CHAPTER

19

A Collaborative Approach in Adaptive Management at a Large-landscape Scale

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Resource managers are increasingly confronted with the problem of how to make informed decisions that rely on new information or tools. This is especially true as we attempt to shift land management practices to a regional or ecosystem perspective. Federal agencies and others have variously defined ecosystem management, which has led to many debates over the concept (Haeuber 1996). Recently, increasing conflicts over resource management have resulted in a number of area ecosystem planning efforts (e.g., Great Lakes–St. Lawrence River Basin, Interior Columbia Basin Ecosystem, Everglades-South Florida, Sierra Nevada Ecosystem Project, and Southern California Natural Communities [Johnson et al. 1999]). There have also been many well-publicized efforts to develop comprehensive landscape plans for managing individual species, focusing mainly on those that are federally listed under the Endangered Species Act (ESA) such as the northern spotted owl (*Strix occidentalis caurina;* USDA/USDI 1994a,b), California spotted owl (*Strix occidentalis occidentalis;* Verner et al. 1992), and grizzly bear (*Ursus arctos;* Burroughs and Clark 1995). For a variety of reasons, not all of these planning efforts have been successful, but all were costly.

Adaptive management has been emerging as a central theme in the management of natural resources on federal lands in the United States, particularly as it applies to the concept of ecosystem management (Walters and Holling 1990). A true adaptive process involves a rigorous scientific and repeatable approach to resource planning (Holling 1978; Walters 1986). There is a distinction between active and passive adaptive management where in the former there is an active pursuit of information as an objective of the decision-making process (Nichols et al. 1995). Walters (1997) stated that "adaptive management should begin with a concerted effort to integrate existing interdisciplinary experience and scientific information into dynamic models that attempt to make predictions about the impacts o£ alternative policies." He emphasized that this serves three functions: (1) problem clarification and enhanced communication among scientists, managers, and other stakeholders; (2) policy screening to eliminate options that are least likely to succeed; and (3) identification of key knowledge gaps.

Adaptive management is complex and conceptual, and the methods are ambiguous and rarely or only partially applied (Lee 1993; Gunderson et al. 1995; Walters 1997; Carpenter 1998; Rogers 1998). Failures of traditional management that did not use an adaptive approach have occurred most obviously with problems in large complex ecosystems (Johnson 1999b). Many efforts to implement large-area management plans (including early attempts on the northern spotted owl, hereafter spotted owl, or owl) failed for a variety of reasons. Managers are often limited by one or more of the following: a lack of data,

inadequate knowledge or understanding of available data, lack of useful methods to analyze and interpret data in a meaningful way, and/or lack of effective communication with researchers (Arnett and Sallabanks 1998). Modeling has seldom been a part of natural resource management efforts where model predictions could be tested and used to enhance knowledge and improve management (Conroy 1993). In some cases, there may be considerable information, but it may not be useful for informing decision makers. Often there are insufficient resources to use the data, especially in a timely manner. Other problems such as political pressures or resistance to change within federal agencies have also contributed. A few, efforts, such as those on North American waterfowl (Nichols et al. 1995), are succeeding because the primary constituents agreed that a problem existed, that specific information was needed to address the issue (and was sought), and how the resulting data would be used to modify management plans (Johnson and Williams 1999).

Many recent books and papers discuss problems and lessons learned from attempts at large-scale resource management, including those of manager-scientist interactions (e.g., Marzluff and Sallabanks 1998; Bormann et al. 1999; Carey et al. 1999; Concannon et al. 1999), but few described specific steps and results that led to successful implementation of a management plan. Although some tools and particularly some of the lessons that were learned from exercises such as those cited above were pertinent to parts of our work, comprehensive guidance or consistent methods had not emerged. This is not unusual given the evolving state of large-landscape-scale assessments under an adaptive management construct.

We were confronted with many of these problems in our roles as managers and regulators of the spotted owl on federal lands in northern California. The questions we sought to address led to a unique collaborative approach in adaptive management that would support informed decision making. We did not begin this effort in a formal structured way. Instead, we went through a process of trial and error until we eventually realized the importance of following a sequential and integrated adaptive approach to addressing species issues at a large-landscape scale. This was not an easy process, particularly at a spatial scale covering four national forests (more than 2.2 million hectares). Although we experienced lessons similar to those reported elsewhere, we believe our eventual process was unique because we put the main concepts of adaptive management into practice using a genuinely collaborative process. Resource managers and specialists developed hypotheses to test in collaboration with the scientists. We then developed predictive models to apply on a large-landscape basis that addressed a suite of ecological factors. This was a much more direct method than operating separately, as had traditionally been done, and it developed trust, open communication, and understanding among team members. Although the process was time consuming, it turned out not to be difficult. As a result, managers (with scientists' support) will be using the information that was generated for guiding future land-management efforts for the owl. Because we were successful in applying a structured adaptive process, we believe the description of our approach offers a significant learning opportunity that has wider application to future resource planning.

Background

The northern spotted owl has captured the attention and interest of research biologists, land managers, regulators, politicians, lawyers, and the public for over twenty-five years. It has been the focus of numerous management plans by federal, state, and private groups (e.g., USFWS 1990; Thomas et al. 1990; Simpson Timber Company 1992; FEMAT 1993; USDA/USDI 1994a,b; The Pacific Lumber Company 1999).

The Northwest Forest Plan (hereafter Forest Plan) established a system of late-successional reserves (LSRs or reserves) covering over 24 million acres on eighteen national forests and seven Bureau of Land Management districts, including the four national forests analyzed in this effort. Over a one-hundred-year planning period these reserves w should provide habitat for multiple late-successional-associated species, including the spotted owl (see Fig. 19.1 in color section). Given this assumption, there was an implicit expectation that further analyses to test and adapt management approaches would occur. These

analyses would provide the information necessary to address future changes to species and forest management throughout this period.

Northern spotted owls are among the most-studied and well-known owls in the world (Gutiérrez et al. 1995) and the best-known owl in northern California (e.g., Solis and Gutiérrez 1990; Blakesley et al. 1992; Hunter et al. 1995; Zabel et al. 1995; Gutiérrez et al. 1998; LaHaye and Gutiérrez 1999; Thome et al. 1999; Franklin et al. 2000). However, major gaps in our understanding of spotted owl habitat selection remain, particularly from the large-landscape perspective. Survey results were inadequate for large-scale analyses because of biases in selection of sites (e.g., centered around timber sales), inadequate descriptions of survey boundaries, and to a lesser extent variation in survey protocol. Lastly, data were not always available or in a useable format. Data that were available only partially represented the full range of habitat conditions found within this ecologically heterogeneous area of northern California.

Current Situation

Most planning and regulatory evaluations for owls continue to apply the traditional project-by-project or site-by-site approach. Interagency efforts to plan projects, such as timber harvests, that meet the National Forest Management Act (NFMA), ESA, and Forest Plan requirements are also hampered by organizational and logistical factors. These include differences in terminology, inconsistent habitat descriptions, varying quality of owl-habitat databases, difficulty of evaluating proposed management activities beyond the project or site level to a larger landscape scale, varying opinions of individuals involved, and a lack of methods to adequately assess cumulative impacts of proposed management activities in time and space. As a result, resource specialists mostly rely on their professional judgment to evaluate impacts. In some cases, each national forest, U.S. Department of Interior (USDI) Fish and Wildlife Service (hereafter Fish and Wildlife Service) field station, and U.S. Department of Agriculture (USDA) Forest Service (hereafter Forest Service) ranger district uses its own unique description(s) of suitable habitat or evaluation methods. In addition, owl surveys are no longer conducted in most areas, resulting in a greater dependence on analyses of habitat rather than on evaluation of known owl nest locations. Consequently, there remains a strong emphasis on evaluating and planning around individual owl sites instead of at larger spatial scales. These issues have resulted in disagreements between the regulatory and land management agencies on owl management, even among personnel from different agencies with similar objectives.

A Collaborative Process in Adaptive Management

In 1995, the Fish and Wildlife Service and Forest Service in northern California began an informal effort to improve the ability of managers to address questions about owl management under the Forest Plan. Early efforts focused on updating the spotted owl habitat database on national forest lands in the California portion of the Klamath Province. Although this informal approach is common to everyday application of resource assessments under the ESA, NFMA, and other laws, these early informal efforts to address large-landscape issues had little success. Finally, in 1997, managers formally directed a team of biologists from the four national forests and the Fish and Wildlife Service's three northern California field offices to improve the basis for resource planning and decision making under the Forest Plan. This project eventually represented a three-way collaboration among resource managers, specialists, and scientists, with each team member bringing their own unique expertise. Although the primary group responsible for this effort consisted of wildlife biologists, we were supported throughout by a variety of specialists, includeing resource planners, foresters, forest ecologists, silviculturists, geographic information system (GIS) specialists, fire/disturbance modelers, and ingrowth modelers. The term "resource specialist" refers to this larger group-. The four major tasks the team undertook were to

1. Update and improve the quality of the forest vegetation databases for owl habitat.
2. Identify and apply more applicable tools to analyze and interpret the data at multiple scales.
3. Determine how to provide the results to decision

makers in a form that would be useful for owl management at larger landscape and longer temporal scales.
4. Create and implement an adaptive approach to owl management on Forest Service lands in northern California.

Because of the importance of these steps to large-area planning, herein we describe the approach, outcome, and implications of our efforts and products.

Collaboration among Resource Specialists

The initial basis for successful resource planning, whether for single or multiple species, is development of a credible up-to-date habitat database and, map. The recent improvement and general availability of GISs has greatly increased our ability to develop these products for use at larger spatial scales and with greater spatial consistency. Although existing forest vegetation and spotted owl habitat databases in northern California were about twenty years old, each of the four national forests had recently made efforts to update their timber-attributed databases to support resource planning. These databases set the limits of our efforts to develop habitat descriptions and a new map that reflected spotted owl habitat use in northern California (i.e., we were unable to include some habitat features that we felt were relevant to owls when those features did not exist in the GIS databases).

Map Development, Quality, and Accuracy

We used published information on owl habitat use within the province and expanded the description of owl habitat based on limited analyses of known owl sites and the vegetation types in which they occurred, and the professional judgment of resource specialists knowledgeable about owls in the Klamath Province. The draft descriptions were evaluated and corrected using a modified Delphi approach (Coughlan and Armour 1992) until specialists were comfortable with the quality of the results. To improve our understanding of future habitat conditions and trends, we also used this approach to describe criteria to identify vegetation that would be capable of becoming owl habitat in the future. The resulting map was consistent with our understanding of owl habitat use and was more amenable to evaluating ecosystems, as required by the Forest Plan.

Development of an acceptable map was more difficult and time-consuming (nearly three years) than anyone on the team expected. The quality and accuracy of the forest vegetation databases and our interpretation of owl habitat relative to those databases were significant issues that had to be addressed. Our efforts were hampered by the fact that the existing GIS vegetation databases among northern California forests were not always compatible (not an uncommon situation among resource agencies and administrative units). For example, each database originated from different mapping efforts, and coding or labeling was not consistent for the same attributes. In addition, resource specialists and managers had rarely questioned the quality of the information contained on old maps, which made it difficult to ensure map accuracy. This resulted in numerous false starts as errors were found and the maps had to be recreated. Eventually a single seamless map of suitable and capable owl habitat across the four forests was completed. Based on our best professional judgment, we assumed this map offered a better basis for analyzing management actions on owls under the Forest Plan.

Collaboration among Scientists

In response to questions raised about the use and quality of the updated vegetation database and habitat descriptions, scientists from the USDA Pacific Southwest Research Station undertook an effort to quantitatively evaluate the effectiveness of these habitat descriptions at predicting owl presence-absence. They also recommended that formally applying a probabilistic approach to modeling the landscape for owl occurrence would significantly enhance the quality of the map. This step represented a significant departure from management and regulatory agencies' traditional approach to using available data and maps. Involvement of scientists required integrating their goals with those of management. Consequently, the following specific goals were agreed upon:

1. Develop habitat models for predicting owl presence-absence using both the old and new habitat descriptions.

2. Determine the optimal spatial scale to apply the models.
3. Compare and rank the various models using objective criteria.
4. Test the highest-ranked models on independent data sets.
5. Evaluate various methods to apply the best model(s) for management needs.

Because of the significance of these products (from an ecological and economic perspective), this science-based modeling approach became the major focus of our effort and laid the foundation of our adaptive process (for a thorough treatment of the modeling effort, see Zabel et al. in review).

Model Development

Developing habitat-based models to predict the presence-absence of wildlife species is relatively straightforward. First, several attributes hypothesized to be important to the species in areas that are occupied and unoccupied (though apparently available to the species) are measured. Then, sites with and without the species are compared to determine which attribute(s) are most closely associated with presence-absence. Alternative models developed in this manner are evaluated and compared, and the best model is selected (e.g., Johnson et al., Chapter 12; Young and Hutto, Chapter 8).

To develop habitat models for this project, we used data from sites that had been randomly selected and surveyed for spotted owls on national forests in northern California. These sites had been surveyed according to a standardized protocol for two consecutive years (1988 and 1989) so that both occupied and unoccupied sites were determined. To facilitate our understanding of owl-habitat associations, we developed models that discriminated between sites with and without owls at three spatial scales using concentric circles that approximated different aspects of an owl's home range size: 200 hectares, 550 hectares, and 900 hectares. Models were developed by placing concentric circles over the vegetation polygons using ARCANFO software (ESRI 1998) and then calculating the quantity of each covariate within those circles. Three habitat covariates were evaluated: (1) the total area of nesting, roosting, and foraging habitat; (2) the total length of linear edge between habitat and non-habitat; (3) and the amount of core area within each polygon (defined by buffering each polygon by 100 meters and determining the interior area). Linear, quadratic, and threshold forms of the relationship between the probability of owl occupancy and the three habitat covariates were then evaluated using logistic regression (sensu Franklin 1997) (Fig. 19.2). Six habitat descriptions were also compared that allowed us to take into account different quantities and forms of relationships between the covariates and probability of owl occupancy.

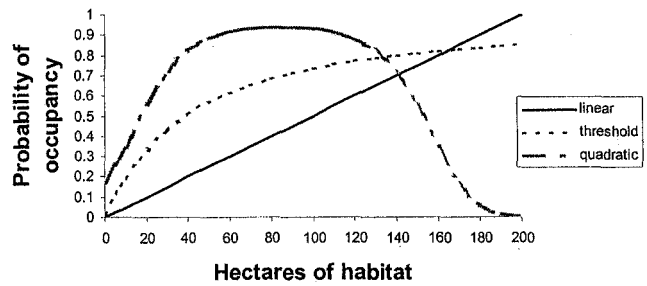

Figure 19.2. Example of linear, quadratic, and threshold forms of the relationship between habitat quantity and probability of owl occupancy.

Ranking and Selecting Models

We developed approximately one hundred models at each of the three spatial scales (200, 550, and 900 hectares). The bias-corrected Akaike's Information Criterion (AIC; see Burnham and Anderson 1998) was used to determine the most parsimonious model(s) that discriminated between occupied and unoccupied owl sites. The two models with the lowest AIC within each of six habitat descriptions, and at each of three spatial scales, were selected for further comparison and testing on independent data (i.e., a total of thirty-six models).

After critically evaluating the merits of both AIC and percentage correct classification, we decided that AIC and the percentage of owl-occupied sites correctly classified would be used to select the best models. Under percentage correct classification, predicted probabilities of occupancy are considered correct (assigned a value of 1) if they exceed some predetermined cutoff point, and incorrect (assigned a value of 0) if

they fall below that cutoff point. Although most statistical software packages use 0.5 as the arbitrary cutoff point, there are many instances when 0.5 may be inadequate. Choice of a probability cutoff point is analogous to decisions regarding Type I and II errors. As Nichols et al. (1995) noted, in science there is a strong bias against Type I errors in which a null hypothesis is mistakenly rejected. Therefore, scientists typically assign a low probability (e.g., 0.05) for Type I errors despite the fact that lower probabilities of Type I errors produce higher probabilities for Type II errors (failure to reject false hypotheses) and, hence, to detect real differences. As a result, this places the burden of proof with resource managers. Because of ESA requirements to protect known individuals of a species, the Fish and Wildlife Service was more concerned with errors of omission (i.e., predicting absence when owls were present) than errors of commission (i.e., predicting presence when owls are absent). Therefore, we decided it was more important to correctly predict owl presence than it was to correctly predict their absence. We separately determined an optimal cutoff point for each model based on the following criteria: (1) percentage correct classification of owl-occupied sites was greater than 75 percent, and (2) any loss in percentage correct classification of owl-occupied sites was more than compensated for by a gain in percentage correct classification of unoccupied sites. Final model rankings were based on the average of the AIC rank plus ranks of percentage correct classification of owl-occupied sites. As recommended by Nichols et al. (1995) and Burnham and Anderson (1998), an empirical Bayesian approach was also used to rank the models and compare results.

Model Testing

Models should not be used as the basis for management decisions without testing (Conroy 1993). Testing should be conducted on truly independent data (Fielding, Chapter 21). Therefore, we selected the best two models within each habitat description at each spatial scale and then tested them using eight independent data sets. Each independent study area had been completely censused for owls. Thus, both presence and absence were documented, most over periods of longer than two years. The study areas were well distributed throughout the Klamath Province and provided a representative test of our best models for this region. Again, we used both AIC and the percentage of owl sites correctly classified to evaluate the performance of each model on the independent data sets. This allowed us to compare the accuracy of the twelve best models at each spatial scale. Model ranks for the best models were fairly consistent for both the development data set and the test data sets. In addition, the percentage correct classification of owl-occupied sites was greater than 90 percent for our best models. The approach we developed ([AIC rank + percentage correct classification rank] / 2) and the Bayesian approach gave very similar results for the top models. This further strengthened our confidence in our choice of the best models; they fit all of the independent study areas with a high degree of accuracy. This exercise produced a best habitat model and two potentially competing models. We used the best model to evaluate the quality of owl habitat across the landscape.

Owing to the collaboration of researchers and managers, this phase of our process differed from what would have been done had this been a pure research project. First, we would not have selected the top two models within each habitat description for subsequent testing. Instead, we would have chosen a subset of the top-ranking models. Our decision to keep the best two models within each description was management driven. For example, the top-ranking model (habitat description) currently used by the management and regulatory agencies ranked fifty-fifth using the developmental data set, nowhere near the top twelve models. However, since it was the habitat description being used, it seemed important to give it a "fair chance" in both the model development and testing phases because our results could ultimately lead to a change in that habitat description.

A Framework for Future Collaboration

Although it may seem obvious to some, it is critically important for managers and resource, specialists to understand (at least conceptually) the analytical techniques that will be used by those who develop wildlife habitat models. For example, once the resource specialists and managers on our team understood what AIC

was, we collectively made purposeful choices regarding the weight we gave it relative to errors of commission. If this had been a pure research project, different criteria may have been chosen and the results may have been less understandable or useful to resource managers. Equally important, the scientists had to understand the needs of managers and specialists. This was an example of the collaborative interaction between scientists and managers that embodies the principles of conservation biology and adaptive management: the application of the best information to management, even in the absence of complete information, where the results of the application will provide new information.

To accommodate the application of habitat models in resource management, we suggest the following hierarchical (adaptive) approach to model development, testing, and application:

1. Resource scientists, managers, and specialists should work together closely from the beginning phases of any planning effort to ensure the usefulness of resulting models.
2. Models should be developed using data from large-enough areas to warrant their application to a variety of conditions.
3. Models should be tested on independent data to evaluate their accuracy.
4. Models should be tested in a manner consistent with how they are intended to be used.

Although incredibly useful for elucidating features of the biology of organisms of interest, many wildlife-habitat models have fallen short of being applied practically. To be fair, many times model application has not been the goal of the scientists, although we suspect that most expect their work will be of practical use. Regarding the concerns of scientists versus managers about models, Salwasser (1986) noted that "determining accuracy is the purview of the scientist; practicality, that of the manager." Therefore, ultimate decisions on the performance of habitat models must be made with or by the managers who will be using them.

Collaboration for Successful Adaptive Management

The final collaborative step in this exercise was for the managers, resource specialists, and scientists to establish a basis for interpretation of owl habitat quality so that management recommendations pertinent to the scale of the Klamath Province could be developed. Our thoughts on approaches and methods for analysis evolved as we refined our questions about owl habitat relationships through the process of map development and model testing. We eventually realized that many of our traditional ideas about data analysis and methods at the site scale were not appropriate at larger scales. Consequently, we strove to complete our efforts with a more rigorous and collaborative approach to developing management recommendations within an adaptive management framework.

TABLE 19.1.

Questions used to identify and prioritize Late Successional Reserves for managing northern spotted owls (*Strix occidentalis caurina*) in the Klamath Province in northwest California.

Question 1	What is the quality of owl habitat within and between reserves and groups of reserves?
Question 2	Does an opportunity exist (and where) to improve owl habitat through silvicultural treatments?
Question 3	Is there a need (and where) to manage for fuel hazard and risk?

The first step was to jointly refine the questions of management interest in northern California. Table 19.1 identifies the three primary questions that we agreed were the most significant to both regulatory evaluation and owl management under the Forest Plan in the Klamath Province. These questions helped focus our efforts to select appropriate landscape features, evaluate the available data, and use the results to rate habitat quality for spotted owls at different scales.

Application of the Model to the Map

The primary task in the interpretive process was to assess the current habitat quality of individual reserves and their potential quality. Thus, we evaluated how best (or whether it was reasonable) to apply the habitat model at the scale of a reserve or a group of interacting reserves. The models generated spatially explicit predictions within a large landscape, but the absolute results (i.e., the quality of habitat within each reserve) were the values of interest. Using the best model, we applied a hexagonal grid that covered the

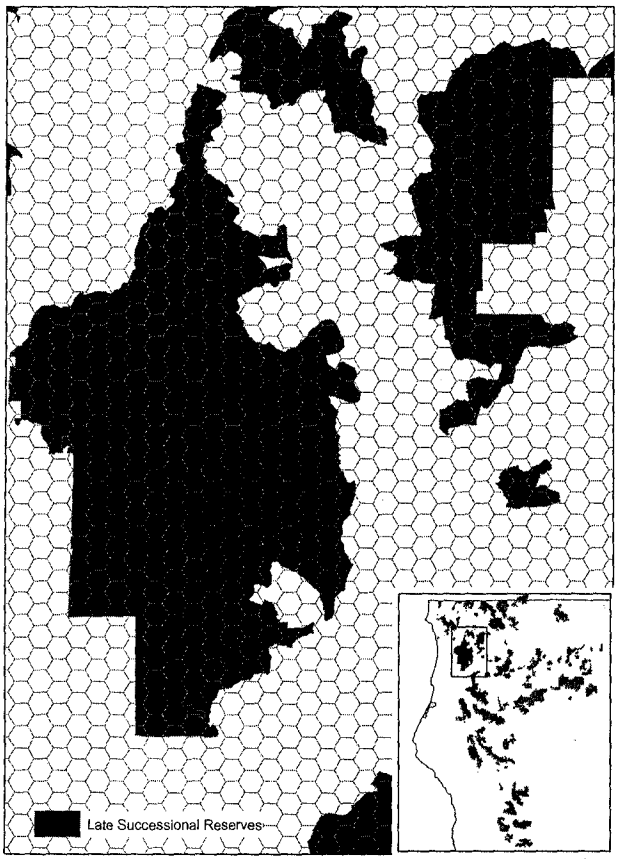

Figure 19.3. Example of hexagon grid applied to a group of Late Successional Reserves in the Klamath Province in northwestern California. Each hexagon has the probability of northern spotted owl (*Strix occidentalis*) occupancy attached to it.

landscape using the scale of the model that performed best: 200 hectares. The spatially explicit predictions were only applicable to this scale. We chose to use hexagons rather than circles to apply our model. When linked in a grid network, hexagons fully cover the landscape, unlike circles, and their shape closely resembles a circle (Fig. 19.3; Noon and McKelvey 1996b). The product of this exercise was a map in which each hexagon contained a probability of owl occupancy that we assumed to represent habitat quality. This approach allowed us to evaluate habitat quality at different spatial scales, from small to large reserves, to groups of reserves and intervening forested land.

Knowledge of landscape patterns and the factors that affect them are important to fully understand resource issues (Concannon et al. 1999). For example, Perry (1995) discussed the importance of considering the role and scale of disturbance in managing landscapes. To ensure an adequate suite of factors were included, we identified a set of other qualitative and quantitative factors that were important to evaluate the reserves to complement the modeling results. These factors included the probability and estimated intensity of wildfire, estimates of reserve connectivity based on published spotted owl dispersal distances, and projections of areas that were capable of becoming suitable or higher quality in the future. Because it is also important to know the scale at which these factors interact, we determined the spatial and temporal nature of each and whether they lent themselves to qualitative or quantitative analysis. For example, fire data were provided as probabilities of future occurrence across relatively large areas, while distance between reserves was used to assess connectivity. Data representing these factors were compiled and tabulated from other planning documents or databases developed by the national forests. Although there were concerns about the accuracy and currency of some of these data, there were neither useful methods nor other data to address them. These factors were modeled, reported as percentages, or qualitatively summarized in tabular form to make further comparisons of the reserves.

Application of the Results by Management

To provide the basis for interpretation of the compiled data, a spreadsheet was created that was linked to the updated GIS database. Within this spreadsheet, we divided the more than 2.2 million hectares of national forest lands in northern California into different landscape categories associated with the Forest Plan (reserves, non-reserved or matrix lands, and other administratively reserved areas such as wilderness). This spreadsheet allowed us to easily evaluate and compare results among reserves for a suite of factors pertinent to federal owl management at a large-landscape scale.

The probability results from the hexagon model and the summary data from each of the selected factors were evaluated and numerical ratings or condition indices were generated for each. The resulting table of indices provided the basis for a qualitative cumulative assessment of habitat quality or condition for both current and expected future conditions within each reserve. The indices and base data for

TABLE 19.2.

Summary results of Late Successional Reserve (LSR) analyses for each management question about northern spotted owls in northern California.

	Management questions			
Ecological zone	**Number of LSRs analyzed**	**Number of LSRs with low habitat**	**Number of LSRs with high priority for silvicultural treatment**	**Number of LSRs with high priority for fuels reduction treatment**
Western Klamath	18	0	2	15
Eastern Klamath	5	3	1	2
Western Cascades	2	2	2	0
Modoc	1	1	1	0
Interior Coast	7	3	4	0

each factor were ranked and displayed as a frequency distribution. This frequency distribution was used to determine whether obvious thresholds or cutoff points existed that would relate to levels of management interests or needs. Finally, a new table was created that rearranged the reserves into threshold categories for each factor. This new list was used to rank the reserves for each of the three management questions noted earlier (see Table 19.1). Three separate lists were generated that prioritized reserves (Table 19.2) according to (1) quality of habitat (question 1), (2) need for silvicultural treatment to improve quality of owl habitat (question 2), and (3) need for fuel or wildfire reduction treatment (question 3). An array of recommendations for management and regulatory use was then collaboratively determined for each reserve based on the cumulative assessment and priority of management need. Recommendations included prescribed burning, thinning, timber harvest, and other activities that would contribute to management of spotted owl habitat at different landscape scales and were specific to the needs of individual reserves. The range of recommendations we developed offers flexibility for resource management at different spatial and temporal scales that endeavors to meet owl conservation needs. As further conditions or data change, the assessment can easily be revised and recommendations adjusted accordingly.

Future Application of Model Results

Adaptive management, in which science is a substantial part of planning, evaluating, and modifying management strategies, can improve interactions between scientists and managers thereby increasing the effectiveness of planning, allocation, and management of resources (NAS 1997). To ensure the results of our exercise have lasting utility to both the regulatory and management agencies, we developed four products to support future planning and decision making: (1) a comprehensive database and seamless map (and associated metadata), (2) a table that ranks and lists recommendations for each reserve and larger area, (3) guidelines for using the information and tools, and (4) a procedure for incorporating new information and adjusting recommendations. We expect these products to be used by managers to draw reasonable and supportable conclusions about owls and owl habitat at scales much larger than an individual owl site, allowing for more-efficient land management planning and fulfillment of regulatory requirements under the ESA and NFMA. For example, the model can be used as a planning tool to help regulators evaluate potential effects of management activities and to identify areas where projects (management activities) such as timber harvests are most likely to improve owl habitat quality or to minimize the reduction of habitat quality. However, we realize this cannot be accomplished without educating staff and managers to use the products and process we have developed.

We envision an active approach to continuing application of our efforts, as described by Nichols et al. (1995). Adaptive management treats management as an experiment and evaluates whether the desired and hypothesized outcome emerges after some period of

time (Gunderson 1999). In our case, the experiment was evaluating a large number of competing habitat models. Our treatment is implementing the new map/model in resource management where implementation has a hypothesized outcome, in particular, stability of owl populations in the long term and a reduction in the rate of population decline in the short term (5-10 years). Although the specific steps to do this have not yet been implemented, we have identified a number of key activities that will allow us to continue to test, improve, and revise both the products and their implementation over time.

To ensure that our initial attempt at applying an adaptive approach succeeds, several critical tasks remain. There is a need to continue to collect and test data because of the complexity of owl-habitat relations, the stochastic nature of forest dynamics, and the recognition that our efforts reflect only what we currently know. This will provide the data to allow our predictions to be tested (Walters 1997). A major step is to integrate this exercise into the owl-monitoring program so that results from studies of spotted owl demographics can be used to link demographic performance with habitat quality and management actions. This will allow us to evaluate associations among management activities (actions), probability of owl occupancy, and demographic parameters. Related to this is the need to test the results of our "Delphi" approach to refine the different habitat descriptions used in the five ecological zones and in particular to investigate the effects of variation in vegetation structure within these different habitat types. We made other assumptions that can and should be tested concurrently with this process. These include evaluating whether the owl is an indicator or umbrella species for other late-successional species, investigating the utility of this process to addressing other species/habitat conflicts, and understanding how forest management and manipulation of habitat quantity and distribution affects spotted owl and barred owl (*Strix varia*) interactions. Future success, however, is predicated upon a continuing effort to improve and maintain GIS vegetation databases, using new remotely sensed and ground-plot data, and ensuring that the databases accurately reflect continuing changes in the forests due to fires and other disturbances. A formalized cyclic approach needs to be undertaken in which use and revision of the above products are linked with research and monitoring programs, both at the regional and national-forest scale.

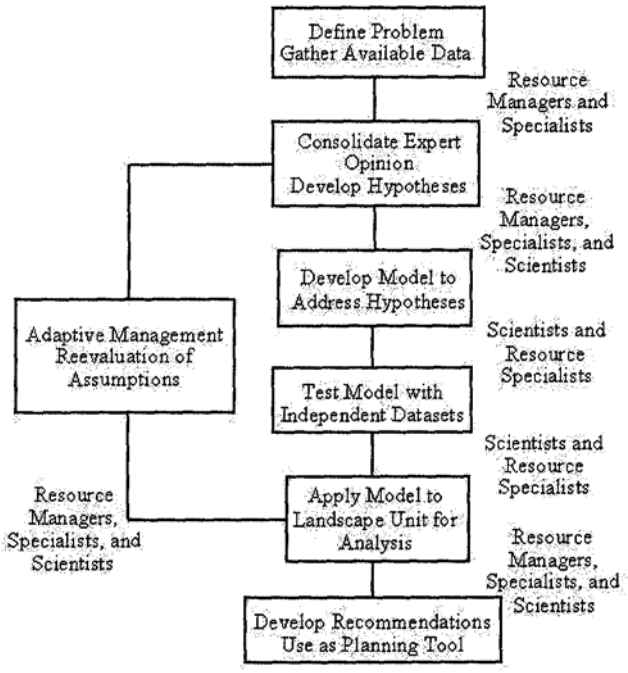

Figure 19.4. Conceptual model of the collaboration process among managers, resource specialists, and scientists.

We hope that the application of our best model to the landscape and our focused concern on reserves that are not currently providing well for owls will result in a reduction in the rate of population decrease in northern California in the short term (ten years). However, because of the new approach described here, we must view these products as a first generation that will be improved and revised as we learn more about analyses, management, and owl habitat use and population dynamics at this scale. As a result, we will need to continue to work to integrate this process into future planning efforts so that our respective field units can repeat it indefinitely. This will enable us to routinely test and revise our results and associated management recommendations as new information becomes available—in other words, to practice adaptive management (Fig. 19.4).

Lessons Learned

Although we did not begin this effort under an adaptive management framework, the learning process it-

self became an adaptive process by default. Over the four years of this effort, we learned much about the steps involved and the problems encountered in using large-scale resource information for management in a structured and adaptive setting. In particular, maintaining contacts among disciplines and between scientists and managers has become more critical than in the past. However, there is an increasing workload associated with resource management, primarily due to the complexity and general lack of understanding about ecosystem management at any scale. Therefore, although the following is by no means an exhaustive list, we offer a synopsis of the key lessons learned that may be helpful to others attempting to undertake similar efforts.

Collaboration

Close collaboration between managers and scientists has not been the traditional approach to resource management. Large-scale resource planning, especially from a landscape perspective, requires an interdisciplinary approach, specialized knowledge, open communication, team compatibility, and integrated thinking. Although it has been recommended that scientists and managers should have a "translator" to foster communication (Schonewald-Cox 1994), we realized it was more critical for our team to have each group do the translating. Through this interaction, we eventually realized that scientists, managers, and resource specialists need to work closely from the beginning phases of any planning effort and should maintain their collaboration into implementation. By applying an adaptive and collaborative approach from the start, research could more easily be directed to support management needs, and management could more efficiently take research findings into consideration, thus reducing uncertainty and improving resource management. Although we did not include representatives from special interest groups on our team, we gave several public presentations to such groups. Based on their comments, all seemed supportive of our process and conclusions.

Changing Paradigms

Dealing with change, particularly change brought about by applying new concepts, was critical in our endeavor to adaptively manage. However, there continues to be resistance among people and institutions to change. For example, even six years after the Forest Plan mandated the change from project-scale to large-area planning, this shift had not occurred. Seeking, analyzing, and applying new information and methods involves taking levels of risk that make some people and institutions uncomfortable. We believe that people will be more open to change if they are included from the beginning phases of a project rather than having new systems imposed on them from higher levels of government. Adaptive management is a structured and formal approach that requires focused and collaborative efforts to successfully integrate it into everyday operations. That had not been our experience as agency resource specialists or scientists, where it was often treated as an additional task or sometimes a constraint, if it was applied at all. Adaptive management offers a potential solution to dilemmas encountered when managing natural resources, such as uncertainty, conflicting information, and how to evaluate whether management is successful, and if not, why not (Lancia et al. 1996). We need to take a proactive approach to acquire the information necessary to avoid reacting to a problem after it has occurred. This is particularly important given the assumptions that underlie management policies, especially over these large areas.

Temporal and Spatial Scales

Temporal and spatial scale (extent and grain) issues are poorly understood in resource management, particularly when evaluating larger landscape units. We often found that data we had used to make management decisions prior to this project were applicable only at the site or local level and often had little relevance to questions that were pertinent to resource management at larger scales such as reserves or ecological zones. Although not usually considered, we should recognize that landscape goals dictate the level of analysis. By analyzing the context of an action within the larger landscape, we felt that we were better able to understand not just the effects of an action, but also the significance of those effects important to the scale of the Forest Plan. Managers and scientists must continue to ask whether a species needs to be

managed at a coarse or fine scale, and to identify questions and apply techniques that are appropriate to that scale.

Data Quality and Availability

There is an increasing need for more resource data that address critical management questions, and particularly for data and maps of known quality and accuracy to carry out large-area assessments such as this one. The quantity of new and existing information about spotted owls is immense (Fig. 19.5). Even with all of the previous work completed on the spotted owl, we were continually surprised at how poorly data were maintained, how inconsistently they were reported, or how few data were accessible or even useful. This problem alone caused the most frequent and longest delays in our effort. This, coupled with the rapid rate of emerging ideas on habitat analyses, resource selection, mathematical and statistical models, and issues of scale, makes it extremely difficult for agency managers and specialists to remain current. As agencies attempt to improve their efforts toward ecosystem management, major emphasis needs to be placed on maintaining and spatially linking data, keeping data accessible, and using long-term data sets, all in collaboration with scientists.

Methods and Tools

There is a general lack of applicable and easily used methods or models for resource specialists and managers to apply when addressing large-landscape-level questions. The lack of supported methods and inconsistent terminology continually hampered our project. In addition, the way in which we used tools such as GIS add a level of complexity, cost, and time that managers and resource specialists are reluctant to fund. Because of skepticism regarding conceptual or theoretical, approaches, testing or piloting new methods in real situations with actual data is critical and should be a normal part of the process (Ringold et al. 1999). This is particularly important in testing assumptions and addressing the relationships in species/habitat interactions. We agree with the suggestion of considering multiple models (rather than a single most-probable model) in developing management strategies and then assessing their relative credibility by comparing competing predictions with subsequent observations (Conroy 1993). We also agree with the perspective of Young and Varland (1998) regarding "meaningful" research in a management environment-in other words, research that can be used to help make management decisions.

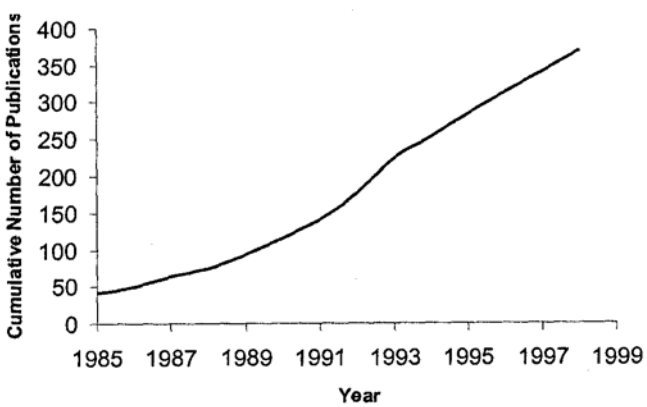

Figure 19.5. Cumulative number of publications on northern spotted owls (*Strix occidentalis caurina)* from 1985 through 1998.

Conclusions

Our process is amenable to new information (e.g., dispersal data, habitat relationships in additional areas, etc.) that may emerge in the future. It is specifically set up to be an adaptive (repeatable) process that will further the progress we have made through this collaborative effort. Using an adaptive approach should not only change the way we work but also should make our work more efficient and proactive. It is our hope that this analytic process will serve as an effective model during future efforts to develop a comprehensive owl conservation plan for all public and private lands in northern California.

Close collaboration increased our appreciation and understanding of each other's perspectives and priorities. This effort was not easy and was at times frustrating (see Hejl and Granillo 1998 for additional insights). Had we not learned to work together, however, we would not have gained the ability to shift our way of viewing, and thus managing, the landscape from a deterministic to a probabilistic manner. Project impacts would have continued to be evaluated indi-

vidually without looking at cumulative effects in time and space. We would have had no quantitative way to guide project planning into the future as our knowledge improved and changed. We strongly encourage this model of collaboration among scientists, resource specialists, and managers because we found it was fundamental to successful adaptive management.

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