Chapter 5: Application of State-and-Transition Models to Evaluate Wildlife Habitat

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Summary

Wildlife habitat analysis often is a central focus of natural resources management and policy. State-and-transition models (STMs) allow for simulation of landscape-level ecological processes, and for managers to test "what if" scenarios of how those processes may affect wildlife habitat. This chapter describes the methods used to link STM output to wildlife habitat to determine how estimated habitat varies across the landscape, how habitat is affected by different land management scenarios, and how management might enhance estimated habitat for particular species. Using the Washington East Cascades as an example, we provide sample output of habitat analysis for the American marten and western bluebird under two management scenarios. Wildlife habitat assessments based on the methods illustrated here will differ greatly based on habitat characteristics important to individual species, and the ability to interpret wildlife information accurately.

Introduction

Wildlife habitat analysis and conservation often are a central focus of natural resources management for both ecological and social objectives. Ecologically, wildlife is an indicator of ecosystem conditions. Each species depends on a range of ecosystem features for life activities such as foraging, roosting, nesting, denning, and hiding from predators (Bolen and Robinson 1999). Therefore, presence or absence of a species in a location assumed to contain habitat characteristics linked to that species may provide clues about both habitat condition and integrity of ecological processes (Grimm 1995). Wildlife also has social value (Decker et al. 2001). This value is illustrated by hunting and fishing fees paid, wildlife viewing (e.g., birdwatching), and the wealth of existing nonprofit groups that focus on wildlife (e.g., World Wildlife Fund, National Audubon Society, Boone and Crockett Club). Ultimately, wildlife plays an important role in both ecological and social systems.

Wildlife habitat is relevant to both ecological and social natural resource objectives.

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The importance of wildlife within both ecological and social contexts has resulted in many wildlife-related policies. Among the most notable federal policies is the Endangered Species Act (ESA) which was established "to protect and recover imperiled species and the ecosystems upon which they depend" (USFWS 2011). Regional and state-level policies, such as the U.S. Department of Agriculture Forest Service (USDA FS) Northwest Forest Plan (USDA FS 1997) and state land harvest regulations, respectively, may complement or supplement federal guidelines for wildlife conservation, or focus on regional priorities. However, mismatches between geopolitical boundaries, land use, and geographic ranges of wildlife species often result in inconsistent management needs and conflict related to management strategies for species (Morzillo et al. 2012). Such conflict can become even more prolific when wildlife management is placed within a context of broader natural resource policy goals. A need exists to provide a useful interpretation of available knowledge at a defined scale of analysis for decisionmaking about wildlife in the context of other management objectives.

State-and-transition models allow for landscape-level evaluation of simulated ecological processes. The STMs can be used to project changes in future vegetation condition and allow managers to test "what if?" scenarios about how landscape change may affect natural resources. The STMs divide the landscape into state classes that characterize the cover type (dominant species or functional group) and structural stage (percentage cover, canopy layers, etc.). The STM state classes do not measure wildlife habitat directly, but rather particular vegetation features that may be related to species-specific habitat variables. Transitions between state classes simulate dynamic processes such as succession, disturbance, and management activities. The STMs have been used in many coarse-scale analyses of vegetation dynamics, as well as those that include examples of management questions focused on wildlife (Barbour et al. 2005, Evers et al. 2011, Wisdom et al. 2002, Wondzell et al. 2007). In this study, we linked STM state classes to habitat relationships for selected wildlife species.

This research was part of the Integrated Landscape Assessment Project (ILAP), the objective of which was to prioritize land management actions based on fuels conditions, wildlife habitat, economic values, and climate change across Arizona, New Mexico, Oregon, and Washington. This chapter describes the methods used to link STM output with wildlife habitat information. Specific research and management questions pursued with that linkage include:

- How does estimated habitat for focal species differ across the study landscapes?
- How do different land management scenarios affect estimated habitat?
- What management efforts are necessary to enhance estimated habitat for focal species?

As follows, we describe the use of STMs to answer these questions. Using the Washington East Cascades modeling zone (chapter 2; fig. 2.4) as an example, we provide example output of habitat analysis from STM modeling results for two species and two management scenarios.

Methods

We integrated species-habitat relationships with STM output for two regional analyses: the USDA FS Pacific Northwest Region 6 (Oregon and Washington; OR/WA hereafter), and the USDA FS Southwestern Region 3 (Arizona and New Mexico; AZ/NM hereafter). See chapter 2 for details on STMs. Our analysis included all forested and arid land areas, and our observational unit of analysis was habitat. Construction of the wildlife habitat module consisted of three phases:

- Phase 1: Identify data capabilities and limitations
- Phase 2: Select focal species
- Phase 3: Build wildlife habitat models

Phase 1: Identify Data Capabilities and Limitations

There are many approaches to modeling estimated wildlife habitat, which we classify here into two categories: “bottom-up” and “top-down” models. Bottom-up models are constructed using ecological variables known to be important to a species. For example, a habitat suitability index (HSI) is a mathematical index based on known habitat characteristics that represents the estimated ability for a location to support a particular species (US EPA 2008). Many agencies, including the U.S. Geological Survey, U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service, and U.S. Army Corps of Engineers use HSIs as tools for landscape evaluation. In contrast, top-down models are constructed using information derived from models used for observation of ecological processes (e.g., vegetation community succession or response to disturbance), but were not built primarily for evaluation of wildlife habitat dynamics. The species-habitat relationships described here are top-down models, such that they are constructed based on output variables from STMs.

We used STM state classes, comprised of vegetation cover type and structural stage, as a basis for evaluating potential wildlife habitat (see chapter 2 for a detailed description about the construction and application of STMs). For forest STMs, cover types were based on forest type importance value (Horn 1975), and structural stages included tree size (quadratic mean diameter), canopy cover (percentage closure), and canopy layers. Because we used a top-down modeling approach, wildlife habitat models were constructed solely from species-habitat relationships that could be derived from STM state classes. As a result, STM state classes do not align perfectly with key wildlife habitat features that might be identified as important when using a bottom-up habitat modeling approach. Therefore, as also suggested by other researchers (e.g., Shifley et al. 2008), we recommend that the utility and precision of our wildlife habitat models be perceived as limited to mid- to coarse-scale evaluation, the state classes defined by STMs, and the available scientific information that aligns habitat features with those state classes.

Phase 2: Select Focal Species

Our objective was to construct wildlife habitat models for approximately two-dozen focal species across both study regions. Identifying focal species consisted of a three-step process.

Step 1: Focus on terrestrial vertebrate species—

We included only terrestrial vertebrates in this analysis. Terrestrial vertebrates were more likely than other species to be related to habitat characteristics that could be evaluated using ILAP STM state classes. During our investigation, we determined that wildlife habitat models for many amphibians and small mammals required consideration of fine-scale habitat features, such as water, soil moisture, and ground nest or burrow sites that are not associated with ILAP STM state classes (but could be associated with STM state classes if models were designed differently). Although we initially sought to include a wide variety of terrestrial vertebrate species, or even invertebrates, this step resulted in a general focus on mammals and birds because the habitat features important to those species are best represented in the coarse-scale ILAP STMs.

Step 2: Identify species of management concern—

Species of management concern include endangered and threatened species under the ESA, those species proposed to be listed under ESA, state-level listed species, and management indicator species (i.e., species identified by agencies to be representative of particular land cover characteristics such as forest types). We compiled information about species of management concern for several organizations, including federal and state agencies and nongovernment organizations. We sought further guidance for OR/WA from sources such as the USDA FS Region 6 focal species list[2] and Washington Department of Fish and Wildlife Comprehensive Wildlife Conservation Strategy (WDFW 2005). For AZ/NM, we used USDA FS Region 3 focal species list,[3] U.S. Department of the Interior Bureau of Land Management (USDI BLM) sensitive species lists, and New Mexico State Game and Fish BISON-M database.

Use of listed and sensitive species was advantageous for several reasons. First, those species already are recognized by federal agencies or other land management organizations. For example, the northern and Mexican subspecies of the spotted owl are listed as federally threatened in northern and southern portions of their range, and therefore, were selected as candidate focal species in both study areas. Second, lists of species of management concern already exist, and mechanisms are in place for consideration of them in project and land use planning. Third, there already exists a statutory, regulatory, and policy framework for designation and consideration of those species. Fourth, there already is substantial "buy-in" for those species within agencies and nongovernment organizations. Thus, species of management concern already are part of the planning process.

Step 3: Match species-habitat relationships with STM output—
After identifying species of management concern, we attempted to match habitat requirements for those species to STM state classes (see chapter 2 for a detailed description of state classes). This step greatly reduced the potential number of focal species, as many critical habitat associations were beyond the scope of STM models. For example, the mule deer is a species of economic interest in both study regions. Important habitat characteristics of mule deer include thermal cover (i.e., canopy cover), hiding cover (i.e., shrub and stem density), and forage quality (i.e., forbs and shrubs; Feldhamer et al. 2003). Assessment of thermal cover characteristics was possible from canopy information derived from STM state classes. However, we were unable to associate hiding cover and forage quality to STM state classes with acceptable precision, and as a result, we were unable to include mule deer as a focal species. Therefore, focal species were limited to those with habitat characteristics that could be matched to the thematic detail of vegetation data provided by STM models. Our final lists included 24 focal species for OR/WA and 13 focal species for AZ/NM (table 5.1).

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[2] Terrestrial species assessments: Region 6 forest plan revisions. Unpublished document. on file with: U.S. Department of Agriculture, Forest Service, Portland, OR.

[3] Federally listed threatened and endangered (including critical habitat) found within national forests in the USDA Forest Service Southwestern Region. Albuquerque, NM: U.S. Department of Agriculture, Forest Service. Unpublished document.

Table 5.1—Focal species for the two study regions

Oregon and Washington	Arizona and New Mexico
American marten	Desert bighorn sheep
Ash-throated flycatcher	Giant spotted whiptail
Black-backed woodpecker	Gray vireo
Cassin's finch	Grey checkered whiptail
Fisher	Lesser prairie chicken
Flammulated owl	Mountain plover
Gray wolf	Northern goshawk
Greater sage-grouse	Northern sagebrush lizard
Lark sparrow	Mexican spotted owl
Lewis's woodpecker	White Sands woodrat
Loggerhead shrike	White-sided jackrabbit
Northern goshawk	Yellow-nosed cotton rat
Northern harrier	Zone-tailed hawk
Northern spotted owl	
Olive-sided flycatcher	
Pileated woodpecker	
Pygmy rabbit	
Red tree vole	
Sharp-shinned hawk	
Snowshoe hare	
Swainson's hawk	
Western bluebird	
Western gray squirrel	
White-headed woodpecker	

Phase 3: Build Wildlife Habitat Models

We used simple tools and decision rules to build wildlife habitat models, which allowed for transparency, transferability, and consistency in methods and between regions. The model-building process consisted of three parts:

Part 1: Build species-habitat relationships—

We developed data sheets in Microsoft Excel to construct habitat models for focal species identified in Phase 2 above. For each focal species, we constructed two spreadsheets. One spreadsheet was used to develop a matrix linking STM state classes to species-habitat relationships. The other spreadsheet was used to summarize the data matrix (i.e., first spreadsheet) into lists of state classes that were identified as "habitat" for each species. All remaining state classes not identified as habitat for an individual species were considered "nonhabitat." This summary of habitat relationship information was used as a foundation for step two of this section.

To create a matrix linking STM state classes to species habitat information, we reviewed available scientific literature for each focal species. Literature reviewed included peer-reviewed publications, general technical reports, reference books, theses and dissertations, gray literature from dependable sources (e.g., habitat management plans), and Internet references from reliable sources (e.g., "The Birds of North America," distributed by the Cornell Laboratory of Ornithology and the American Ornithologist's Union; http://bna.birds.cornell.edu/bna/). We extracted any information that would allow for matching STM state classes to important features of a species' habitat, and recorded that information on our spreadsheet matrix. Our focus was primarily on quantitative data (e.g., certain size class categories of trees), but we used best judgment to interpret qualitative data (e.g., "large trees") into STM categories, as appropriate.

During this matching process, we developed decision rules for useful yet incongruent information related to particular situations in order to maintain consistency among selections of cover types and structural stages for all species. In some cases, a number of variations were nested within a dominant cover type in the STMs. For example, lodgepole pine and lodgepole pine/mixed conifer represented variations of cover types nested within lodgepole pine-associated cover types. Thus, we developed a decision rule to select all cover types that contained variations of the cover type of interest. In this situation, focal species habitat that was matched to lodgepole pine would also be matched to lodgepole pine/mixed conifer. Because our observational unit of habitat (and projected potential habitat) was based on habitat characteristics rather than current species occurrence, similar decision rules were adapted for actual versus potential geographic range of each species. In other words, cover type and structural stage combinations within a modeling zone were classified as habitat if that cover type and structural stage combination would provide suitable habitat for the species, even if the species does not currently occur in that modeling zone. For example, the gray wolf is a habitat generalist for which forest cover types and structural stages in western Oregon and Washington provide potential habitat because of potential presence of prey species (e.g., deer and elk). Although gray wolves currently do not occupy western Oregon and Washington, suitable habitat exists and was identified in those locations. Conversely, the black-backed woodpecker is a habitat specialist that occupies more specific dry-forest cover types and structural stages particularly in eastern Oregon and Washington, and identified habitat closely mirrors current distribution of the species.

Decision rules remained intact with very few exceptions, but we recorded those exceptions on the habitat summary Excel spreadsheet. Exceptions included completely illogical matches, and additions or deletions recommended by external reviewers during the quality assurance process (see "Step Three" of this section). For example, Douglas-fir is one cover type associated with spotted owl habitat. Following our decision rule, all cover types containing Douglas-fir would be considered spotted owl habitat. However, one reviewer suggested that Douglas-fir/oak should not be considered habitat because of increased probability of contact with the more aggressive barred owl. Therefore, even though the Douglas-fir/oak cover type contains Douglas-fir, it was not considered a suitable cover type for the spotted owl. Similarly, cover types that included mountain big sagebrush initially were included as lark sparrow habitat based on the described decision rules and information from the literature. However, the mountain big sagebrush cover type (and combinations thereof) was later removed because an external reviewer noted that lark sparrows only are observed among it during migration.

Part 2: Build wildlife habitat database—

We constructed a database in Microsoft Access to link information from the wildlife habitat models to STM simulation output. This database served as an external module that can "dock" to the STMs. This module approach allows for flexibility for additional focal species, linkages with STM output from future study areas, and addition of new wildlife habitat research and information that becomes available. Because of limited ability to derive species-habitat relationships from STM state classes, we used a conservative binomial numbering method to transfer information from the Excel worksheets to Access. In the Access query for each focal species, we entered a "1" to indicate state classes that were identified as habitat, whereas those state classes that were not identified as habitat were left blank.

Part 3: Quality assurance—

Our quality assurance process consisted of an external review of wildlife habitat models and intragroup proofreading of Access data. We solicited expert reviews of habitat models to identify errors created during model-building, and clarify information from the scientific literature that did not match regional observations. At least one external review was completed for each species. Reviewers were sent the Excel datasheets and directions for interpreting habitat information. Although information provided by reviewers was extremely helpful for fine-tuning the habitat models, several reviewers commented that STM state classes were not well-suited for capturing key habitat features related to particular focal species (see "Identify Data Capabilities and Limitations").

We completed an intragroup proofreading process to error check transformations of data from wildlife habitat models to the Access database. For each species, this process was led by a different individual than the one who constructed the habitat model for the same species. The Excel worksheet containing summarized STM state class information was used as the basis for proofreading efforts. Any discrepancies between the Excel worksheet and Access database were recorded by the proofreader, and the worksheet or database were then modified by the lead for that species as appropriate. A second proofreading was completed, if needed.

Example Results and Discussion

The objective of this example is to evaluate estimated changes in area of wildlife habitat in the Washington East Cascades (WEC) modeling zone (see fig. 2.4 in chapter 2) during a 50-year period (2006 to 2056). Our focal species of interest are the American marten and western bluebird. The American marten is a small- to medium-sized carnivore, typically associated with a variety of forests that contain large trees and closed canopy (Feldhamer et al. 2003). This species is a USDA FS management indicator species for late-successional conditions for all forests in the Pacific Northwest. The western bluebird is a medium-sized songbird typically associated with a variety of open forests (Guinan et al. 2008). It is a focal species for open forest communities across all forest types (USDA FS 2006). We used the process described in preceding sections to construct habitat models for both species (tables 5.2 and 5.3). Then, we applied the habitat models to STM output for two management scenarios within forested areas of the WEC. For the STM runs, 30 Monte Carlo simulations were completed for each management scenario, and thus results are reported as average values across those 30 simulations. Results of habitat analysis were visualized at the 5th field HUC scale (USGS and USDA NRCS 2011), as both hectares per watershed and percentage of area modeled within each watershed.

The marten is a carnivore typically associated with large trees and closed canopy. The western bluebird is a songbird typically associated with open forests.

The first scenario was a fire-suppression-only (FSO) scenario, in which no management prescriptions, such as logging or prescribed burning, are implemented. Under this scenario, it is assumed that fire suppression continues at the same rates as it has under the management regimes of the last few decades. With STM simulations for this scenario, change was minimal in moist and cold forest types where there was a long fire-return interval compared to dry forests. However, under the FSO scenario, dry forests became denser and more susceptible over time to stand-replacing fires.

In the FSO scenario, about 1.83 million ha of estimated marten habitat existed initially (currently), as well as 415 700 ha of estimated bluebird habitat (fig. 5.1). During the course of the simulations, estimated marten habitat decreased gradually to 1.68 million ha in 2056 (net loss = 8 percent). Estimated bluebird habitat remained relatively constant during the first 25 years of simulations, but then increased to approximately 516 900 ha in 2056 (net gain = 24 percent; fig. 5.1). Loss of marten habitat appears to be concentrated in the northern portions of the study area, as well as at relatively lower elevations (fig. 5.2). Gains in bluebird habitat are well-distributed across the study area (fig. 5.3). Thus, the small net decrease in

Table 5.2—Habitat model for the American marten, as derived from state-and-transition model state classes for Oregon and Washington

Suitable size classes:	Size description:
Grass/forb	0 or nonstocked
Small tree	25.4 to 38.1 cm quadratic mean diameter (10 to 15 inches)
Medium tree	38.1 to 50.8 cm quadratic mean diameter (15 to 20 inches)
Large tree	50.8 to 76.2 cm quadratic mean diameter (20 to 30 inches)
Giant tree	>76.2 cm quadratic mean diameter (>30 inches)
Suitable canopy closure:	
Medium	40 to 60 percent
Closed	>60 percent
Suitable canopy layers:	
Multiple layers	
Suitable cover types:	
Alaska cedar	
Barren	
Black spruce	
Cedar swamp	
Douglas-fir	
Engelmann spruce	
Grand fir	
Grass/forb	
Jeffrey pine	
Lodgepole pine	
Montane chaparral	
Montane hardwoods	
Montane riparian	
Mountain hemlock	
Pacific silver fir	
Ponderosa pine	
Red fir	
Riparian lodgepole pine	
Sitka spruce	
Spruce	
Subalpine fir	
Western hemlock	
Western larch	
White fir	
White bark pine	
White spruce	

Table 5.3—Habitat model for the western bluebird, as derived from state-and-transition model state classes for Oregon and Washington

Suitable size classes:	Size description:
Grass/forb	0 or nonstocked
Open shrub	NA
Seedling/sapling	12.7 to 25.4 cm quadratic mean diameter (5 to 10 inches)
Pole tree	<12.7 cm quadratic mean diameter (<5 inches)
Shrub	NA
Small tree	25.4 to 38.1 cm quadratic mean diameter (10 to 15 inches)
Medium tree	38.1 to 50.8 cm quadratic mean diameter (15 to 20 inches)
Large tree	50.8 to 76.2 cm quadratic mean diameter (20 to 30 inches)
Suitable canopy closure:	
Open	10 to 40 percent
Postdisturbance	
Suitable canopy layers:	
Single	
Suitable cover types:	
Douglas-fir	
Grand fir	
Noble fir	
Ponderosa pine	
Ponderosa pine/Gambel oak	
Pacific silver fir	
Western hemlock	
Western hemlock/Douglas-fir	

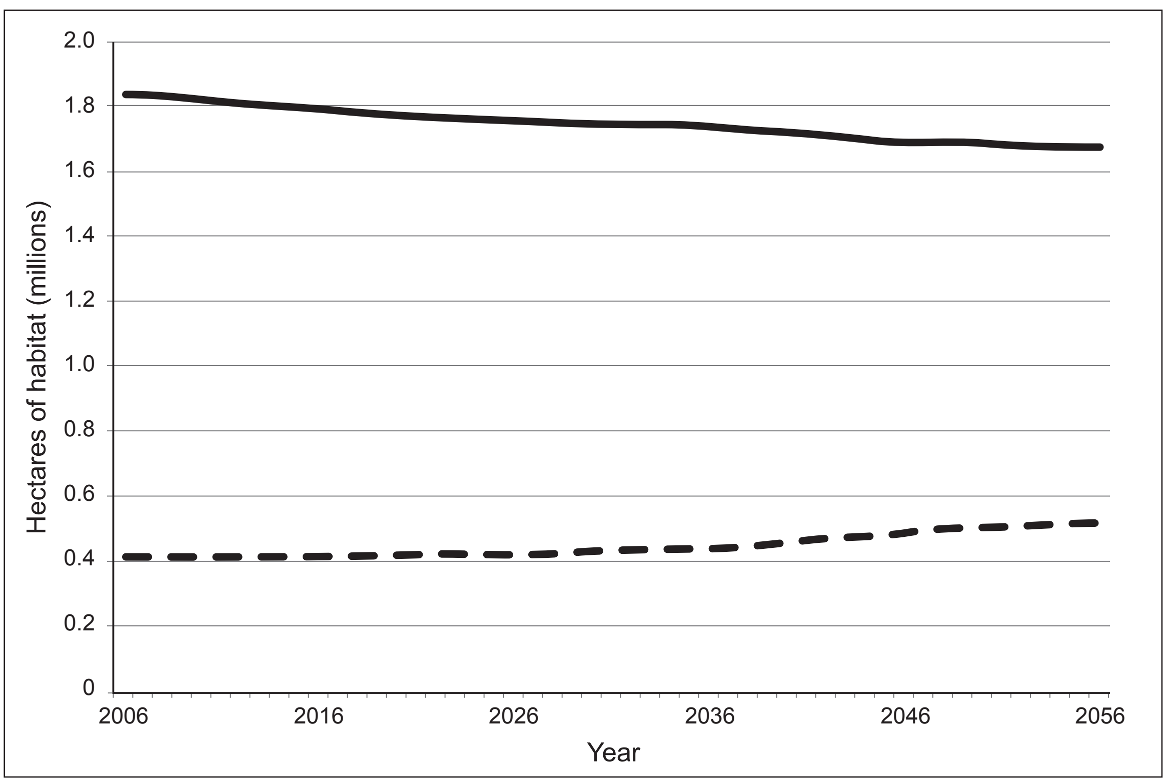

Figure 5.1—Estimated American marten (solid line) and western bluebird (dashed line) habitat for the fire suppression only scenario.

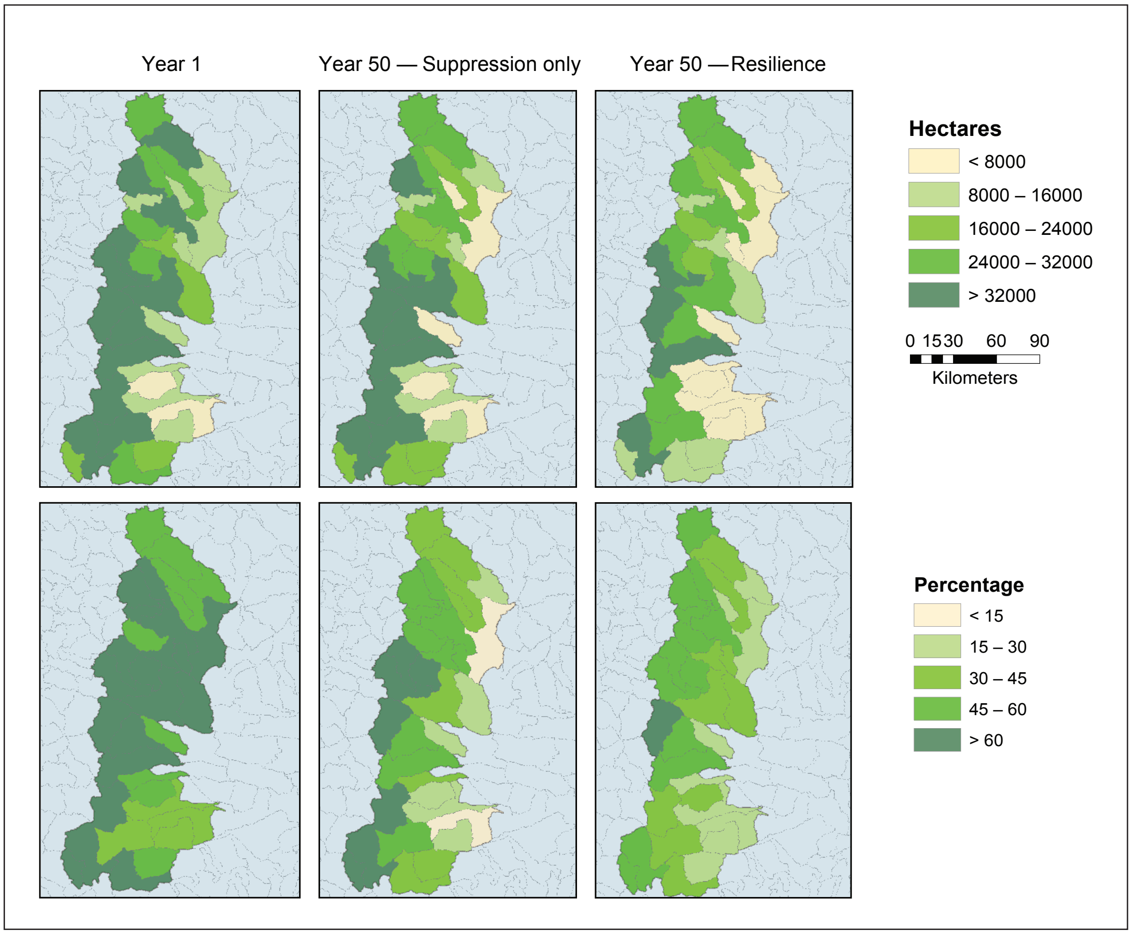

Figure 5.2—Projected habitat for the American marten at the watershed scale under fire-suppression-only and resilience scenarios. The top row illustrates area (hectares) of habitat within each watershed. The bottom row illustrates percentage of area of each watershed that is classified as habitat.

estimated area of marten habitat likely corresponds to an initial increased amount of closed forest, yet is concurrent with losses of big trees and closed forest as a result of an increase in high-severity and stand-replacing fires. Conversely, the gradual then more-pronounced increase in bluebird habitat likely is influenced by an initial closing of the forest followed by forest opening as a result of projected stand-replacing fire.

The second scenario is a resilience scenario, the objective of which is to create more fire-resilient dry forest while also maintaining or even increasing the number of large trees in the dry forest landscape. Treatments included prescribed fire and thinning from below on USDA FS and USDI BLM lands, excluding wilderness areas. We assumed that more area was treated annually on private and tribal versus public land. We also assumed that some prescribed fire took place, particularly on public lands. With STM simulations for this scenario, there was an increase in open forest and reduction in closed forest over time, even for the large tree category.

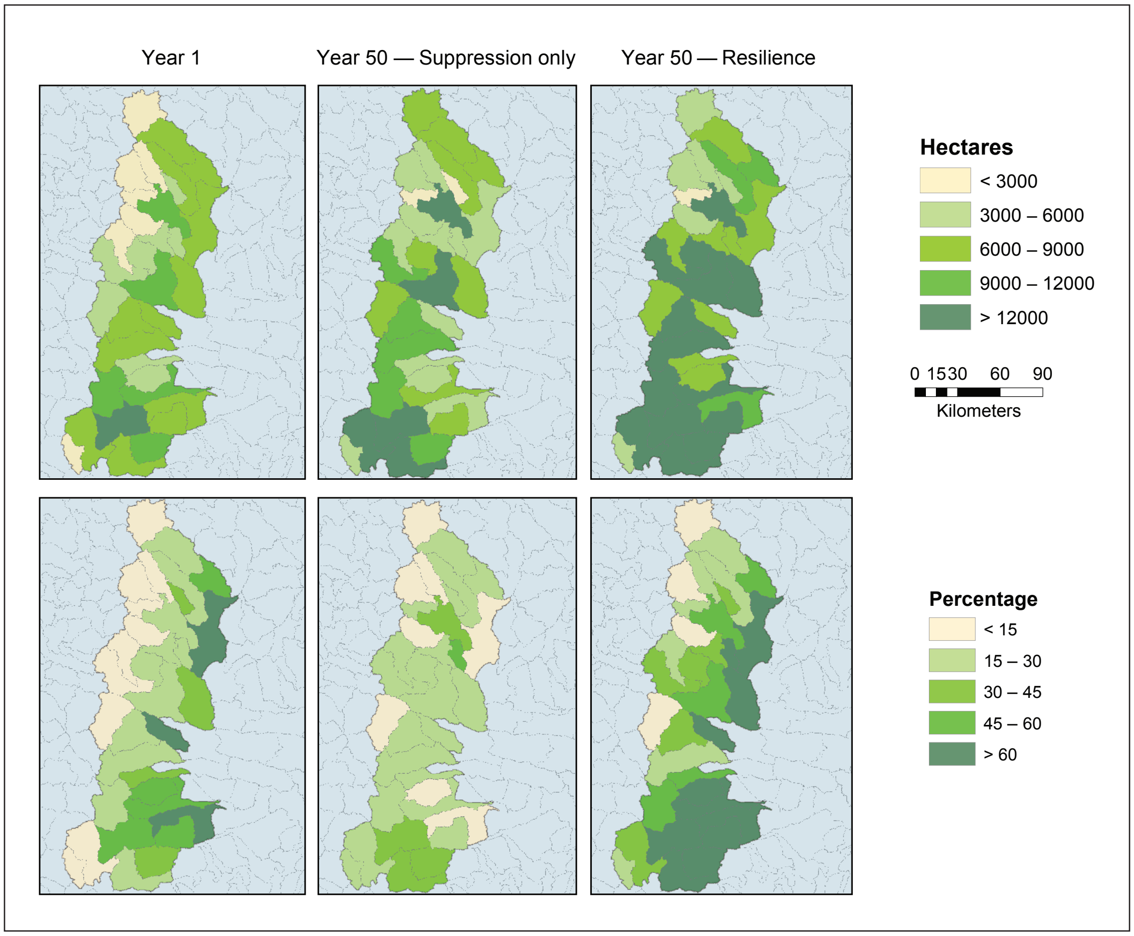

Figure 5.3— Projected habitat for the western bluebird at the watershed scale under fire-suppression-only and resilience scenarios. The top row illustrates area (in hectares) of habitat within each watershed. The bottom row illustrates percentage of area of each watershed that is classified as habitat.

In the resilience scenario, approximately 1.83 million ha of estimated marten habitat existed initially (fig. 5.4), as well as 415 700 ha of estimated bluebird habitat (i.e., same initial conditions as the FSO scenario; fig. 5.4). During the simulation, projected estimated marten habitat decreased to 1.26 million ha in 2056 (net loss = 31 percent). Estimated area of bluebird habitat doubled during the first 25 years of simulations; this rate then slowed, but estimated habitat continued to increase to 865 600 ha in 2056 (net gain = 108 percent). Losses of marten habitat appear to be concentrated in the northern portions of the WEC study area, as well as at relatively low elevations (fig. 5.2). Although similar spatially to the FSO scenario, marten habitat losses are greater in magnitude in the resilience scenario. The greatest gains in bluebird habitat are projected to take place among the central and southern portions of the area (fig. 5.3). Thus, although efforts to maintain or increase large trees initially may seem beneficial for promoting marten habitat, thinning and burning to

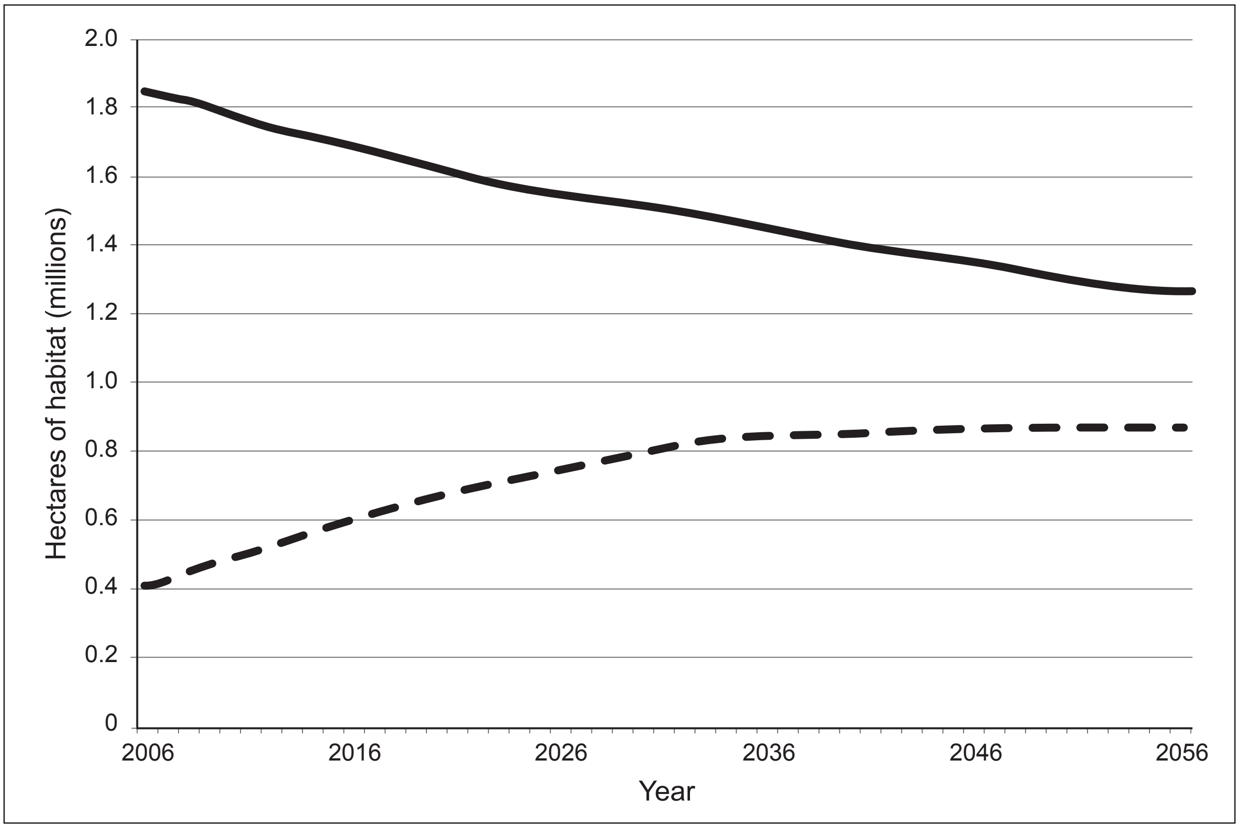

Figure 5.4—Estimated American marten (solid line) and western bluebird (dashed line) habitat for the resilience scenario.

open the forest may outweigh benefits of maintaining large trees. However, opening of the forest is expected to be beneficial for bluebird habitat across all size classes of trees. Simulations using additional management scenarios will allow users to further evaluate estimated changes as a result of management treatments and disturbance.

The methods and habitat models described here are not intended to be used for site-level management, but rather to provide managers with a vision for broader land-use planning. General trends in wildlife habitat across the study area (figs. 5.1 and 5.4) provide information about how decisions at the regional level may affect net habitat across the landscape within the context of other management objectives. Further assessment at the watershed scale (figs. 5.2 and 5.3) provides spatial information about where within the study area changes in habitat are projected to occur. Hypothetically, the resilience scenario may not be a viable option if the primary management goal is to increase the area of marten habitat in the eastern portions of the study area. However, management actions often have positive effects on some species and negative effects on others. In this case, management actions had a positive effect on bluebird habitat. Ultimately, coarse-scale analysis can provide a broad illustration of potential impacts on wildlife habitat as a result of management actions, but further site-specific evaluation will enhance this approach by providing more detailed assessment of habitat characteristics.

Conclusions

Wildlife habitat is an important component of land management and related policy. Using habitat as the unit of observation, the approach described and illustrated here can aid managers with evaluating potential impacts of management activities on estimated wildlife habitat across landscapes at mid to coarse scales. A benefit of such analysis is the ability to assess both spatial and temporal effects of land use decisions, and where and when those effects might be most beneficial or harmful to estimated wildlife habitat in the context of overall management objectives. Caveats of using this approach to address wildlife habitat management objectives, particularly the use of STM models, are that information reported at mid to coarse scales does not account for site level distribution of wildlife, and the ability to build wildlife models is limited to those variables used to evaluate vegetation dynamics. For example, this assessment at the watershed scale cannot account for management impacts on habitat distribution, and related life history traits such as dispersal. Therefore, confidence in wildlife habitat assessments based on the methods illustrated here will vary greatly based on ability to address habitat characteristics important to individual species, and ability to interpret wildlife information created by these models accurately.

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