communities, but are now occupied by large human habitations or by people who are not in support of restoration would be unlikely places to begin a restoration program. Suitable sites for restoration should be in conservation ownership with an institutional commitment for long-term funding for management.

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CHAPTER 11

The Role of Sensitive Species in Avian Conservation

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Conservation Issues and Previous Research

In the logging community of Saratoga, Wyoming, a bumper sticker on a pickup reads, "Biologists are Predators." This message illustrates the frustration that some people have with sensitive-species management. It suggests that the providers of biological knowledge prey on members of the community who depend on extracting natural resources for their livelihood. Species such as the Northern Spotted Owl (*Strix occidentalis caurina*) epitomize the political, social, and biological challenges that face society when managing species of concern. Their dependence on old-growth forests (Forsman, Meslow, and Wight 1984; Carey, Reid, and Horton 1990; Thomas et al. 1990) makes conflict inevitable between powerful economic interests and local communities that face job losses, and preservationists who wish to conserve ancient forests. Land management agencies were caught between economic and conservation interests, at first denying the Spotted Owl problem, only to play catch-up when public pressure demanded conservation action (Yaffee 1994). These events demonstrate that wildlife is best managed before becoming endangered. Management options that balance development with conservation become increasingly limited as species become rare. Remedial actions under the Endangered Species Act (ESA) of 1973 are not triggered until populations become low (Orians 1993).

To be proactive, the U.S. Forest Service (USFS) initiated a sensitive-species program with the explicit goal of developing and implementing management practices to ensure that species do not become threatened or endangered through the agency's actions (USDA 1995b). Other goals of the program included maintaining viable populations of all native and desired non-native wildlife, fish, and plants in habitats distributed throughout their geographic range, and developing and implementing management objectives for populations and/or habitats of sensitive species.

To prevent species from becoming endangered biological evaluations (BE) are written to examine how proposed management activities will impact sensitive species. These evaluations support planning under the National Environmental Policy Act (83 Stat. 852 as amended: 42 U.S.C. 4321, 4331–4335, 4341–4347). Biologists writing BEs face the difficult task of assessing whether management activities will adversely impact the population or habitat within the area of concern and the persistence of the species as a whole (see Ruggiero, Hayward, and Squires 1994 discussing problems with scale). If projects will have significant impacts on a sensitive species, management objectives may be developed in cooperation with the state wildlife agency. An important outcome of USFS policy regarding sensitive species is the consideration these species receive in impact analyses.

Our goal in this chapter is to discuss how sensitive-species management and research contribute to avian conservation. Because both operational and biological challenges influence the efficacy of these programs, we will discuss both but will stress biological issues. We will review characteristics associated with successful sensitive-species programs, including potential problems. Finally, we will explore the role of research in the conservation of sensitive species.

To gain a broader appreciation of the issues that confront biologists when managing sensitive species, we sent an informal questionnaire to district biologists of the USFS during September 1996. Our questionnaire consisted of fourteen short-answer questions that addressed the following topics: magnitude of their sensitive-species program; how funds were distributed among species; how sensitive species impact management actions in their districts; their opinion of how the program should be improved; and their opinion of how research can best help management efforts. We encouraged biologists to participate, but we stressed that their participation was optional. Questionnaires were sent by e-mail on region-wide mailing lists, so we do not know how many biologists actually received them. We received thirty-seven responses from five regions (R2 Rocky Mountain, 12 responses; R3 Southwest, 2; R4 Intermountain, 7; R5 Pacific southwest, 6; R6 Pacific northwest, 10). This was not a random sample of opinion (our sample may include systematic bias because participation was voluntary), but we believe it was sufficient to identify important issues that concern biologists who are responsible for sensitive-species management. However, we cannot estimate the prevalence of issues.

Designating and Defining Sensitive Species

Federal agencies have differing criteria for designating and defining sensitive species. In the USFS, regional foresters designate sensitive species within their region (nine regions within the United States). Each region develops its own criteria to evaluate proposed species. In most regions, a species is considered sensitive if a decline in either population abundance or habitat conditions suggest it is trending toward endangerment. However, determining population trends is difficult, especially for species that are rare. The individual regions of the USFS gather data from many sources that include state and federal biologists, research scientists, academics, conservation organizations, and others. Both qualitative and quantitative information are synthesized to determine if a species' population is declining and the "sensitive" status is warranted. For many sensitive species, trend data for populations are either lacking, limited, or in many cases are flawed. Determining habitat trends is also difficult but is becoming easier as agencies adopt geographic information systems technology.

In 1996, the nationwide list of sensitive species for the USFS included 2,339 species: 5.6 percent birds, 4.4 percent mammals, 5.0 percent reptiles/amphibians/snails, 4.8 percent fish, 2.9 percent clams/crustaceans, 3.7 percent insects, and 73.6 percent plants (L. Fenwood, USFS, personal communication, 1996). Our questionnaire of district biologists indicated their districts averaged 12 species of terrestrial vertebrates (range 2–49 species, SD 12, $n = 36$) listed as sensitive; approximately 8 species were birds (range 0–29 species, SD 7, $n = 36$). These biologists spent approximately 52 percent (range 1–100 percent, SD 34 percent, $n = 33$) of their total threatened/endangered/sensitive-species budget managing sensitive species.

According to district biologists responding to our survey, 35 percent (range 0–90, SD 31, $n = 36$) of management actions (e.g., timber harvest, road construction, recreation facilities) were altered because of sensitive-species considerations. Although sensitive-species management almost never resulted in projects being denied ($\bar{x} = 0.6$ percent, range 0–10, SD 2, $n = 37$), considerations for sensitive species resulted in approximately 25 percent (range 0–90 percent, SD 28, $n = 37$) of projects having timing restrictions and approximately 25 percent (range 0–80 percent, SD 25, $n = 37$) undergoing design modifications.

The U.S. Fish and Wildlife Service (USFWS) is responsible for declaring species as threatened or endangered under the Endangered Species Act of 1973 (16 U.S.C. 1531 et seq.). All federal departments and agencies must ensure that their activities are consistent with conserving endangered and threatened species, including their critical habitats. In 1996, in the United States there are 215 endangered vertebrates, including 74 species of birds and 89 species of threatened vertebrates, of which 16 are birds (USDOI, Fish and Wildlife Service 1996). The USFWS also lists 182 species (including plants) as "candidate species"; this designation includes species that existing data suggest should be listed in the near future.

Prior to 1997, the USFWS maintained a "Category 2" list that included species whose status was unknown but of concern due to declines in population trend or habitat. This list is somewhat analogous to the sensitive-species lists of the USFS, because species were identified as possibly needing management consideration before becoming endangered. The decision to drop Category 2 listings may significantly impact sensitive-species management. For example, the Bureau of Land Management (BLM) identifies "Special Status Species" of plants and animals that may need additional management consideration (USDOI 1988). These include species that either are listed under the Endangered Species Act or were listed as Category 2 species by the USFWS. Currently, many BLM biologists still give special management attention to species on the old Category 2 list, but this may decrease over time. In our opinion, the FSFWS's decision to drop Category 2 designations may decrease the political impetus to manage sensitive species before they become endangered.

Management Context of Sensitive-Species Programs

Sensitive-species management has evolved from intra-agency programs to an integral part of ecosystem management. The sensitive-species program of the USFS is an extension of both past and present conservation efforts that stress biodiversity. The Northern Spotted Owl and old-growth forest issues during the 1980s demonstrated that land-use agencies needed a new way of viewing land management and forestry. In response, the USFS adopted a philosophy called "New Perspectives" that promised to foster a more sustainable and resilient forest management (Salwasser 1991; see Frissell, Nawa, and Noss 1992 and Lawrence and Murphy 1992 for dissenting views). One theme of New Perspectives was the concept of adaptive management that encourages a fluid and dynamic land management philosophy that evolves when new information warrants change (Walters 1986). New Perspectives provided the philosophical shift that has recently evolved into a new paradigm called ecosystem management. In 1992, the USFS officially embraced ecosystem management as a new management philosophy that impacts 77 million hectares of National Forest System land (Robertson 1992, as cited by Salwasser 1992). Ecosystem management seeks to achieve an ecological approach to achieve multiple-use management of National Forests and Grasslands as sustainable ecosystems. Ideally, the application of ecosystem management accounts for the needs of sensitive species while managing sustainable systems through an adaptive approach.

Research plays a central role in the adaptive management of sensitive-species. As management plans become more rigorous and complex, there is an increasing need for sound empirical data. Land managers, physical scientists, and biologists who must determine how management actions impact sensitive species rarely have complete answers to central questions concerning ecosystem function and restoration. Yet informed decisions are made as needed; this process involves risk. Adaptive management facilitates adjustments as new information is derived through the management process (Walters 1986). Managers should not be judged right or wrong unless they fail to make any decision or fail to amend land management plans in light of new data. Thus, research plays a critical role in evaluating how management actions impact sensitive species so that adaptive management is possible.

Challenges of Managing Sensitive Species

Managers face significant operational challenges when managing sensitive-species. Some of the most formidable challenges include managing with limited funding, fostering an environment that embraces change, enhancing intra-agency cooperation and line-officer support, and developing interagency cooperation. Determining the true "cost" of managing sensitive species is difficult. Many costs, such as the time agency personnel dedicate to surveying, monitoring, evaluating, and writing management plans for sensitive species, are not delineated as separate operational costs. The USFS spends approximately $12.5 million (1992–95 average) on sensitive-species management (L. Fenwood, personal communication 1996). In addition, it receives approximately $2.8 million from partnerships with private organizations and state agencies to help fund conservation efforts. Although the USFS commitment to fund sensitive-species management is substantial, efforts to fully develop and implement conservation measures for sensitive species still lack adequate funding and staffing. For example, the districts responding to our questionnaire indicate that approximately one management plan ($\bar{x}$ = 0.8 plans, range 0–5, SD 1, n = 37) has been written per district for sensitive-species. Thus, most sensitive species in the districts responding to our questionnaire lacked management plans because of limited personnel and funding.

Sensitive-species programs also suffer from inconsistent coordination among agencies and organizations. Within agencies, the quality of interaction between organizational regions is highly variable. Much information regarding the distribution of sensitive species is organized according to state boundaries, even for species with multistate ranges. This may be due to state and federal agencies frequently relying on the Natural Heritage databases as maintained by The Nature Conservancy on a per-state basis or to the state government's jurisdiction of the wildlife resource. Some states develop panels of species "experts" from various state and federal agencies that use a delphi-process to assess the biological status of sensitive species.

Efforts to revise the Tongass Forest Plan in Alaska provide a striking example of effective intra-agency coordination when managing sensitive-species. In 1993, the regional forester in Alaska, in cooperation with USFS Research evaluated potential impacts of management actions on several sensitive-species (e.g., Marbled Murrelet [*Brachyramphus marmoratus*], Northern Goshawk [*Accipiter gentilis*], American Marten [*Martes americana*]). Conservation assessments were then written for each species by a team of both researchers and managers (Iverson et al.

1996). This close cooperation provided a unique perspective throughout the forest planning process and helped ensure that the resulting plans were scientifically sound. This example also illustrates that line supervisors need to be fully committed to sensitive-species management before meaningful intra-agency co-operation can be achieved.

As the number of sensitive species increase, more administrative boundaries between agencies are crossed, which hampers coordination and communication. Therefore, close cooperation between agencies is critical when conserving sensitive-species. Conservation agreements are valuable tools for sensitive-species management because they encourage interagency communication throughout the planning process. A conservation agreement is a pledge from a land management agency to a regulatory agency (i.e., U.S. Fish and Wildlife Service, National Marine Fishery Service) to faithfully apply mutually agreed upon conservation practices. To insure accountability, the management agency reports regularly to the regulatory agency regarding conservation activities. As long as the conservation agreement is implemented and surveys show the species habitat and/or population is stable, the regulatory agency will not list the species. For example, in Idaho, the management of four sensitive species representing diverse taxa—Idaho ground squirrel (*Spermophilus brunneus brunneus*), Christ's Indian paintbrush (*Castilleja christii*), Stanley Whitlow-grass (*Draba trichocorpa*), and guardian buckwheat (*Eriogonum meledonum*)—are protected with approved conservation agreements. Both state and federal agencies have vested interests in these species, including the Idaho State Governor's Office. All parties hold frequent meetings to review species status and to develop conservation strategies. Idaho also has formalized steering/oversight committees of key managers and people knowledgeable of the species to help with the effort.

Although operational challenges make sensitive-species management difficult, land managers who are committed to conserving sensitive-species do initiate meaningful actions. When expertise or funding is lacking, partnerships are formed with other agencies, conservation organizations, and industry to help forward sensitive-species management.

In addition to substantial operational challenges, managers of sensitive species must consider significant biological challenges. Several management approaches exist that enhance or hamper conservation efforts depending on implementation.

Single versus Multiple Species

The sheer number of sensitive species requires prioritization from both research and management perspectives. Tight monetary constraints make it impossible for intensive autecological studies of all sensitive species. Biologists responsible for evaluating potential impacts and for prescribing management actions are overwhelmed by the enormity of their task. The responsibility of managing so many sensitive species on dwindling resources heightens the dichotomy between wildlife managers who advocate single-species management (fine filter) and those who promote approaches that stress ecosystem patterns and processes for conserving biodiversity (coarse filter). Some land managers believe that managing "sensitive or impacted ecosystems" will be easier than managing individual sensitive-species. They argue that less empirical data will be needed or that management actions will be less contentious if we manage at the ecosystem level. Assessing strengths and weaknesses associated with these different philosophies is important because they impact future funding, listing, and the very existence of sensitive-species programs.

As currently practiced, sensitive-species management by federal agencies is a fine-filter approach that seeks to provide requisite habitat needs on an individual-species basis. Franklin (1993b) argues that efforts to preserve biodiversity on a species-by-species basis will fail because we lack the time, money, societal patience, and scientific knowledge (Wilcove 1994a).

However, single-species management is not necessarily a one-species-at-a-time approach (Tracy and Brussard 1994). Managing for charismatic species such as Northern Spotted Owls, Northern Goshawks, California Condors (*Gymnogyps californianus*), and grizzly bears (*Ursus arctos*) may also provide habitat for hundreds of other species. The challenge is to identify appropriate "umbrella" species that have life histories (long generation times, low rates of population increase) that are sensitive to anthropogenic habitat alterations (Tracy and Brussard 1994). However, this hypothesis needs careful consideration. Franklin (1994) points out that despite the large size of conservation areas for Northern Spotted Owls (USDA 1992), these areas do not provide habitat for anadromous fish or Marbled Murrelets; they also excluded the most significant remnants of old-growth forests.

Ecosystem Management

Lesser-known species as well as "endangered ecosystems" may be better protected by focusing on the rarity, distribution, and species diversity of ecosystems rather than identifying conservation areas based on the presence of charismatic species (Franklin 1993b). Invertebrates represent over 90 percent of total biodiversity; these species will be ignored using single-species approaches. Franklin believes we should establish habitat reserves and give special attention to the seminatural landscape matrix that surrounds these refugia. Habitat refugia that are isolated in a hostile matrix will fail to preserve biodiversity for the long term. We often find ourselves in the ironic position of using a species as an indicator of an ecosystem, for example, Spotted Owls for old growth, rather than managing the extent and distribution of the forest itself (Orians 1993). Despite the appeal of ecosystem management, there are significant challenges with this approach.

Selecting conservation areas that represent ecosystems will require prioritization and is scientifically challenging (Pressey 1994). Williams et al. (1996) reviewed how well the biodiversity of British birds was conserved using areas selected based on richness hot spots (Prendergast et al. 1993; Sisk et al. 1994), rarity hot spots (Terborgh and Winter 1983; N. Myers 1990; Sisk et al. 1994), and complementary areas (areas high in both richness and rarity; Ryti 1992; Kershaw, Mace, and Williams 1995; Humphries et al. 1996). Although species richness hot spots were easily identified in Britain, correlations between diversity and rarity were low. Rare species were not nested within distributions of more widespread species; thus, these two measures were not surrogates of one another and left some species without protection. Richness hot spots included 89 percent of British breeding bird species, while rarity hot spots included 98 percent. Complementary areas included all species but still would not fully serve conservation until factors affecting viability, threat, and cost were incorporated. Similarly, in South Africa, identifying hot spots of species richness was not an efficient method to identify ideal reserves that protect vertebrates because areas of high species richness were not coincident with areas of endemism (Lombard 1995). These studies illustrate the lack of well-established methods for identifying and ranking the importance of conservation areas. The degree to which selection models are appropriate will vary depending on the distribution of biodiversity within given ecosystems. Combined models that incorporate both richness and diversity are promising, but they will need to be evaluated on an ecosystem-by-ecosystem basis. In addition, individual species act as templates that spatially set the scale of proposed conservation areas (Wilcove 1994a; Kochert and Collopy, this volume). The spatial arrangements of conservation areas must be consistent with the demographic and habitat needs of the sensitive-species most threatened.

Beyond technical considerations, aesthetic preferences of the public may differ from the opinions of scientists interested in conserving biodiversity (Shrader-Frechette and McCoy 1994). Laypersons are often most interested in protecting charismatic birds and mammals (Franklin 1987). Ecologists may argue the scientific merits of a given program but often fail to address whether the action is politically feasible (Shrader-Frechette and McCoy 1994). Ecosystem-level protections that fail to conserve high-profile species like spotted owls and grizzly bears will be regarded a failure by the public regardless of the total biodiversity preserved. Although, in some cases, conserving ecosystems may protect the most total biodiversity, it may not be the best choice in terms of policy as it relates to the chance of implementation (Shrader-Frechette and McCoy 1994).

Multispecies Management

Between the single-species and ecosystem extremes are multispecies management philosophies such as those of indicator species (Szaro and Balda 1982; Landres, Verner, and Thomas 1988; Williams and Marcot 1991), guilds (Severinghaus 1981; Verner 1984; Block, Brennan, and Gutiérrez 1986), and keystone species (Paine 1969; Estes and Palmisano 1974; Power et al. 1996), which vary in the resolution of management. These management philosophies are appealing because they potentially reduce cost by considering a subset of species that may be easier to manage and monitor. Hutto (this volume) discusses the merits and shortcomings of these approaches.

Rectifying Single- versus Multispecies Management

We agree with Wilcove (1994a) that contrasting "single-species management" with "ecosystem management" creates a false dichotomy; both are necessary components for protecting biodiversity. Ecosystem management approaches that maintain large conservation areas could be important for conserving the many species with ecologies that are completely unknown, especially plants and invertebrates. But, no matter how rigorously ecosystem management is applied, the needs of some sensitive species will remain neglected. Researching their autoecology as it pertains to population persistence will still be an important part of conserving biodiversity. Multiple-species management may have a role in conserving sensitive species, but these management philosophies must be cautiously applied. No grouping of species will serve as the perfect surrogate for an individual species. Finally, we recognize that highly charismatic species have an important role in conserving all sensitive species because they capture public support and galvanize conservation action.

Features of Previous Research That Improved Conservation

Boreal Owl and Northern Goshawk management illustrate some of the strengths and weaknesses of sensitive-species programs. Boreal Owls were first recognized as breeding residents in the United States south of the Canadian border about the time sensitive-species programs were initiated by the USFS (Palmer 1986; Hayward, Hayward, and Garton 1993). Just four years after breeding populations were discovered, managers and research biologists outlined management directions in a proactive context. Consequently, Boreal Owl management has avoided some of the conflicts associated with other sensitive-species programs. The Northern Goshawk is a sensitive species that epitomizes many of the contentious issues confronting land-use agencies. Northern Goshawks often nest in old-growth or mature forests (Hayward and Escaño 1989; Speiser and Bosakowski 1987; Squires and Ruggiero 1996) that are impacted by forest management (Reynolds 1983; Crocker-Bedford 1990). The conflict between producing forest products and managing goshawks was most acute in the ponderosa pine forests of the southwestern United States. Goshawk management in the Southwest provides an interesting model of sensitive-species management because research had a central role in helping resolve this conflict by offering scientifically based management recommendations. In this section, we identify the characteristics of effective sensitive-species programs based on our experience with these two forest raptors.

Involvement of Researchers throughout the Planning Process

Research scientists should be involved in formulating management strategies of sensitive species at all stages of the planning process. When the Northern Goshawk was listed as a sensitive species in the southwestern United States, the USFS regional forester established the Northern Goshawk Scientific Committee in 1990. This nine-person committee was composed of foresters and silviculturalists, program coordinators, staff officers, district biologists and research scientists, and academics. Together they published *Management Recommendations for the Northern Goshawk in the Southwestern United States* by Reynolds et al. (1992), hereafter referred to as the *Recommendations.* Research scientists had a central role in developing the goshawk *Recommendations,* which greatly enhanced their credibility (D. Garcia, USFS, personal communication 1996).

Formulating scientifically based management recommendation of sensitive species requires diverse professional expertise. Only a varied array of scientists and managers can provide the broad knowledge necessary to develop ecologically sound management recommendations. In the Southwest, wildlife biologists and researchers helped ensure that habitat requirements of Northern Goshawks were provided in a manner that was spatially consistent with their biology, whereas foresters and silviculturalists helped ensure that management prescriptions were consistent with forest ecology and disturbance patterns of ponderosa pine forests.

Managers and researchers also developed a close working relationship during the early stages of Boreal Owl management. A coordinated program was formalized at high levels in the USFS soon after Boreal Owls were located in the Rockies. This coordination and high-level administrative involvement greatly contributed to the success of the Boreal Owl program. However, recent changes caused by reductions in federal budgets have stagnated efforts to develop conservation strategies based on national conservation assessments written for the species (see Hayward and Verner 1994). Budget reductions also hindered progress with other national sensitive-species programs that were initiated concurrently with the Boreal Owl assessment (see examples in Ruggerio, Hayward, and Squires 1994; Young 1995).

Recent developments in Boreal Owl management demonstrate the problems that can develop when management is not coordinated across regions for widespread species. Interregional coordination of owl management has been lost. Given the metapopulation structure exhibited by Boreal Owls (Hayward, Hayward, and Garton 1993), local management actions may have broadscale impacts; these impacts cannot be addressed without communication among regions. Furthermore, biologists in individual national forests are once again faced with the task of developing individual management plans; they must reinvent the wheel for each administrative unit without linkage to neighboring units and the broader metapopulation. The absence of a coordination team leading efforts toward a broadscale conservation strategy may also hinder long-term monitoring efforts. Because the demographic patterns in Boreal Owls spans broad geographic scales, monitoring patterns of abundance requires information from dispersed sample points. Thus, monitoring is difficult, if not impossible, without close coordination among administrative units.

Recommendations Consistent with Ecosystem Structure and Function

Effective sensitive-species programs are firmly grounded in ecological knowledge that supports management recommendations. Understanding the ecological characteristics associated with a given ecosystem, such as food webs, predatory relationships, disturbance patterns, vegetative structure, and landscape characteristics is essential for providing the specific habitat needs of sensitive species within the constraints of ecosystem function. Autecological information at varying spatial scales is also valuable because management actions may encompass several spatial scales. For example, the Northern Goshawk recommendations discuss nesting habitat at three spatial scales—nest area (approximately 30 ha), post-fledging area (approximately 170 ha), and foraging area (approximately 2,200 ha) (Kennedy et al. 1994; Reynolds et al. 1992). The most effective efforts to manage sensitive species combine autecology with community ecology from a broad information base.

Given that Boreal Owls were only recently discovered south of the Canadian border, our understanding of their ecology is limited. To date, only four major published investigations from North America provide the ecological basis for management planning (Bondrup-Nielsen 1978; Palmer 1986; Hayward, Steinhorst, and Hayward 1992; Hayward, Hayward, and Garton 1993). None of these investigations represent experimental approaches to ecological questions, none of these were designed to directly address forest management issues, and all extended for four years or less, a temporal scale insufficient to address important issues in forest management or the ecology of a long-lived vertebrate. However, existing information suggests that populations of Boreal Owls may be threatened by habitat change resulting from certain forest management practices. Therefore, four National Forest Regions list the owl as sensitive, and the bird was the focus of a national conservation assessment (Hayward and Verner 1994).

An important aspect of early Boreal Owl research was its focus on the ecological system that supports owl populations. Initial studies examined the dynamics of small mammal populations as well as habitat associations of the owl. Current research extends from the fungi and lichen species important to prey populations to landscape-scale examination of owl habitat associations (Hayward, in press). Research also examined the geographic variation in Boreal Owl ecology. This helps avoid problems with applying management recommendations to very different ecological settings from the one for which they were developed. (Iverson et al. 1996). Boreal Owl management will suffer until a coordinated research program is implemented that relates owl ecology to ecosystem processes.

Our limited understanding of the ecology of many, if not most, sensitive-species represents the single most important barrier to developing ecologically based management recommendations. For most species, we lack a basic understanding of distribution and abundance, limiting factors, response to changes in landscape pattern, and natural disturbance patterns. This information is needed when developing defensible conservation strategies. For example, we do not know if prescribed changes in forest structure will favor Great Horned Owls (*Bubo virginianus*), a potential predator of Northern Goshawks, or how habitat alteration affects goshawk foraging and wintering biology. Understanding the dynamics of long-lived sensitive species, like Northern Goshawks and Boreal Owls, requires long-term research (Valiela, Parsons, and Johnson 1989). Likewise, understanding habitat associations and population dynamics of mobile vertebrates requires that we address these questions at appropriate geographic scales (Wiens 1989). Species with large home ranges and high vagility require researchers to consider very broad geographic scales, which is difficult and expensive. Field experiments that account for broad ecological scales are difficult, which in turn hinders our attempts to implement adaptive management. Until further field research is completed, managers are forced to extrapolate from limited information collected at few study sites, an uncomfortable situation at best.

In order to cope with our uncertainty, assumptions must be clearly identified so they can be tested and changed if warranted. For example, the scientific committee that developed Northern Goshawk recommendations made three assumptions (Reynolds et al. 1992): (1) they assumed that forests are dynamic and that goshawk nesting habitat should be a mosaic interspersed with many different structural classes from young to old forests; (2) they acknowledged the poor understanding of the extent to which southwestern forests were modified by Native Americans prior to settlement by Europeans but assumed that land-use practices such as timber harvest, grazing, and fire suppression by Europeans changed forest structure; and (3) they assumed that large trees, snags, and large downed logs provide habitat for goshawk prey and that every hectare of goshawk habitat needs to include clumps of large trees that are allowed to mature, die, and become snags that fall and decompose. These assumptions were clearly articulated in the management recommendations and could be tested if necessary.

Proactive versus Reactive Management

The Boreal Owl represents an example in which potential threats to persistence were identified soon after the species was discovered breeding in the western United States. The species enjoyed "sensitive-species" status before a majority of its breeding range south of Canada was documented. Within two years of the discovery, managers began a proactive program that included researchers from Colorado and Idaho. In 1984, just four years after breeding populations were first documented, nearly sixty biologists in four Rocky Mountain states participated in surveys designed to document the distribution of Boreal Owls in the Rockies (Hayward et al. 1987). Thus, land managers in coordination with researchers began active owl management prior to public pressure.

In 1992, the proactive approach to Boreal Owl management was formalized when funding was provided by the USFS to develop a national conservation assessment (Hayward and Verner 1994). This assessment, initiated jointly by research and management staffs in Washington, D.C., represented the first critical step toward defining a coordinated conservation strategy for the species. By evaluating current understanding of the species' ecology, conservation status, and information gaps, the assessment provided a foundation from which to build an adaptive approach to conservation based on efforts from both research ecologists and managers.

Adequate Funding and Line-Officer Support

Effective programs have funding available for research, habitat manipulations, computer modeling, and other conservation work. The amount of funding required depends on the complexity of the issues and on our understanding of the species' biology. Surprisingly little funding is sufficient for some species that require limited management programs; other species with life histories that are more difficult to manage require substantial funding.

Successful sensitive-species programs also depend on a strong commitment by line officers at all levels (district rangers, resource-area managers, forest supervisors, state directors). To foster that commitment, researchers must communicate with line officers throughout the planning process; participation builds ownership. For Boreal Owls, a close cooperative relationship developed between research and management during these initial surveys and continued for the next decade as studies expanded to examine habitat use and test monitoring methods and evaluate demography. Close cooperation between research scientists and managers may represent the most important factor contributing to managing this sensitive-species. As line officers watch their staffs become involved in coordinated efforts to manage species like Boreal Owls, they are more likely to provide the necessary funds for sensitive-species management.

Charismatic Species Galvanizing Conservation Action

If success is measured in terms of actual conservation actions implemented on the ground, then the *Recommendations* by the Goshawk Scientific Committee were successful. Forest plans have been amended throughout the Southwest to accommodate habitat prescriptions for Northern Goshawks and Mexican Spotted Owl (*Strix occidentalis lucida*). Forest management on the N. Kaibab National Forest has changed from a 150-year rotation, even-aged, evenly spaced forest before the *Recommendations*, to a 250-year rotation, mature forest with uneven age structures and a clumped tree distribution that is more consistent with the forest ecology pre-European settlement (K. Menasco, USFS, personal communication 1996). Prior to the *Recommendations*, it was difficult for biologists to convince line officers of the need to retain snags. After the *Recommendations*, forest planners now consider both micro-habitat elements and landscape characteristics in an ecosystem context (K. Menasco, personal communication 1996). The *Recommendations* have encouraged forest managers to view the ecosystem as an assemblage of interacting species. Goshawk management in the Southwest has helped to change an agency's culture and to begin achieving very real steps toward ecosystem management.

The *Recommendations* were formulated from the perspective of the goshawk rather than a general ecological-based plan for ponderosa pine ecosystems (R. T. Reynolds personal communication 1995). It was a top-down rather than a bottom-up approach. The habitat needs of goshawks were provided first in the landscape, before the scope of effort was expanded to ecosystem-level considerations. We believe that management would have changed little had the Scientific Committee simply authored a general ecosystem plan for ponderosa pine forests. The goshawk served as a flagship with broad public appeal. It provided the catalyst that galvanized the necessary resources to formulate a management plan. However, as the plan is implemented in daily forest management, it is viewed less as a plan for goshawks and more as an ecosystem plan for ponderosa pine forests (K. Menasco, personal communication 1996).

Partnerships

Successful sensitive-species programs have active, willing, and in some cases adversarial partners. Potential partners include state government, industry, and private organizations. Partners with national standing are most effective because they have the political and financial clout to lobby Congress and generate funding. For example, the Pacific River Council was interested in stream management, which led to the formation of the Columbia River Basin Initiative. This effort, initiated to manage aquatic species, could stimulate sensitive species management for forest carnivores, raptors, and big game. Partners in Flight (a nongame landbird conservation program based upon cooperative partnerships among an array of federal and state agencies, NGOs, private industry, and academic institutions that fosters coordinated avian conservation efforts through its framework of working groups at the international, national, regional, and state levels) has the backing of several conservation groups that can directly benefit sensitive Neotropical migrants. The proposed federal Teaming with Wildlife tax on bird seed, binoculars, and field guides may provide partners in industry that will help fund sensitive-species conservation. Often adversarial partners "encourage" the management of a sensitive-species. Adversarial partners may encourage agencies to alter their operations in ways more consistent with sensitive-species management and ecosystem function. For example, goshawk management is a hotly contested issue (Hitt 1992; Henson 1993). The management recommendations for goshawks in the Southwest describe ways that timber harvest can be used as a tool for restoring a forest structure that was present pre-European settlement; this will help prevent catastrophic crown fires while maintaining goshawk habitat. In this case, adversarial partners helped encourage agencies to actively manage this sensitive-species.

Multiple Benefits

Finally, successful sensitive-species programs usually benefit other species of concern. Often sensitive, Neotropical migrants are impacted by the degradation of riparian areas. If management recommendations for riparian birds also benefit species such as bull trout, the program has a greater chance of implementation. Multiple benefits may include commodity production such as timber or grazing that is extracted in an ecologically sensitive manner. For example, thinning trees of small diameter may help Northern Goshawks by restoring ponderosa pine forests while producing a valuable commodity (Reynolds et al. 1992).

Future Research Needed to Further Conservation

The availability and quality of knowledge accessible to biologists and policy makers plays a significant role in determining the success of sensitive-species management. As mentioned earlier, close cooperation between management and research is a common characteristic of strong sensitive-species programs. Thus, research must play a critical role in future sensitive-species management. But what focus should research adopt to most effectively meet the information needs of managers of sensitive species?

We summarized the responses of thirty-five wildlife biologists who replied to our questionnaire request to list two general research needs that would help them manage sensitive species. The fifty-five ideas voiced by the biologists resulted in eighteen research needs (table 11.1). Information regarding the range of natural variation in population characteristics along with research on autecological habitat relationships were listed as the top research priorities by biologists responding to our questionnaire. Many biologists also asked for help monitoring sensitive species and expressed a need for information on habitat relationships at a landscape scale.

Table 11.1. Responses of district biologists employed by the U.S. Forest Service when asked to list two general research needs that will help them manage sensitive species. Thirty-five biologists provided 55 responses; some only offered one response.

Research need	Percent of responses
Define the range of natural variability for species and autecological habitat requirements	27
Assist with monitoring and surveys	13
Determine necessary habitat conditions at landscape scale	9
Develop cumulative effect models at landscape scale	7
Determine effects of disturbances on sensitive-species	7
Conservation guidelines of management strategies	5
Determine effective management techniques	5
Dependable methods of determining population viability with limited data	4
Determine effects of fire suppression	4
Study laws and regulations regarding protection and management	2
Add spatial features to computer programs used by agency	2
Review sensitive-species lists	2
Collect prey base data	2
Research peripheral populations	2
Develop database of ecological information of sensitive species	2
Study impacts of grazing	2
Study the importance of management indicators	2
Ecosystem management as it relates to human-use factors	2

Obtaining information on responses to disturbance, population trend, and dispersal is important for sensitive-species management, but these topics are discussed in detail elsewhere (chapters 1, 5, 6, and 11). Below, we discuss additional research needs.

Distribution

Knowledge of how a species' geographic range changes over time provides managers with an initial screen to evaluate potential impacts of proposed management. Management actions scheduled outside the current and historic distribution are of low concern unless the distribution of the species is expanding and will reach the impacted site during the temporal life of the project. Without knowledge of current and past distribution, management cannot determine potential impacts.

Limiting Factors

Wildlife research often focuses on identifying important habitat characteristics, but few studies are designed to determine what factors limit populations. Our poor understanding of limiting factors may result from the difficulties associated with conducting field experiments with large mobile vertebrates. Therefore, limiting factors must be inferred from an understanding of the natural history and ecology of species. Efforts directed toward identifying factors that likely limit sensitive-species are important despite the difficulties with designing and implementing these studies.

Employing a combination of envirograms (Andrewartha and Birch 1984) and sensitivity analysis of life history represents one approach for identifying potential limiting factors. An envirogram is a graphical description of environmental characteristics that directly and indirectly influence population persistence. Sketching an envirogram for a sensitive species provides a graphical hypothesis of potential links between the species and other parts of the ecosystem that "limit" population growth. Demographic sensitivity analysis can further refine hypotheses concerning limiting factors by identifying life-history characteristics that have the strongest influence on population growth. Based on the insights gained from these exercises, research priorities can be identified to test hypotheses regarding potential limiting factors.

Ranking Habitat Quality

When managing habitat for sensitive species, we assume that individual organisms select particular habitats because doing so enhances their fitness (Rosenzweig 1985). Habitat loss has been associated with declines in many species as a consequence of a variety of mechanisms (Hunter 1996). Most studies of wildlife habitat associations focus on identification of habitats "selected" from some set of "available" habitats. However, management of habitat for sensitive species requires more than just identifying good versus bad habitat. Knowledge of the relative ranking of habitat is necessary to evaluate the short- and long-term impacts of proposed management actions. Therefore, future habitat studies for sensitive species should strive to rank habitats in terms of quality for particular functions. This is a tall order, because habitat quality must be examined at a number of spatial and temporal scales. Furthermore, identifying quality habitat depends on measuring demographic rates (survival and/or reproduction) of individuals occurring in particular habitats and comparing those with rates observed in alternative habitats.

Demographic Analysis

"Demography is a tool for understanding population-level dynamics in terms of events . . . at the level of the individual" (McDonald and Caswell 1993, 139). Demographic analysis, in particular sensitivity analysis, can be a powerful tool in allocating research effort and directing management. Sensitivity analysis pinpoints the most ecologically important life-history stage for a population. Therefore, the analysis of a life-cycle graph or projection matrix can identify those life-history stages that must be understood most completely in order to understand threats to population persistence. After identifying critical life-history characteristics, researchers and managers can coordinate programs that examine the environmental factors most important for that life-history stage.

Knowledge of Environmental Interactions at Varying Spatial Scales

Ecologists and managers increasingly recognize the importance of geographic and temporal scales in determining the processes that affect species abundance (Wiens 1989). Likewise, biologists recognize that diverse biological interactions (mutualism, competition, predation, parasitism) affect species abundance (examples in Ehrlich 1994; Estes 1995). Despite this knowledge, management planning often ignores scaling issues and complex interactions. For instance, in 1991 we reviewed management recommendations for Great Gray Owls, (*strix nebulosa*) which are considered sensitive in two national forest regions. Recommendations for eight of nine forest-level plans provided direction to protect nest sites or to protect raptor nests in general. These plans ignored processes occurring at geographic scales broader than the nest site or those operating during the nonbreeding season. Great Gray Owls interact with an array of small mammals at differing spatial and temporal scales, each of which must be understood for effective management.

Biological invasions threaten the long-term persistence of some sensitive species and need to receive much greater research attention. The range expansion by Barred Owls (*Strix varia*) into the range of the Northern Spotted Owl (Taylor and Forsman 1976) and the consequence of exotics to island avifauna (Rodda, Campbell, and Derrickson, this volume) provide examples of how invading species can disrupt ecological communities. Managers will increasingly need to predict how habitat alterations impact the ecological relationships that determine the assemblages of species.

Evaluation of Threats to Persistence

Ideally, a population viability analysis (PVA) should be conducted for each sensitive species. PVAs consider all factors that threaten a species with extinction (Gilpin and Soulé 1986). A formal (one that is analytically comprehensive) PVA integrates factors such as demographics, genetics, and environmental stochasticity, with life-history and habitat-use information. In addition, ecological processes like dispersal, competition, and predation are evaluated. This comprehensive process is expensive in terms of time and money. Thus, our ability to conduct formal PVAs for most sensitive species is highly unlikely.

Given the usual dearth of empirical information that is necessary for PVAs, resource managers face considerable difficulties when evaluating threats to species persistence. We need to learn more about how best to evaluate threats to the persistence of sensitive species in a manner that is economically achievable. Several tools are available that may help biologists approach the issue of assessing persistence in the absence of local demographic and ecological information. We suggest an approach that integrates demographic sensitivity analysis (McDonald and Caswell 1993) and evaluation of an envirogram in the context of ecological theory. Ruggerio, Hayward, and Squires (1994) discuss several guidelines that can aid in this evaluation. Ecological understanding can be incorporated into the evaluation most rigorously by applying the hypothetico-deductive approach to management (Murphy and Noon 1991). Through a rigorous assessment of the assumptions that form the basis of management, they reduce the uncertainty clouding an evaluation of the efficacy of various management options. Caughley and Gunn (1996, 223–270) provide an extended discussion of a similar approach to evaluate population declines. They demonstrate the application of hypothetico-deductive logic at several stages of management planning that may be applicable to sensitive species.

Abundance, Persistence, and Distribution

Fundamental to sensitive-species programs is the notion that wildlife should be actively managed before reaching low population densities. Thus, determining how abundance impacts the persistence and distribution of wildlife is relevant when evaluating sensitive-species management. The abundance of species and the extent of their geographic distribution appear correlated (Hanski 1982; Brown 1984). Within taxa, species with large geographic distributions tend to have greater local abundance at sites where they do occur compared to geographically restricted species (Lawton 1993). Brown (1984) hypothesized that species with wide-niche breadth (i.e., that can exploit many resources) become both widely distributed and locally abundant; empirical support of the hypothesis is equivocal (Lawton 1993). If widespread environmental changes such as pollution or the introduction of a predator or competitor cause populations to decline, then overall ranges are expected to contract, even without habitat destruction. If the species' original distribution has a well defined center, we expect that range contraction is expected to compress distribution toward the core; if the original distribution had multiple modes, ranges are expected to fragment and to contract into former hot spots (Lawton 1993).

The broadscale relationships between abundance and distribution are poorly understood and need additional research. We have only a short time to learn about these effects, as anthropogenic factors increasingly impact most vertebrate populations. However, our limited understanding of these relationships does reaffirm the importance of active intervention through management before population abundance is reduced to the point of range collapse.

Prioritizing Research Dollars

Land management agencies are confronted with an increasing number of sensitive species to manage with declining budgets. Funding conservation actions for all sensitive species is impossible. Some land managers argue that we should abolish lists because we have progressed beyond a "listing mentality" through ecosystem management. Although ecosystem management may render listing individual species unnecessary in the future, we are not there yet. We fear that abolishing sensitive-species lists will reduce management's focus as more pressing issues capture its attention. We believe the most cost-effective way to protect biodiversity is to actively manage wildlife of concern before they become endangered. Thus, programs that manage sensitive species are cost effective as well as ecologically defensible.

As we have stressed throughout this chapter, efforts to conserve biodiversity need to include both single-species and ecosystem management. Each approach has strengths and weaknesses. Ecosystem management needs to provide the necessary habitat elements and ecosystem structure for many, if not most, sensitive-species. Species that are obscure to the public, such as some plants and invertebrates, will not garner public support for large-scale management actions. In addition, often the ecologies of these species are poorly understood and little empirical data are available for developing management plans. Ecosystem management may represent the best chance for conserving this element of biodiversity. Managing entire ecosystems may include establishing conservation areas imbedded within an ecologically favorable matrix. Possibly, conservation areas that include hot spots of both rarity and species richness will prove most valuable for conserving maximum biodiversity (Williams et al. 1996). However, conservation efforts that embrace ecosystem or other multispecies management philosophies, regardless of how comprehensive, will fail to protect all species. Individual species act as templates, spatially setting the scale of landscape conservation efforts (Wilcove 1994a). Determining the autecological habitat needs of rare and specialized species will continue to be an important part of conservation planning.

We previously described some important autecological research needs that are important to conservation. These included determining changes in species distribution, population trend, limiting factors, habitat quality, demography, dispersal, and responses to disturbances. Clearly, meeting these needs is beyond the financial means of many organizations. This is more than a question of allocation; funding detailed research on a few species or general research on many. There are other considerations that may prove helpful when prioritizing how we spend our limited research dollars for sensitive species.

Highest research priority should be assigned to those sensitive species that are most threatened in terms of rarity or sharply declining trends in habitat quality. Establishing population trends for sensitive-species that occur at low population densities is difficult (Verner 1984) and requires efforts from both management and research. For some low-density or secretive species, a delphi-process involving researchers familiar with the species' life history and habitat associations may begin to address population trends. Although species can decline without habitat alteration, research priority should be given to species that inhabit ecosystems that have undergone significant changes in size, structure, or distribution.

Keystone species have a larger effect on commmunities and ecosystems than is expected based on their abundance (Power et al. 1996). Keystone modifiers can impact community structure in ways that are critical to maintaining biodiversity. We reiterate the concern of Mills, Soulé, and Doak (1993) that species are not inherently keystones, that their keystone status depends on ecological context. An important role of research is to determine the ecological context in which species serve as keystones. Once keystone species are determined for a given ecosystem, we believe that allocating funds to research their ecologies is highly justified and ecologically important.

Although we recognize that charismatic species are not perfect surrogates for other species or "endangered" ecosystems (Franklin 1994), we believe they have an important role in sensitive-species management. Our credibility with the public demands that we maintain charismatic species throughout their range. Management plans that fail to provide for these species will be viewed as a failure. In addition, ecosystem plans that focus on a high-profile species have a better chance for effecting real change (see Reynolds et al. 1992). Charismatic species, especially those whose habitat requisites will serve as an umbrella for other species, should be given priority for management and research funding.

Preserving both within and between species genetic variation is important in conservation planning (Lesica and Allendorf 1995). Should land management agencies spend dwindling conservation dollars on species considered sensitive at the periphery of their distribution but secure at the center? The answer to this question impacts sensitive-species programs across the country. Some land managers believe that peripheral populations, which often occur at low population densities and in ecologically marginal habitats, are less valuable to conservation compared to those at the center of a species' distribution. However, sensitive species at the periphery of their ranges may be disproportionately important for conserving genetic diversity relative to their size and frequency (Ehrlich 1988; Lesica and Allendorf 1995). Peripheral populations that differ genetically from parent populations are most valuable. Priority for funding autecological studies should target the most genetically divergent sensitive-species populations.

Close coordination between research and management is required at all stages of conservation planning. Conservation strategies that involve both research and management throughout all stages of the planning process are cost effective compared to efforts that lack coordination (Young and Varland, this volume; Kochert and Collopy, this volume). Wildlife biologists, often frustrated with the basic lack of biological knowledge of sensitive-species frequently initiate small, poorly funded investigations that have insufficient power to answer the important questions they must address. These well-intended efforts often lack coordination and may result in research that is conducted at inappropriate spatial and temporal scales. A joint implementation team should set research priorities, play a strong role in formulating research hypotheses, and coordinate information sharing. Close coordination between research and management is also a necessary component of adaptive management, so that both small- and large-scale experiments are tested under alternative management schemes using rigorous scientific methods.

Land management agencies have a legal and an ethical obligation to be actively involved in conserving biodiversity. The philosophy behind sensitive-species management recognizes that wildlife populations need management before becoming rare and endangered. This basis has considerable social and ecological merit. Sensitive-species programs should continue to be a cornerstone of agencies' efforts to conserve biodiversity. We are concerned that agencies are under increasing political pressure to reduce their commitment to sensitive-species management. Agency leadership is critically important to avian conservation.

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PART IV

Conservation in Forested Landscapes

Avian Conservation

Research and Management

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