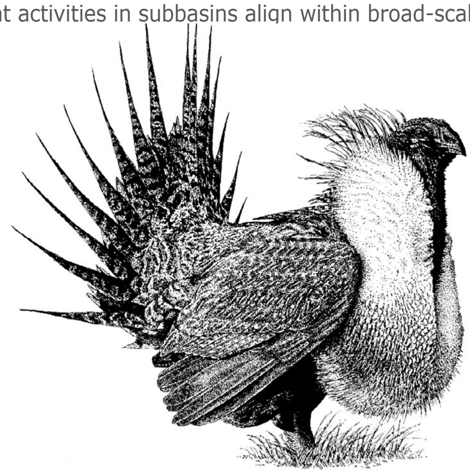
Formal or informal risk assessments will assist you in making decisions about the selection of species for habitat monitoring. These assessments are most helpful if accomplished for all emphasis species rather than for individual species in isolation so that priorities can be evaluated and the relative value of monitoring particular species compared. The risk assessment is undertaken to determine the relative cost (monetary, temporal, management risk) associated with **not** monitoring habitat for each emphasis species. The assessment, therefore, must consider the relative cost of obtaining information on population trend versus habitat and the relative value of habitat information for one species versus other species.

This analysis evaluates the potential for modifying habitat through climate change, management, natural disturbance, or succession. The analysis also evaluates whether an actual need for monitoring exists. Species associated with relatively stable habitats will have a low priority for habitat monitoring (all else being equal). In contrast, monitoring habitat for a species at risk will have a high priority for those species that are associated with disturbance-prone vegetation types, habitats likely to be intensively managed, or habitats that are particularly vulnerable to climate change.

Orders of Habitat Selection

The greater sage-grouse (*Centrocercus urophasianus*) habitat assessment framework provides an example of evaluating habitat at several hierarchical levels (Stiver et al. 2010). First order selection is the range of the species defined by the association of greater sage-grouse with sagebrush landscapes. Although habitat monitoring is seldom conducted across this extent, the range helps define the monitoring boundaries, and unoccupied sites within the range may be monitored for potential reintroductions of greater sage-grouse. Populations of greater sage-grouse define second order selection, with subpopulation or lek-group home ranges affected by configuration of sagebrush patches within the landscape. Within a home range, third order selection occurs in seasonal habitats (e.g., riparian areas, herblands, wet meadows, and grasslands) in proximity to sagebrush communities, and includes nesting, roosting, or feeding sites. Within seasonal habitats, greater sage-grouse select high-quality forbs during brood-rearing and nesting at the fourth order. Spatial and temporal scales are evident in this selection process, both becoming finer as selection order increases, and each higher order of selection is conditional on the prior order. Broad-scale greater sage-grouse population and habitat data include information generated at the national and regional levels, such as regional vegetation distribution maps (e.g., Gap Analysis Program [GAP] data; Jennings 2000). Midscale data reveal how management activities in subbasins align within broad-scale ecosystem and public land management emphasis.





2.3.2 Develop a Conceptual Model of the Emphasis Species' Habitat

A conceptual model is critical to developing a successful habitat monitoring program to ensure that monitoring is based on knowledge and founded in ecological theory (Vesely et al. 2006). Conceptual models describe the habitat requirements, threats, and limiting factors that influence population dynamics of a species and help identify gaps in our knowledge about a species (Manley et al. 2006, Mulder et al. 1999, Noon et al. 1999). Conceptual models document our understanding of the relationship of habitat attributes to the ecosystem components and processes that influence the species, they document our assumptions about how the habitat attributes and processes are related, and they identify gaps in what we know about the habitat attributes we wish to monitor (Manley et al. 2000). The overall purpose of the conceptual model is to provide a logical sequence to the selection and use of monitoring indicators (see examples of conceptual models in chapter 10).

Relevant Spatial Scales

When developing a conceptual model, first identify the spatial scales relevant to the emphasis species based on the orders of habitat selection (e.g., geographic range, home range [Johnson 1980]; see section 2.2.6). Target the most critical scale(s) by evaluating the ecological relationships of a species in the context of the spatial extent of management. Explicit consideration of scale ensures that wildlife-habitat relationships are integrated with land management activities at ecologically relevant scales (Apps et al. 2001). The species' natural history, limiting factors, and habitat relationships help define the orders of habitat selection and relevant spatial scales.

Issues of scale must be clearly considered and documented to be certain that monitored habitat attributes relate to the emphasis species and the specific threats experienced in that setting. Monitoring habitat attributes at an inappropriate spatial scale will result either in information that is too detailed and not helpful if the feature is measured with a resolution that is too fine or failure to identify relevant change if recorded with a resolution that is too broad (King 1997).

Habitat Requirements, Limiting Factors, and Threats

Our approach to selecting habitat attributes is based on the assumption that habitat monitoring is conducted to track environmental characteristics that are critical to emphasis species. Population growth is determined by a variety of factors influencing immigration, emigration, survival, and reproduction (Caughley 1977, 1994). Within the context of individual populations, however, in specific geographic and ecological settings, a small number of threats and limiting factors may strongly influence population growth. The threats and factors along with habitat requirements provide the foundation for identifying key habitat attributes to consider for monitoring. Therefore, habitat requirements, limiting factors, and threats are identified and assessed as a means to identify important habitat attributes to monitor.

Habitat Requirements, Limiting Factors, and Scale

Boreal owls (*Aegolius funereus*) provide a good illustration of how habitat requirements and limiting factors can be identified at different spatial scales (figure 2.3). Populations of this forest owl are likely to be limited by summer daytime high temperatures, nest site availability (large cavity), and prey availability (Hayward et al. 1993, Hayward 1997). The first factor (daytime high temperatures) limits these owls to boreal forests or high-mountain, subalpine forests and therefore defines the biome in which they occur. Monitoring the effects of climate change that are related to this factor may be useful to fully understand the response of boreal owl habitat to land management activities. Nest cavities represent a fine-grain habitat attribute that must be dispersed across broad areas. Prey availability, on the other hand, could relate to fine- or coarse-grain habitat attributes (Hayward et al. 1993). Vegetation structure within forest stands influences the vulnerability of prey to capture by owls, whereas broad forest vegetation types influence the abundance of principal prey (e.g., mature and older subalpine forest may have 10 times the abundance of small mammals of a midsuccession lodgepole pine (*Pinus contorta*) forest [Hayward and Hayward 1995]). This model of habitat associations suggests that habitat monitoring could focus on the extent of subalpine forest at broad spatial scales, large snag distribution and abundance at the scale of fifth level (Hydrologic Unit Code) watersheds, and forest structure (canopy closure and tree size) at a scale of watersheds or individual stands.

Figure 2.3.—*First recognized as a breeding resident of the central Rocky Mountains in the 1980s, the boreal owl is one of the important predators of small mammals in subalpine and boreal forests of North America. Habitat associations of the owl are determined by a range of factors at different spatial and temporal scales.*

The process begins by listing several of the most important habitat attributes associated with each potential limiting factor, threat, or habitat requirement. Often, these attributes are identified in existing species-specific wildlife habitat-relationships models (e.g., Mladenoff et al. 1995), species assessments (e.g., Johnson and Anderson 2004, Rahel and Thel 2004), species accounts (e.g., Weckstein et al. 2002), and other information sources (e.g., DecAID for snags and down and dead wood [Mellen-McLean et al. 2012]).

You may want to select habitat attributes that could indicate climate change effects. Conduct a **climate change vulnerability assessment** (Glick et al. 2011) for each emphasis species or species group to determine whether climate change might affect habitat requirements or limiting factors, and whether it should be added to the species' conceptual model as a potential threat. In this way, the effects of climate change are incorporated during the process of constructing the conceptual model.

The link between limiting factors or threats and habitat may be indirect. In some cases, habitat may not be directly associated with the limiting factor (e.g., ungulate populations limited by predation [Patterson et al. 2002]). If you can make a case for a functional link between limiting factors or threats and habitat, or if you can identify a habitat requirement, then develop a list of potential habitat attributes. Chapter 7 provides guidance for evaluating human disturbance agents as potential limiting factors and including them in a conceptual model.

Measurable Attributes

After you have identified requirements, limiting factors, and threats and linked them to habitat attributes, you may need to recast them so they are measurable. For example, a species' habitat requirement might be late-seral forest, but this must be translated into one or more measurable attributes such as basal area, quadratic mean diameter, or stand density index (see chapter 4, section 4.3.2).

2.3.3 Species Habitat-Relationships Models

Existing habitat-relationships models may represent a good foundation from which to build a conceptual model for identifying key habitat attributes to monitor. Useful habitat-relationships models have been created for a number of species (Morrison et al. 2006). In some cases, models have been evaluated (e.g., Cook and Irwin 1985, Rowland et al. 2003, Wisdom et al. 2002), while in other cases, they have been peer reviewed and corroborated through expert opinion (e.g., Holthausen et al. 1994), and others may be new models that are currently being tested. Nevertheless, habitat-relationships models represent a synthesis of knowledge regarding habitat associations and a potential resource for building a conceptual model for monitoring.

Because some models provide an index of habitat quality based on a suite of measurable attributes, those attributes may be the ones selected for monitoring if a suitable match in geographic scale and if the expected level of precision is sufficient (Morrison et al. 2006). Habitat-relationships models may also be used to screen large areas of potential habitat and focus monitoring on smaller areas where the probability of finding target habitat attributes is greatest (e.g., Welsh et al. 2006).

Furthermore, use of the outputs of habitat-relationships models (Beck and Suring 2009) to monitor habitat is attractive because the models generally avoid intensive, field-data collection (figure 2.1) (but see section 2.3.1). Well-designed habitat-relationships models may facilitate making habitat-based inferences to population trend. Making those inferences is dependent, however, on documented relationships between habitat condition and population status and on the absence of limiting factors independent of habitat. If a suitable habitat-relationships model exists that incorporates and combines selected attributes, the monitoring program may be designed around the model and its outputs. If such a model does not exist, then it may be developed with the assistance of species experts (see chapter 5). When developing a new model, consider incorporating aspects of human disturbance that could reduce habitat amount or **habitat effectiveness** (see chapter 7).

2.3.4 Identify Habitat Attributes Suitable for Monitoring

The conceptual model likely will result in identifying numerous habitat attributes at several spatial scales that could be monitored. The challenge and art of successful habitat monitoring is to select a subset of these attributes that not only represent key ecological relationships for the emphasis species but also can be monitored at the appropriate scale with existing technology and within the anticipated monitoring budget. The process of attribute selection will likely be iterative. We discuss important criteria in the following section that influence the selection process.

Relationship of the Attribute to Habitat Requirements, Limiting Factors, and Threats

A review of relevant published literature and population surveys, to the extent possible, can help identify potential habitat attributes that are linked to habitat requirements, limiting factors, and threats identified within the conceptual model. For example, the red-cockaded woodpecker uses open, mature pine woodlands (e.g., longleaf pine [*Pinus palustris*]) and savannahs with large trees for nesting and foraging habitat (Conner et al. 2001). Likely habitat attributes associated with these habitat requirements are stand age, tree species composition, tree diameter, and understory composition and height. These relationships have been well established and documented in the published literature (e.g., Hovis and Labisky 1985). A primary limiting factor for this species is the availability of current or potential cavity trees; cavities are nearly always excavated in large, old trees, primarily those with decayed heartwood (Conner et al. 2004). Habitat attributes that represent this limiting factor are the number, size, and condition of trees (see chapter 4, section 4.3.2). Threats affecting this species include habitat loss and fragmentation and subsequent changes in the woodpecker population's genetic structure (Conner and Rudolph 1991). Habitat attributes that represent these threats include size and distribution of habitat patches (see chapter 6).

Degree of Change in the Habitat Attribute Through Time

Consider the potential magnitude of change in each habitat attribute across the timeframe of interest. Little information will be provided if the attribute is unlikely to change perceptibly during the life of the monitoring plan. For example, the American pika (*Ochotona princeps*) is a montane species restricted to talus slopes (broken rock below cliffs) that are fringed by suitable vegetation (Smith and Weston 1990). Although rock size is an important habitat attribute for pikas (Tyser 1980), it would not be a suitable attribute to monitor because average rock size of talus slopes is unlikely to change during the timeframe of most monitoring plans. Whether suitable talus slopes are actually used by American pikas, however, may be more strongly related to changes in predation risk (resulting in less time foraging) that may be stressing populations rather than direct habitat change. In this case, monitoring may more prudently focus on factors such as changes in numbers of human-subsidized predators (e.g., dogs [*Canis familiaris*] or ravens [*Corvus corax*]) rather than structural aspects of habitat. Chapter 7 discusses human-induced disturbance factors.

Also, consider the potential for changes in climate to produce changes in habitat through time. Ample evidence exists that shows distribution and traditional habitats for many species are already changing because of climate change (McKenzie et al. 2004). For example, moths and butterflies have shown elevational changes in distribution, apparently in response to climate change. Ranges of populations of Edith's checkerspot (*Euphydryas editha*) and sachem skipper butterfly (*Atalopedes campestris*) have shifted upward along elevational gradients as compared with historical ranges (Crozier 2003, 2004; Parmesan 1996; also see the *Vegetation Phenology* subsection in chapter 4, section 4.3.2).

Geographic Scale

Consider the relationship between the geographic scale at which the attribute may be measured and the geographic scale of the ecological process of interest. For example, amount of suitable forage may limit elk (*Cervus canadensis*) population size in some locales in some years (Coughenour and Singer 1996). Although forage productivity can be monitored accurately at fine scales, it is more difficult to monitor at scales at which elk populations are generally managed (e.g., game management unit). Furthermore, it is often not apparent how much and which areas of a landscape should be managed for forage production to induce a measurable herd response (Cook 2002). It may, therefore, be infeasible to directly monitor forage productivity but, instead, more prudent to monitor habitat attributes related to forage availability for elk, such as percentage canopy cover within particular land cover types.

Ease of Measuring and Quantifying the Habitat Attribute

The ease of measuring attributes and the amount of inherent variation in attribute values influence the choice of habitat attributes to monitor. The advantages of choosing attributes that can be easily measured include a reduction in errors during data collection and an increase in repeatability among observers (Welsh et al. 1997). Also, using simple techniques will facilitate collection of larger samples resulting in more robust conclusions.

Many habitat attributes have considerable variation when measured, which can be attributed to true sample variation and observer variation (Roper et al. 2002). This variation has important implications for the design of monitoring programs and interpretation of the results (see chapter 3). Estimating required sample sizes will help in selecting habitat attributes by indicating the effort needed to be confident that changes in an attribute will be detected (Scheaffer et al. 1996). Calculating minimum sample sizes necessary to detect differences among sampling periods may provide guidance on which attributes would be best used in a monitoring program (i.e., power analyses [Zar 2010]). Chapter 3 provides a more complete discussion of these aspects, including power, effect size, and confidence levels.

Selecting habitat attributes will also depend on the level of sampling intensity needed for each attribute to meet the monitoring objectives and to provide information for management purposes (see chapter 3, section 3.3.1). Some attributes can be sufficiently measured with existing, remotely sensed data that would be relatively inexpensive to track over time; the same attributes could be measured through intensive field sampling at higher costs if greater precision is needed. Chapter 4 describes approaches for monitoring many common vegetation-based habitat attributes at different levels of intensity.

Similarly, the rigor of the sampling design (e.g., the number of sample sites) will influence cost. Therefore, decisions regarding which habitat attributes to measure and what sampling design to use should focus on what information is necessary to make management decisions. If a general understanding of habitat change is desired and can be obtained from existing remotely sensed data, gathering more accurate but expensive measurements of habitat attributes that are difficult to measure will not provide extra value. Also, if the effects of management can be effectively evaluated based on only an understanding of subtle, but important, changes in vegetation structure, then collecting information on land cover will be a waste of funds, even if it is relatively inexpensive. The most prudent habitat monitoring program will focus on measuring the least expensive habitat attributes that can indicate the status of habitat, for the species (or species group) in question, at a scale and level of precision that is relevant to management.

Potential Response of Habitat Attribute to Management Activities

To be useful for monitoring, a habitat attribute must exhibit some likelihood of change, either in response to management activities or in response to other factors of interest such as climate change. For example, black swifts (*Cypseloides niger*) nest on ledges or in shallow caves in steep rock faces and canyons, usually near or behind waterfalls (Lowther and Collins 2002). Although these nest sites are required habitat and limit black swift populations, few, if any, site-specific management practices exist that will increase the number of nest sites. Therefore, measuring changes in nest site availability would not reflect a potential response to management. In contrast, measuring changes in availability of nest sites for a cavity nester would reflect a potential response to management or to change in climate.

Environmental Context of the Habitat Attributes

Evaluating habitat attributes includes considering environmental context. Does the value of the attribute to be measured depend on the characteristics of the surrounding environment? For instance, mountain bluebirds (*Sialia currucoides*) are secondary cavity nesters (Power and Lombardo 1996); therefore, tree cavities are an important habitat attribute for them. Cavities occurring in interior forests would not be considered a habitat attribute beneficial to mountain bluebirds, however, because they select cavities at prairie-forest **ecotones** or in savannas, recently burned areas, or clear-cut forests.

2.3.5 Set Monitoring Priorities Among Attributes

The list of habitat attributes identified for monitoring will likely exceed budgetary capabilities (Marsh and Trenham 2008). Therefore, it is critical to evaluate the relative importance of all identified habitat attributes for all species and to prioritize among attributes. The following criteria provide guidance for setting these priorities. The criteria are not presented in rank order, rather, each should be weighed from the standpoint of its particular management context.

Attributes Common to Many Emphasis Species

Some habitat attributes will be shared by several emphasis species. Selecting these attributes for monitoring will result in meeting the monitoring needs of several species, especially if the scale of use is similar across species. Monitoring a specific attribute for one species might not be adequate for another species if the second species requires a different context for the same attribute. For example, mistletoe brooms in interior forests are a nest habitat attribute for numerous species, but great gray owls (*Strix nebulosa*) use brooms only in proximity to meadow-forest ecotones (Franklin 1988). Monitoring mistletoe brooms without that context would still indicate the amount of habitat for great gray owls, but only at a coarse level.

Conservation Priority

Prioritizing emphasis species and associated habitat attributes by their perceived threat or need for conservation action has become a standard practice in managing natural resources (Carter et al. 2000). Most conservation priority-setting approaches emphasize maintaining biological diversity and reducing threats when deciding where to focus investment (e.g., Groves et al. 2000). Socioeconomic and political attributes of emphasis species and associated habitat attributes may also influence the effectiveness of conservation actions, however. The need for a conservation priority-setting process is driven by limited resources that necessitate choices among subsets of all possible emphasis species in any given geographic area, given distinct differences among emphasis species and their need for conservation action.

Prioritization systems in conservation planning differ greatly in what factors are considered; how these factors are scored, weighted, and integrated; and how the resulting information is presented and used (Mehlman et al. 2004). Most systems are based on some estimation of risks to species, often using multiple **surrogates** that are thought to directly impact key population parameters, such as population size or trend. Other considerations include the importance of the emphasis species in the ecosystem (Rohlf 1991), its value as an umbrella or focal species (Lambeck 1997, Rohlf 1991), or its commercial value. By documenting the priority ranks by spatial scale, information can be provided on a variety of combinations of habitat attributes to monitor, depending on resources available.

Environmental Trends

Ideally, a selected habitat attribute should have a known short-term and consistent response to natural disturbances, anthropogenic stressors, or management activities through time. Otherwise, interpreting the implications of observed change in the attribute through time will be difficult. For example, creation of early seral habitats, including increases in herbaceous cover, typically follows wildfire. Thus, the attribute of percentage of the area in early seral successional stage is an appropriate one. By contrast, wildfire may lead to highly variable tree canopy cover, depending on the patchiness of the burned area (Swanson et al. 2011).

Cost of Measurement

Cost is often the limiting factor during implementation of a program to monitor habitat (Marsh and Trenham 2008). Priority setting must consider estimates of all implementation costs. Cost evaluation will be most effective when estimates include economy of scale because cost per attribute or cost per sample may be reduced when data are collected for multiple attributes at a given site.

2.3.6 Species Groups and Surrogate Species

When species groups or surrogates are used in land management planning (Wiens et al. 2008), habitat attributes should be selected for monitoring that are directly related to the whole group of species or to the surrogate. The conceptual model for habitat relationships will, therefore, be developed to relate to the group or surrogate. Likewise, the relationships between habitat attributes and limiting factors, threats, and habitat requirements should be defined for the entire species group rather than individual species within the group.

2.4 Conclusions

A habitat monitoring program for several emphasis species within a management area (e.g., national forest) is likely to include a broad spectrum of habitat attributes and associated monitoring approaches. Emphasis species are likely to include some with very narrowly defined niches and other species or groups associated with more generalized habitat attributes. Therefore, the monitoring program for the management area may require a wide range of sampling intensities and sampling designs. Some of the habitat attributes selected for monitoring may provide information on habitat status for several species, whereas others may help evaluate trend for a single species.

The challenge of selecting which habitat attributes to evaluate within an integrated habitat monitoring program is largely one of setting priorities and being honest about the scope of program the management area can afford. Difficult decisions must be made to determine which species will **not** be monitored. For the high-priority species, identifying habitat attributes that are associated with population status and are likely to respond to management practices is imperative; it is useless to track the status of habitat attributes unrelated to the life history of the emphasis species. Furthermore, if the habitat attributes cannot be monitored with sufficient precision to detect biologically meaningful change, it is unwise to collect the data.

We stress the value of using a conceptual model to highlight key habitat attributes to consider for monitoring. The bottom line is to choose habitat attributes based on the biology of the emphasis species and to monitor only if you can actually obtain a useful answer.