# Conservation of Lynx in the United States: A Systematic Approach to Closing Critical Knowledge Gaps

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# Introduction

Large-scale ecological studies and assessments are often implemented only after the focus of study generates substantial social, political, or legal pressure to take action (e.g., Thomas et al. 1990; Ruggiero et al. 1991; FEMAT 1993). In such a funding environment, the coordinated planning of research may suffer as the pressure to produce results escalates. To avoid haphazard research and to maximize the benefits to lynx conservation with limited research funds, a carefully coordinated approach to lynx research is needed. The purpose of this chapter is to provide a systematic framework and rationale for conducting future research in ways that will maximize the applicability and utility of new information.

Research on the ecology of rare and sparsely distributed vertebrates, such as the lynx, is often opportunistic because research must be conducted on populations that are large enough to allow rigorous scientific investigation. Even an intensive, long-term study of a few individuals results in anecdotal information that may or may not represent the population of interest. Consequently, populations are often selected for study simply because their existence and relative abundance is known, and because they are logistically feasible to study. This opportunistic impetus must be tempered, however, with the knowledge that the value of such research will be limited if there is no larger context in which to evaluate study results. Without this context, there will be no scientific basis for applying results beyond the geographic or ecological scope of each study.

To avoid these problems, wildlife scientists must expand the scope of inference by designing research to be representative. To generate reliable inferences about the biology and ecology of lynx in the contiguous United States (U.S.), we must conduct multiple studies that encompass the range of variation in habitats occupied by lynx. The program of research contained in this chapter is predicated upon such an approach. Throughout this book, we have stressed that we know relatively little about lynx biology and ecology in the U.S. (Table 17.1), and we have cautioned against overgeneralization or inappropriate extrapolation of existing information. We believe the lack of representative data on lynx in the U.S. to be a significant impediment to science-based conservation and management.

New research on lynx in the U.S. must address multiple spatial scales and multiple levels of biological organization. In both cases, studies at lower strata are logically nested within higher strata. One of the most useful outcomes of such a hierarchical research approach is that new efforts are facilitated and augmented by results from studies at both lower and higher strata. For example, the results of a survey designed to determine lynx

**Table 17.1**—Published and unpublished studies on lynx in the contiguous United States by subject. Studies are listed under all appropriate headings but are indicated with an asterisk (*) the first time they are listed in the table.

| Topic and author | Location | Method | Duration | Sample size and summary of results |
|---|---|---|---|---|
| **Distribution and relative abundance** | | | | |
| * McKelvey et al. (Chapter 8) | Contiguous United States | Museum and historical records, trapping data, track surveys, questionnaires | N/A | 3,865 occurrence records: historical distribution |
| **Habitat relationships** | | | | |
| McKelvey et al. (Chapter 8) | Contiguous United States | Museum and historical records, trapping data, track surveys, questionnaires | N/A | 3,865 occurrence records: patterns of association with broad vegetation types and elevation zones |
| * Brittell et al. (1989, unpublished) | North-central Washington | Radiotelemetry | 34 months | 23 lynx: patterns of association with forest types |
| * Koehler (1990) | North-central Washington | Radiotelemetry | 25 months | 7 lynx: patterns of association with forest types; 4 maternal dens described |
| McKelvey et al. (Chapter 10)[a] | North-central Washington | Radiotelemetry | 76 months | 22 lynx: patterns of association with forest types and topographic features |
| * Koehler et al. (1979) | Western Montana | Radiotelemetry | 8 months | 2 lynx: patterns of association with forest types |
| * Smith (1984, unpublished) | Western Montana | Radiotelemetry | 23 months | 5 lynx: patterns of association with forest types |
| Squires and Laurion (Chapter 11)[b] | Western Montana and Wyoming | Radiotelemetry | Montana = 22 months, Wyoming = 34 months | Montana = 18 lynx, Wyoming = 2 lynx: 1 maternal den described in Wyoming |
| **Movements and dispersal** | | | | |
| Brittell et al. (1989, unpublished) | North-central Washington | Radiotelemetry | 34 months | 23 lynx: 2 long-distance movements documented |
| Squires and Laurion (Chapter 11) | Western Montana and Wyoming | Radiotelemetry | Montana = 22 months, Wyoming = 34 months | Montana = 18 lynx: 4 exploratory movements documented; Wyoming = 2 lynx: 2 exploratory movements documented |
| Smith (1984, unpublished) | Western Montana | Radiotelemetry | 23 months | 5 lynx: 1 long-distance movement documented |
| * Brainerd (1985, unpublished) | Western Montana | Radiotelemetry | 25 months | 2 lynx: 1 long-distance movement documented |
| * Mech (1977) | Northern Minnesota | Radiotelemetry | 25 months | 14 lynx: 1 long-distance movement documented |

(con.)

**Table 17.1**—Con.

| Topic and author | Location | Method | Duration | Sample size and summary of results |
| --- | --- | --- | --- | --- |
| **Demography and population dynamics** | | | | |
| Brittell et al. (1989, unpublished) | North-central Washington | Radiotelemetry and snowtracking | 34 months | 23 lynx: mean density = 2.0/100 $km^2$; 4 litters: mean litter size = 2.0; mean annual adult mortality rate = 11% |
| Koehler (1990) | North-central Washington | Radiotelemetry and snowtracking | 25 months | 7 lynx: mean density = 2.3/100 $km^2$; 3 litters: mean litter size = 2.7; mean kitten mortality rate = 88% |
| Brainerd (1985, unpublished) | Western Montana | Carcasses | N/A | 18 females: mean litter size = 3.3 |
| Squires and Laurion (Chapter 11) | Western Montana and Wyoming | Radiotelemetry and snowtracking | Montana = 22 months, Wyoming = 34 months | Montana = 3 litters: mean litter size = 2; Wyoming = 2 litters: mean litter size = 3 |
| **Relationships with prey** | | | | |
| Koehler (1990) | North-central Washington | Scat analysis | 25 months | 29 scats: 79% snowshoe hare, 24% red squirrel, 7% deer, 3% white-footed mouse |
| **Community interactions** | | | | |
| Brittell et al. (1989, unpublished) | North-central Washington | Radiotelemetry | 34 months | 23 lynx: 1 bobcat or lynx kill |
| Koehler et al. (1979) | Western Montana | Radiotelemetry | 8 months | 2 lynx: 1 mountain lion kill |
| Squires and Laurion (Chapter 11) | Western Montana | Radiotelemetry | Montana = 22 months, Wyoming = 34 months | Montana = 18 lynx, Wyoming = 2 lynx: 2 mountain lion kills in Montana |
| **Human impacts** | | | | |
| McKelvey et al. (Chapter 10) | North-central Washington | Radiotelemetry | 76 months | 22 lynx: no evidence of road avoidance |
| Brocke et al. (1991) and K. Gustafson (personal communication) | New York | Radiotelemetry | 24 months | 83 lynx translocated from Yukon: 16 road-killed |

[a]McKelvey et al. (Chapter 10) is a reanalysis of data collected by Brittell et al. (1989, unpublished) and Koehler (1990).
[b]Data presented by Squires and Laurion (Chapter 11) represent preliminary results of ongoing studies.

presence or absence at a broad spatial scale (e.g., the western U.S.) provide the basis for selecting study areas for more intensive research on lynx at smaller spatial scales (e.g., northeastern Washington). Conversely, habitat and topographic use patterns derived from intensive studies can help delineate forest types where lynx surveys should be conducted.

We must know where lynx are before we can identify geographic areas where more intensive research should be conducted. Some research questions, such as determining the potential metapopulation structure of lynx in the U.S., cannot be addressed until we adequately describe broad-scale patterns of habitat occupancy. However, the urgency of ongoing lynx conservation efforts precludes us from waiting until we have a more complete understanding of the current distribution of lynx before initiating new research. We must support and expand lynx research in the U.S. while comprehensively delineating current lynx range and describing patterns of relative abundance to provide a framework for planning future research.

# Information Needs

We have identified critical knowledge gaps in many of the previous chapters and emphasized the most important of these in the Qualified Insights (QIs) presented in Chapter 16. Here, we summarize key information needs for the conservation of lynx in the U.S.

## Distribution and Relative Abundance

We have documented the historical distribution of lynx to the extent possible with existing information, but we lack a clear understanding of the distribution or relative abundance of extant populations in the U.S. (Chapter 16 - QI 1). This research need must be addressed before new intensive studies are initiated. Knowledge of lynx distribution will also provide a framework for investigating geographic variation among southern lynx populations. This information is essential for assessing the potential impacts of translocating lynx among populations (Chapter 16 - QI 10).

## Habitat Relationships

We have a very limited understanding of lynx habitat relationships at any spatial scale (Chapter 16 - QIs 2 and 3). Our current understanding of habitat selection for southern populations comes mostly from research conducted on a single, relatively small population in north-central Washington. However, populations occupying more xeric coniferous forests or mixed coniferous-deciduous forests may have very different habitat relationships. In southern boreal forests, only a few natal dens have been described, but all were in late-successional stands with relatively dense understory cover from large woody debris and other complex structures near the forest floor. However, timber harvesting designed to improve habitat conditions for snowshoe hares by creating dense, young stands may eliminate such structures. Management of forest habitats for lynx will be severely constrained until new information is obtained on their habitat relationships at both small and large spatial scales.

## Movements and Dispersal

Dispersal processes will strongly influence conservation planning for lynx, especially for small, isolated populations at the southern extent of their range (Chapter 16 - QI 8). Southern lynx populations may exist in a metapopulation structure maintained by the dispersal of individuals among "islands" of suitable habitat at varying distances from one another. Although long-distance exploratory movements have been documented in several southern populations, successful dispersal (i.e., reproducing in an established home range) has not. Thus, we have no empirical information on success rates for dispersal, dispersal distances, responses to anthropogenic and natural barriers, or the use of corridors.

## Demography and Population Dynamics

Assessments of the population viability of southern lynx populations will not be possible without new information on densities, birth rates, adult and kitten survival rates, and population dynamics (Chapter 16 - QI 9). Limited data from north-central Washington suggest that lynx populations in southern boreal forests may not exhibit the strong cyclic fluctuations characteristic of lynx populations in the taiga; however, trapping data from several states suggest otherwise. High-amplitude fluctuations may have a strong influence on dispersal and connectivity among isolated populations. Thus, conservation planning for southern lynx populations will be influenced strongly by the nature of their population dynamics.

## Relationships With Prey

Limited data indicate that lynx in southern boreal forests depend on snowshoe hares as their primary prey, with red squirrels as important secondary prey (Chapter 16 - QI 4). Management of habitat for snowshoe hares in southern regions must consider how hare abundances vary along both ecological and successional gradients. However, patterns of hare abundance in southern boreal forests are not well understood. We do not know how differences in habitat structure may influence the vulnerability of snowshoe hares and other prey species to lynx predation.

## Community Interactions

Many species potentially compete with lynx for prey (Chapter 16 - QI 7). Exploitation competition may reduce prey availability and result in displacement of lynx, whereas interference competition may affect lynx habitat selection and, in extreme cases, lead to intraguild predation. Mountain lions are absent from the taiga but co-occur with southern lynx populations, and limited data suggest that they may be an important source of lynx mortality. Coyotes are very effective predators of snowshoe hares, are capable of killing lynx, and have recently expanded their range in southern boreal forests. We do not know if predation affects the population dynamics of lynx, nor do we understand the nature and extent of competition with generalist predators or how changes in landscape pattern may mediate these processes.

## Human Impacts

Lynx often appear indifferent toward humans, which may predispose them to direct, human-caused mortality. The indirect impacts of human activity may exert a stronger influence on lynx populations but are difficult to quantify (Chapter 16 - QI 11). The effects of outdoor recreation on lynx populations have not been studied. Observations suggest that some carnivores, especially coyotes, use compacted snow from snowmobiling, skiing, or snowshoeing as travel routes. However, we do not know if snow compaction increases predation rates or competition from generalist predators.

## Snowshoe Hare Habitat Relationships

In Montana and Washington, limited data suggest that hares may have a bimodal pattern of abundance, whereby they reach highest abundances in young, dense stands and old, gap-phase forests. High stem densities in regenerating forests provide dense horizontal cover that is important for hares (Chapter 16 - QI 5), and old forests have similar cover in gaps formed from the death of one or several trees. However, in drier forest types in the northern Rocky Mountains, where regenerating stands often lack high levels of horizontal cover, hares may be most abundant in older forests. We do not understand how patterns of hare abundance change according to forest type, moisture regime, or successional stage.

### Snowshoe Hare Population Dynamics

In the taiga, population dynamics of lynx are closely tied to those of snowshoe hares, and lynx populations fluctuate in lagged synchrony with hare population cycles. We do not know if this model fits southern lynx populations. Limited data suggest that southern hare populations are not as stable as previously believed (Chapter 16 - QI 6), but whether their populations cycle as they do in the taiga, or simply fluctuate stochastically, is unknown.

## A Research Framework

### Where Do Lynx Occur?

As of 1999, we have only a general idea of the current distribution of lynx in the U.S. (Chapters 8, 11, 13). We have documented at least one verified record of occurrence since 1990 in Washington, Oregon, Idaho, Montana, Wyoming, Utah, Minnesota, Wisconsin, New Hampshire, and Maine. If we include track data collected by knowledgeable individuals as evidence of occurrence, we can add Colorado and Michigan to this list. We also know there is at least one reproductive female lynx in both western Wyoming and northern Maine. However, strong evidence of the presence of established populations is limited to western Montana and north-central Washington. In most areas of historical lynx occurrence, we need to determine if populations of lynx are present before we can select new study locations or assess the representativeness of resident populations occurring in Washington and Montana. This information gap must be addressed initially with broad-scale, presence/absence surveys conducted throughout the historical range of lynx.

### Do Lynx Detections Represent a Researchable Population?

Although broad-scale surveys may demonstrate the presence of at least one lynx at a given locality, an intensive radiotelemetry study should not be implemented until surveys conducted at a finer spatial scale have verified the presence of a sufficiently large and established (i.e., “researchable”) population. For example, we know that there are at least two lynx (a male and female) in the Wyoming Range in western Wyoming, and that the female had kittens in 1998 and 1999. These lynx occur farther south than any known native population and are therefore of special interest. Before committing research funds to intensive study, however, we must determine if these lynx are an isolated pair or are part of a larger population occupying contiguous portions of the Greater Yellowstone Ecosystem.

## How Do We Prioritize the Implementation of Intensive Studies?

Simply locating a researchable population does not mean that knowledge gained from an intensive study would be worth the cost. Additional and more useful benefits to lynx conservation may be realized by using research funds in other ways or at other locations. We prioritize intensive studies in locations where researchable populations are identified according to the following three criteria:

**Would an intensive study increase the representativeness of existing information?** For lynx, a representative sample of populations to study should be selected from all known populations within the geographic area of interest. At this time, however, such an approach is impractical because we do not know the locations of extant populations. We therefore need to apply simple criteria that are likely to increase the representativeness of current information on lynx, such as maximizing the geographic extent or variability in major climatic and ecological gradients among lynx studies within the geographic area of interest.

**What will the value of new information be to lynx management and conservation?** New research on lynx in the U.S. must make a significant contribution to lynx management and conservation. Throughout this book, we have identified critical gaps in our knowledge of lynx biology and ecology. Examples include the ecology and population dynamics of principal prey species, competitive interactions with other carnivores, and human impacts. Thus, we would give high priority to potential study areas where assemblages of alternative prey or potential competitors differ markedly from those of previous lynx studies, or where unique opportunities exist to study human impacts on lynx populations, such as adjacent landscapes with and without snowmobile use.

**How feasible is the study and what are the costs?** The cost of lynx research increases with the difficulty of access. In addition, certain types of studies may be infeasible in particular localities, such as snowtracking in areas with significant avalanche danger. Consequently, logistical constraints on research and resulting unit costs for generating new information must be considered when setting research priorities.

# A Research Approach

## Broad-Scale Surveys

Broad-scale surveys are intended to provide information about lynx at large spatial scales (e.g., physiographic regions, ecological provinces, or states). These surveys are most useful when the objective is to document the presence of lynx (Fig. 17.1). Such a survey is currently underway nationally and is designed to provide reliable and representative information about lynx presence/absence and genetic variation. The detection device used is a modification of a rubbing-pad technique for collecting hair samples originally developed by J. Weaver (personal communication; see also Weaver and Amato 1999, unpublished). Survey implementation is based on a protocol developed and tested by the USDA Forest Service's Rocky Mountain Research Station (McKelvey et al. 1999, unpublished). Genetic evaluation will be based on analysis of DNA taken from hair samples.

The first year of the survey (1999) represents a pilot study designed to assess the feasibility of meeting survey objectives, which include determining where lynx occur and where they do not, the pattern of lynx detections

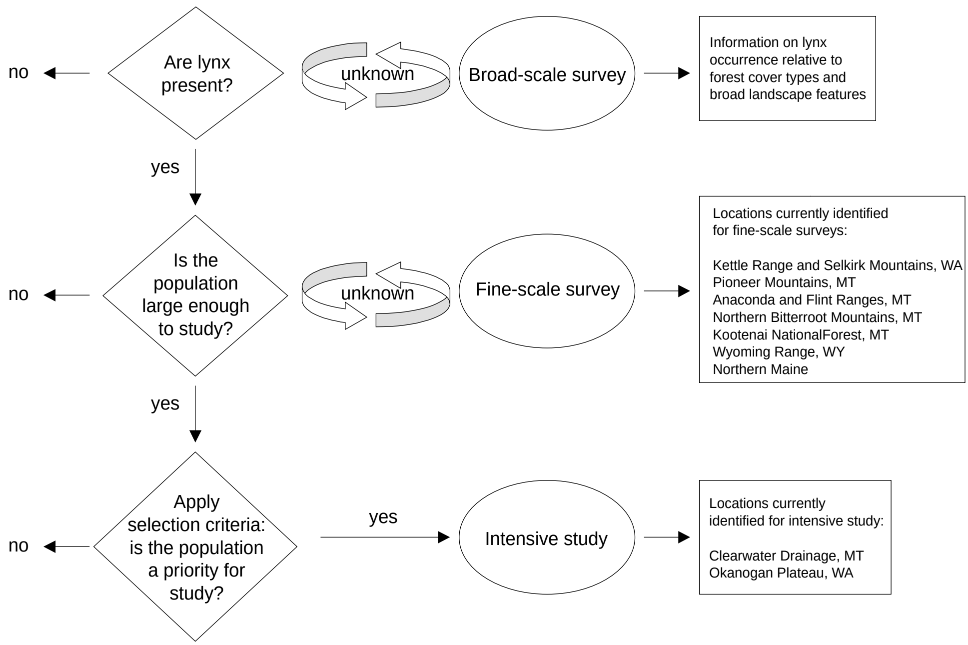


**Figure 17.1**—A schematic representation of the process for identifying potential study areas and implementing intensive research on lynx in the contiguous United States.

relative to broad-scale environmental features, and the degree of genetic structuring among lynx in different geographic areas.

## Fine-Scale Surveys

Fine-scale surveys are conducted in areas where lynx are known to be present. Because these surveys are intended to determine if lynx occur in sufficient numbers to support intensive research (Fig. 17.1), they will most likely employ a combination of detection methods, with snowtracking surveys being the primary means of assessing the relative abundance of lynx. Although most fine-scale surveys will be based on information obtained from broad-scale surveys, there are a number of areas that have already been identified where fine-scale surveys would be appropriate (Fig. 17.1).

Intensive surveys of snowshoe hare distribution and abundance using pellet plots and live-trapping will be used to determine how differences in forest composition and structure (including thinning of young forests) and forest succession along complex moisture/temperature gradients influence patterns of hare abundance.

## Intensive Studies

Intensive studies will be necessary to address most of the information needs we have identified (Fig. 17.1). These studies will employ a variety of research techniques, with radiotelemetry being the primary methodology. Radiotelemetry involves intensive monitoring of the activities of individual animals, enabling data to be gathered on a broad range of research questions including habitat relationships, movements, demography, community relationships, and responses to natural and human-caused disturbance. Radiotelemetry also facilitates the study of snowshoe hare habitat relationships, especially with regard to demographic responses and source-sink phenomena. Accordingly, intensive studies address many objectives at multiple spatial scales and are central to our proposed research program.

Currently, there are three radiotelemetry studies of lynx being conducted in the U.S. These include an intensive study in the Clearwater drainage of western Montana involving 18 radio-collared lynx (Chapter 11), radiotelemetry monitoring of two adult lynx in the Wyoming Range of western Wyoming (Chapter 11), and radiotelemetry monitoring of two adult lynx in northern Maine (Chapter 8). We do not know, however, if radio-collared lynx in Wyoming and Maine are part of more extensive populations. Although all three of these studies will contribute to our understanding of lynx biology and ecology in the U.S., only the western Montana study represents an intensive study of a researchable population (Fig. 17.1).

Our current inability to identify all researchable lynx populations in the U.S. is a critical constraint on the establishment of new intensive studies. The failure of broad- and fine-scale surveys to identify additional populations for intensive study would be significant, as it would provide strong evidence that extant lynx populations in the U.S. are severely restricted. However, until ongoing and proposed surveys identify additional populations for study, we must proceed with intensive studies on known populations.

## A Program of Intensive Research

At the present time, there are only two places in the U.S. where we can state with confidence that intensive lynx studies should be conducted: the Clearwater drainage in western Montana and the Okanogan Plateau in north-central Washington (Table 17.2; Fig. 17.1). Because virtually all of the research needs identified here are most efficiently addressed through intensive studies, we must increase the number of these studies in regions where lynx conservation and related management activities are at issue. For opportunistic reasons, and because the only intensive study currently ongoing is the Clearwater study in Montana, new intensive research should be implemented on the Okanogan Plateau in north-central Washington. Although lynx were studied recently (1980-1988) in this area (see Chapters 10, 13), a number of important landscape-scale habitat changes have occurred on the Plateau since the earlier study, including a major fire. Furthermore, many of the important information needs identified in Table 17.2 were not adequately addressed in previous studies (Chapter 13).

In addition, ongoing research in Montana must be continued and expanded. The Clearwater study area provides a unique opportunity to study the effects of winter recreation, forest fragmentation, and roads on lynx behavior and on competition with generalist predators. The primary study area is located in a relatively low-elevation, intensively managed landscape. However, radio-collared lynx have been moving in and out of the adjacent Bob Marshall Wilderness, which has very different landscape characteristics. Ongoing studies need to be expanded to understand how adjacent wilderness areas are used by lynx. The inclusion of such areas in the study would also increase the representativeness of this research.

Although expanding the Clearwater study and renewing research activity on the Okanogan Plateau are clearly high priorities, it is important to initiate new studies in areas that are ecologically distinct from previous and ongoing studies. To identify such areas, fine-scale surveys to determine the spatial extent and relative abundance of local populations need to be conducted immediately in areas where we know lynx occur. These include several

**Table 17.2**—Studies by location indicating information needs to be addressed.

| | | Pacific Northwest | | Rocky Mountains | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Research approach | Within the historic range of lynx | Okanogan Plateau, Washington | Kettle Range and Selkirk Mountains, Washington | Kootenai National Forest, Montana | Clearwater Drainage, Montana | Pioneer Mountains, Montana | Anaconda and Flint Ranges, Montana | Northern Bitterroot Mountains, Montana | Wyoming Range, Wyoming | North-Central U.S. Unknown | Northeastern U.S. Northern Maine |
| **Broad-scale surveys to determine presence** | | | | | | | | | | | |
| Lynx | | X | | | | | | | | | |
| **Fine-scale surveys to assess relative abundance** | | | | | | | | | | | |
| Lynx | | | X | X | | X | X | X | X | | X |
| Snowshoe hare | X | | | | | | | | | | |
| **Intensive studies—lynx** | | | | | | | | | | | |
| Habitat relationships | | X | | | X | | | | Limited[a] | | Limited |
| Movements and dispersal | | X | | | X | | | | Limited | | Limited |
| Demography and population dynamics | | X | | | X | | | | | | |
| Relationships with prey | | X | | | X | | | | | | |
| Community interactions | | X | | | X | | | | | | |
| Human impacts | | X | | | X | | | | | | |
| **Intensive studies—snowshoe hares** | | | | | | | | | | | |
| Habitat relationships | | X | | | X | | | | | | |
| Population dynamics | | X | | | X | | | | | | |

[a]Radiotelemetry monitoring of several individuals dooes not constitute intensive research but will contribute limited information on habitat relatiionships and movements.

locations in western Montana, western Wyoming, northeastern Washington, and northern Maine (Table 17.2; Fig. 17.1). If additional researchable populations are located in the Rocky Mountains, we would give highest priority to studies in cold, dry forest types, such as the Pioneer Mountains in Montana and the Wyoming Range in Wyoming. New studies in these forest types would contribute more to our understanding of lynx ecology in the U.S. than additional studies in mesic forest types.

Recommendations for intensive research in the southern Rocky Mountains and north-central and northeastern U.S. must await the findings of both broad- and fine-scale surveys. Lynx have never been studied intensively in these regions, where habitat conditions vary substantially from those in the Pacific Northwest and northern Rocky Mountains. For these reasons, ongoing radiotelemetry monitoring of several lynx in Maine and Wyoming will contribute useful information. However, fine-scale surveys to determine whether to expand research efforts in these areas should be given the highest priority.

Hare studies are an important component of our proposed research program. Key conservation issues, including reintroduction efforts and the potential natural range expansion by lynx, will be strongly influenced by patterns of hare abundance. To study differences in hare abundance along successional and moisture gradients and to understand the nature of their population fluctuations, we need to quantify hare abundance over time among different forest types and seral stages. A fine-scale survey program involving cooperative efforts with management agencies will be implemented in representative areas within the historical range of lynx. It is essential, however, that these surveys be conducted in a coordinated fashion using sampling protocols that will generate reliable information about hare habitat relationships and patterns of abundance.

## Conclusions

This research program will proceed on several fronts simultaneously. Broad-scale lynx surveys are underway and by the spring of 2000, we will know more about the efficacy of the survey protocol and, hopefully, patterns of lynx occurrence in the U.S. Fine-scale surveys and intensive studies of lynx and hares should proceed in Washington, Montana, Wyoming, and Maine. And, if we are able to locate other researchable lynx populations, new intensive studies should be implemented to increase the representativeness of our sample, especially in the southern Rocky Mountains and north-central and northeastern United States. Furthermore, as argued previously by Ruggiero et al. (1994), new lynx studies should be integrated within a broader program of research on forest carnivores and other species of concern so that we can develop the information needed to implement ecosystem management in boreal forest landscapes. We must become more proactive in our research programs if we are to effectively address conservation issues before options for conserving sensitive species have become irrevocably limited.

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