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Restoration of the Lynx Lynx Canadensis in Adirondack Park: A Problem Analysis and Recommendations

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PART II

RESTORATION OF THE LYNX *LYNX CANADENSIS* IN ADIRONDACK PARK: A PROBLEM ANALYSIS AND RECOMMENDATIONS

by

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Final Job Completion Report

Job XII - 5

STUDY NUMBER AND TITLE: XII - Biology, Ecology and Range of the Bobcat, *Felis rufus* in New York and its Inferred Interactions with Potentially Reintroduced Lynx, *Felis canadensis canadensis* in Adirondack Park.

STUDY OBJECTIVES:

1. To determine and describe the predation ecology, movement patterns, territorial behavior and habitat of bobcats in New York.

2. To determine vital population characteristics and exploitation levels of bobcats in New York.

3. To recommend management alternatives for bobcats in New York on the basis of an information synthesis, range map and model of current bobcat exploitation levels in the region.

4. To make recommendations concerning the feasibility of lynx reintroduction in Adirondack Park based on the inferred level of lynx-bobcat competition and a survey of potential lynx range in the Park.

JOB NUMBER AND TITLE: XII-5. The feasibility of reintroducing the lynx in Adirondack Park: Potential interactions with the bobcat and extent of suitable lynx range.

JOB OBJECTIVES: To determine the potential interactions of the lynx and bobcat in Adirondack Park and map areas (if any) within the Park which may be suitable for lynx reintroduction.

Author's note: The attached report is a comprehensive one, going considerably beyond the stated job objectives. Besides including a chapter on potential lynx-bobcat interaction and maps on potential lynx range (as the objectives call for), the report additionally includes chapters on historical presence, predation and prey base, habitat ecology, vulnerability to human exploitation, lynx restoration in Europe and recommendations concerning lynx restoration in Adirondack Park. In view of the comprehensive nature of this report, it was retitled: RESTORATION OF THE LYNX *LYNX CANADENSIS* IN ADIRONDACK PARK: A PROBLEM ANALYSIS AND RECOMMENDATIONS.

Abstract: Information for this report was obtained from an associated study on bobcat ecology, field data and field trips to West Germany and northern Minnesota. Historically, the lynx occurred in the western Adirondacks; a population apparently occurred in the High Peaks region. The lynx has been extinct in New York since the late 1800s. Recent scattered records are probably of immigrants, possibly from the northeastern U.S. Elsewhere in North America, lynx populations are associated with heavy snowfall, spruce-fir forest and snowshoe hare prey. On the southern fringes of their range, lynxes occur at high elevations. All these conditions occur in the High Peaks region of the Adirondacks with a mean elevation exceeding 900 m (3000 ft.). An area generally coinciding with the High Peaks spruce-fir vegetational zone was designated as the Potential Lynx Restoration Area (PLRA. Area is 1740 km^2 or 670 mi^2). The mean estimated pre-breeding (March) snowshoe hare density for high Adirondack elevations is 55 hares/km^2 (146 hares/mi^2). The corresponding July, October and December hare densities are computed to be 170 hares/km^2 (453 hares/mi^2), 121 hares/km^2 (321 hares/mi^2) and 104 hares/km^2 (277 hares/mi^2) respectively. On the basis of mean lynx-hare ratios in Alberta, the average carrying capacity for the hare prey base in the PLRA is 71 lynxes. Higher and lower lynx densities have been reported in the literature. The chances for potential competition in the PLRA between bobcats and potentially restored lynxes is minimal. Telemetry data indicate that bobcat activity is generally confined to elevations below 760 m (2500 ft.). Bobcat harvest data show that bobcats are scarce or absent from the PLRA. Competition for prey between the bobcat and lynxes in winter at any elevation in winter is likely to be minimal as bobcats prey heavily on deer, apparently a response to stress. On Cape Breton Island, Nova Scotia, a lynx population occupies the highlands while bobcats are confined to adjacent low-lands. Lynxes are very vulnerable to human exploitation, especially trapping. Lynxes have been eliminated from those parts of their former range which have a high degree of road access. From the standpoint of inaccessibility, conditions in the PLRA favor lynx restoration. Almost the entire PLRA is Forest Preserve Land classified as Wilderness by the Adirondack Park Agency; access to the interior is via established hiking trails only. The European lynx *Lynx lynx* is approximately twice as large as its North American counterpart. Some European lynx restoration efforts have been successful. A lynx restoration effort in Bavaria failed because hunters killed deer preying on roe deer within their leases. Various factors contributing to the success and failure of lynx reintro-ductions are discussed. On the basis of the information and analysis provided, I believe that lynx restoration in the PLRA is feasible. Models of a restored population show that groups of lynxes introduced in Year 1 and 2, and in Year 1 and 3 respectively, increase at approximately the same rate. The following recommendations are made: Establishment of a lynx restoration program should be implemented by the New York State Department of Environmental Conservation, Bureau of Wildlife in the PLRA, integrated with a contracted lynx restoration study. Cooperation of various conservation groups and the public can be solicited through communications media. The promotional potential for a lynx restoration program is great. Possible regulatory aspects are briefly discussed.

CONTENTS

INTRODUCTION

The potential restoration of the lynx and other extirpated species in Adirondack Park is briefly discussed by Clarke (1971) in his Wildlife Technical Reports for the Temporary Study Commission on the Future of the Adirondacks. Legal consolidation of the Adirondack Park concept through the establishment of the Adirondack Park Agency in the early 1970's (Graham 1978) implied a greater emphasis on wilderness values. These events encouraged a group of scientists and agency biologists to develop a comprehensive package of proposed wildlife studies, the Adirondack Wilderness Fauna Program. This set of proposals sought to determine why various wildlife species had declined or were extirpated in the Adirondack region. The package included a proposal for a lynx study (Brocke 1975).

From its inception, it appeared that a study to determine the feasibility of lynx restoration in Adirondack Park should include a comprehensive study on the bobcat, as the latter species is ecologically and taxonomically similar (Hemmer 1977). On the suggestion of E. McCaffrey, New York State Department of Environmental Conservation (N.Y.S.D.E.C.), the lynx proposal was rewritten as an integral segment of a lynx-bobcat study (Brocke 1976, Study XII, W-105-R, Jobs 1-6), and the study was funded through the N.Y.S.D.E.C. Bureau of Wildlife. The Final Reports on the bobcat portion of the study (L. Fox and J.S. Fox, 1982, Final Reports for Study XII, Jobs 1-4 and Job 6) should be read concurrently with this report, as it provides a basis to assess potential competition between the lynx and bobcat.

The legal status of the lynx in New York has changed considerably in recent years. The lynx was originally unprotected in New York and bounties for lynx pelts were paid until 1970 (Bergstrom 1977). The bounty was removed after 1970, but the lynx remained unprotected (New York Fish and Wildlife Law 1970). In 1976, the lynx was listed as a game species by New York State (New York Fish and Wildlife Law 1976). This particular listing only authorized the State to permit hunting but not trapping. Since 1976, the State conferred complete protection to the lynx by maintaining a closed hunting season.

Initiation of New York's lynx-bobcat studies in 1976 was timely from a national perspective. Following the passage of the Endangered Species Act in 1973 (Dept. of State Publ. 8729, 1973), both species were placed on the Appendix II list of the act which includes, "all species which although not necessarily now threatened with extinction may become so unless trade in specimens of such species is subject to strict regulation---". Listing of the lynx and bobcat under Appendix II placed export of their pelts under the jurisdiction of the Endangered Species Scientific Authority (ESSA). ESSA sought status reports and harvest data from states to establish harvest quota limits, under its jurisdiction to regulate trade. Reports to ESSA on the bobcat were subsequently tendered by New York State (Parsons 1977). In response to a Federal request seeking information on the lynx for its possible listing as an endangered species, Bergstrom (1977) prepared a report on its status in New York.

In 1978, the ESSA convened a working group of scientists (including the author) and agency representatives in New Orleans to review the Appendix II listing of the lynx and bobcat. The group recommended the development of biological criteria for future international listing of various species. It also recommended delisting of the bobcat in Appendix II and similarly delisting of the lynx, but only for Alaska. The working group's concern for the lynx applied particularly to the welfare of populations along the southern edge of its current range in Canada, including the northern fringe of the coterminous United States. In this fringe area, lynx populations are sparse, biologically weak and fluctuate in response to cyclic immigrations from Canada (e.g. in Minnesota, Mech 1980, Mech pers. comm. 1982, Berg pers. comm. 1982).

Data and information for this report were obtained from the associated bobcat study, collection of snowshoe hare pellets at high Adirondack elevations, snowshoe hare censuses by removal through trapping, converstions with knowledgeable biologists, lynx observations collected by the N.Y.S.D.E.C. Bureau of Wildlife, unpublished manuscripts, the published literature, and two field trips (personally funded), one to West Germany in October 1981 to visit a European lynx reintroduction site, and the other trip to lynx range in northern Minnesota in February 1982.

Lynx *Lynx canadensis* restoration in North America has, to my knowledge, not been attempted on a significant scale. Clarke (1971) refers to an "Ontario release" but provides no other information. Restoration of the European lynx *Lynx lynx* has been attempted in various parts of its European range, with partial success. To learn more about one such reintroduction, I visited a release site in eastern Bavaria, West Germany, in October 1981. Information from the European lynx releases would at first glance seem to be of considerable value for lynx restoration in North America. However, inferences from European data have limited value because (1) the European lynx is approximately twice as large as its American counterpart, preying regularly on roe deer in the southern portions of its range, and (2) it is often the only predator of its size class within its ecosystem.

I am indebted to L. Fox, Ph.D. candidate, S.U.N.Y. College of Environmental Science and Forestry, for his tireless efforts in executing the bobcat study which provided critical data for this Report. Fox generously developed the population models given here. Data on snowshoe hare censusing by removal trapping were collected by J.S. Fox. My trip to the lynx reintroduction site in eastern Bavaria was arranged by Professor W. Schröder, the University of Munich; Dr. W. Thiele, Assistant Director of the Nationalpark Bayerisher Wald hosted the trip. Information on lynx ecology and movements was provided by Herr Schwarz and M. Waldherr of the Forstampt Zwiesel. Dr. L. D. Mech, Wildlife Research Biologist, U. S. Fish and Wildlife Service, arranged a flight over lynx range in the Boundary Waters Canoe Area, Ely, Minnesota. Mech also contributed first hand impressions of lynx ecology

and original data on lynx movements. Data and impressions on lynx ecology in Minnesota were also provided by W. E. Berg, Wildlife Research Biologist, Minnesota Department of Natural Resources, Grand Rapids, Minnesota. Important information for this report, including an unpublished manuscript on lynx ecology on Cape Breton Island, New Brunswick, were furnished by G. R. Parker of the Canadian Wildlife Service. Assistance in the development of the original proposal was provided by E. R. McCaffrey and G. Parsons, wildlife biologists of the N.Y.S.D.E.C. Bureau of Wildlife. Data and observation records for New York were furnished by P. Nye and A. Hicks, also of the Bureau of Wildlife. For their assistance in the execution of the study, I am grateful to W. Tierson, former Director, as well as S. Sage and R. Masters of Huntington Forest, S.U.N.Y. College of Environmental Science and Forestry, Newcomb, New York. I thank the students at the Forest who collected data, particularly D. Kinney and G. Warbunton.

PROCEDURES

Much information for this report was obtained from the associated bobcat study. For procedures, the reader is referred to the latter study (Fox 1982, Final Report, W-105-R, Study XII, Jobs 1-4). Additionally, information was obtained from unpublished manuscripts, published articles and two personally funded field trips, one to West Germany in October 1981 to visit a European lynx reintroduction site, and a second field trip to lynx range in the Boundary Waters Canoe Area in northern Minnesota and to north central Minnesota.

Maps prepared by the Adirondack Park Agency and U.S. Geological Survey were used to develop maps and plastic overlays. Various statistics prepared and mapped for the New York cougar study (see Brocke 1981, Final Report, W-105-R, E-1-3, 188 pp.) were adapted for maps in this report. They include snowfall, topography, vegetation type, road and human population density and estimated deer densities. Snowshoe hare population densities at high Adirondack elevations were estimated on the basis of fecal pellet counts related to the corresponding hare population level. The latter was determined by removal trapping of hares using wire box traps in a central Adirondack study area. Pellets were counted in 1 m^2 quadrats located in a linear sample group 1 m apart, 10 quadrats per sample group. Sampling locations were established in dense conifer cover (Base Cover, see Brocke 1975) wherever it occurred at lower elevations and at random at higher elevations. Pellet sample groups were located at representative elevations on six mountains or mountain ranges. As pellet counts were related to the pre-breeding (March) snowshoe hare density, hare population densities for other months in the year were reconstructed using previously calculated conversion factors based on snowshoe hare population models (See Brocke, 1977, Final Report, W-105-R, Study IX, Jobs 1-3, 45 pp.). A computer model using a Leslie Matrix was developed by L. Fox (Lescore Model) to simulate growth of a restored lynx population. Assumptions are given in the text.

A base map with two acetate overlay maps is provided with this report. The overlays are keyed to the base map by four points. The reader is encouraged to seek out detail on these maps and refer to them as needed.

List of Maps:

Map No. 1. Base Map - Adirondack Park, Land Use and Development

Map No. 2. Map Overlay - Snowfall and March Snow Depth and Outline of Potential Lynx Restoration Area (PLRA).

Map No. 3. Map Overlay - Topography, Vegetation, Statistics and Outline of Potential Lynx Restoration Area (PLRA).

RESULTS AND DISCUSSION

SECTION 1. HISTORICAL PRESENCE AND DISTRIBUTION IN NEW YORK.

In the East, the lynx Felis canadensis was historically distributed as far south as Connecticut, southern New York, Pennsylvania, Virginia, West Virginia, Ohio, Indiana, Illinois and Iowa (Burt 1954, Hall and Kelson 1959). Seton (1909) depicted lynx range as lying somewhat north of the boundary given by Hall and Kelson (1959). Presumably, Seton was writing about lynx range as it appeared in the late 1800s. Judging from its ecological requirements, the lynx was probably never distributed uniformly along the southern fringes of its range (i.e. the northern tier of the United States). Rather, it probably occurred in scattered populations inhabiting the conifer forests at higher elevations.

Currently, the principal range of the lynx in eastern North America is limited to Canada (DeVos and Matel 1952, VanZyll De Jong 1971). Weak population centers apparently occur south of the Canadian border in Minnesota (Mech 1980, pers. comm. Berg 1982, Mech 1982), on Isle Royale, Michigan (Adams 1909, Hanson, Krefting and Kurmis 1973), Maine and New Hampshire's White Mountains (Silver 1957, Siegler 1971). Lynx distribution in the Northeast is shown by Hamilton (1943) as extending from the eastern Adirondacks across northern Vermont, northern New Hampshire and northern Maine. Hamilton's distribution map is probably based on recent scattered records that do not necessarily indicate the presence of reproducing populations. (4)

In New York, the lynx was apparently never prominent, at least not within recorded history. DeKay (1842) observed that,"the lynx is not uncommon in the northern districts of the state." Merriam (1882) wrote,"The lynx is, and so far as I can learn, has always been a rather rare inhabitant of this region. It is most often met with on the Champlain or eastern side of the Woods but is nowhere common." By "Woods", Merriam was referring to the Adirondack woods. Harper(1929) wrote,"Godfrey Dewey stated, on the authority of Henry Van Hoevenbergh, that this (5) species was fairly common about Heart Lake in the late 80s and 90s." Heart Lake is adjacent to Adirondack Loj in the High Peaks area, North Elba Township, Essex County. I infer that Van Hoevenbergh may have reported the presence of lynx sign or may have sighted lynx around Heart Lake, a rather small lake. Such records may have represented one, or at most a few individual lynxes.

The statements of Merriam (1882) and Harper (1929) are of considerable ecological interest as they suggest that the Adirondack lynx population was centered approximately in the High Peaks area. This inference is consistent with recent information on the preference of lynxes for higher elevations where they are sympatric with the bobcat (Parker 1980, Parker et al. 1982 in press). This point will be discussed in greater detail in Sections 2 and 3 of this report. (6)

There is evidence that a lynx population originally existed in the Catskills. Miller (1899) quotes Mearns (1898) as follows: " Hunters told me that there are still a good many lynxes ... in the (Catskill) mountains. Very large tracks of a lynx which I suppose to have been this species... were seen almost daily on the summit of Hunter mountain during the latter part of August... During the winter of 1877-78, a Canada Lynx was killed near Rhinebeck on the Hudson and brought to Prof. James M. DeGarmo, in whose collection I saw it soon afterwards. This is the only record of its occurrence in the immediate vicinity of the Hudson River during recent years that has been brought to my attention."

Apparently, lynx populations in New York were approaching extinction by the late 1880s, judging from the general tenor of the citations above, and the observation of Miller (1899) that,"The Canada Lynx is rapidly approaching extinction in New York and in fact throughout the eastern portion of its range." Indeed, scattered lynx observations dating to the late 1800s, solicited by naturalists eager to prove the existence of lynxes, may be suspect. Apparently, many hunters did not or could not differentiate the lynx and the bobcat and may have reported observations of the latter species as lynx observations. In this connection, Harper(1929) wrote, "Although there are a number of alleged records in recent years from various parts of Essex County, the local hunters seem to be very uncertain in differentiating Lynxes from Wildcats. It is hardly worthwhile to report those supposed occurrences until an opportunity is afforded to examine specimens." Similarly in New Brunswick, Squires (1946) observed," The records concerning the different lynxes occurring in the province are so interwoven that they can scarcely be separated." He goes on to mention reports of as many as three forms of lynxes, including the Canada Lynx and wildcat (bobcat).

Recent lynx records for New York State, compiled by Bergstrom (1977) are given in Table 1. These records, widely scattered over time, clearly indicate that no self sustaining lynx population has occurred in New York during this century. In view of the large scale, annual trapping effort in northern New York, lynxes would have been collected more regularly and in larger numbers, if a population had been present.

The geographic pattern of these observations (Table 1) is of interest. Nine of the 13 observations are located in central and northeastern Adirondack counties. Two observations were made in the western Adirondacks, while the Washington County observation is not far from the Adirondacks. The two lynxes killed in 1907 in Tioga County are geographically out of character with the other observations. Although the observations are sparse, their geographic pattern suggests that the lynxes recently observed in New York probably immigrated across the forested high ground of New Hampshire and Vermont into northeastern New York, rather than from Canada across the St. Lawrence Plain. A lynx population has occupied the White Mountain area of New Hampshire until 1965 (Siegler 1971); apparently a few animals still survive there. Between 1931 and 1965, 230 bounties were paid for lynxes in New Hampshire (Siegler 1971).

In sum, while the evidence is by no means conclusive, the available historic record suggests that (1) lynx populations in New York were centered in the Adirondack High Peaks region and possibly in the Catskills; (2) the lynx population in the Adirondacks held out the longest, apparently becoming extinct in the late 1800s; (3) lynx observations recorded since 1900 are probably of wandering immigrants, possibly from New Hampshire and points to the northeast.

Table 1. Recent lynx records of variable authenticity for New York State, 1900 to the present time, from Bergstrom (1977).

Year	Observation	Location	Authority
1907	2 lynxes killed, a "pair"	Tioga County South central New York	Hamilton 1943 Seagers 1948
1916	1 lynx killed	Oneida County Western Adirondacks	Anon. 1952
1918	1 lynx killed	Essex County Northeastern Adirondacks	Anon. 1918
1928	1 lynx killed	Essex County Northeastern Adirondacks	Anon. 1952
1930	1 live capture	Essex County Northeastern Adirondacks	Seagers 1948
1934	3 lynxes seen alive in a group	Franklin County Northern Adirondacks	Chase 1953
Late 1930s	1 lynx killed	Franklin County Northern Adirondacks	Will 1977
1951	1 lynx shot	Washington County Eastern New York	Seagers 1951
1961	1 lynx shot	Essex County Northeastern Adirondacks	Will 1977
1962	1 lynx taken	Hamilton County Central Adirondacks	Anon. 1963
1964	1 lynx killed	Lewis County Western Adirondacks	Fountain 1976 Will 1977

Table 1. (Continued)

Year	Observation	Location	Authority
1965	1 lynx trapped	Hamilton County Central Adirondacks	Anon. 1966
1973	1 lynx trapped	Clinton County Northeastern New York	Will 1977

SECTION 2. PREDATION AND HABITAT ECOLOGY.

In this section, predation and habitat ecology will be considered at two levels, namely (1) in general terms, regarding the lynx throughout its North American range, and (2) in specific terms, relating to potential lynx range in the Adirondacks. To follow the latter discussion the reader should refer to base Map No. 1 and overlay Maps No. 2 and No. 3.

General Discussion

The lynx inhabits boreal climatic zones throughout its range where its physical features, including large feet, long winter fur and long legs adapt it to severe winters and deep snow. The principal prey of the lynx is the snowshoe hare *Lepus americanus*, wherever the lynx occurs (Saunders 1963, Van Zyll de Jong 1966, Nellis and Keith 1968, Nellis et al. 1972, Berrie 1974, Brand et al. 1976, More 1976, Koehler et al. 1979, Brand and Keith 1979, Parker 1980, Parker 1982 unpub. MS). Indeed, a lynx attack on a trapper was apparently induced by the 12 hares he was carrying (Hancock et al. 1976). (8)

Because the lynx is largely dependent on snowshoe hare prey, lynx habitat tends to be synonymous with snowshoe hare habitat. Saunders (1963) found that lynx habitat in Newfoundland coincided with 10 to 20 year old timber, including a burned area favored by snowshoe hares. In Montana, Koehler et al. (1979) observed that activity of telemetered lynxes was concentrated in areas of high snowshoe hare activity, particularly in dense stands of lodgepole pine. In the Boundary Waters Canoe Area (BWCA) of northern Minnesota, lynxes are closely associated with snowshoe hare cover (i.e. conifer cover, Mech 1982, pers. comm.). In the northern BWCA, hares occur in the mature jackpine forests where hares also occur. In southern sections of the BWCA where conifer cover has been locally removed by logging, hares are absent and lynxes are also absent (Mech pers. comm. 1982).

The most detailed study of lynx habitat has been conducted by G. R. Parker and his associates on Cape Breton Island, Nova Scotia (Parker 1980, Parker et al. 1982, unpub. MS.). The Cape Breton Plateau, where the latter authors conducted their research, is similar ecologically to some of the five successional areas of the central Adirondacks. Dominant tree species are balsam fir Abies balsamea, white spruce Picea glauca, black spruce Picea mariana, and paper birch Betula papyrifera (Parker et al. 1982, unpublished MS.). The principal prey of lynxes on the plateau is the snowshoe hare. Its remains were found in 93% of winter lynx scats and 70% of summer scabs (Parker et al. Op. Cit.). The latter authors state: "Winter tracking and radio telemetry showed lynx selected for regenerated mixed forest habitats approximately 20 years following cutting. Forest stands of this type also represented optimal habitat for snowshoe hares. Mature conifer habitat was used proportionate to its availability. Mature mixed and deciduous stands were selected against by lynx at all seasons."

The most important secondary prey items recorded for the lynx include the ruffed grouse Bonasa umbellus, flying squirrel Glaucomys sp., mice and voles, various bird species and carrion (Saunders 1963, Nellis and Keith 1968, Nellis et al. 1972, Brand et al. 1976, More 1976, Brand and Keith 1979). The lynx of North America does not usually prey on ungulates, unlike the European lynx Felis lynx which is approximately twice as large (See Section 5). However, exceptions do occur. Moose and caribou were recorded as food items by Saunders (1963) in Newfoundland. He states: "Moose and caribou provided food for lynxes resulting from the fall hunting season and from poaching in late winter, and possibly as a result of predation. All moose and caribou material analyzed were from adult animals." Also in Newfoundland, Bergerud (1971) identified the lynx as a major cause of mortality for caribou calves. Apparently lynxes attacked caribou calves on their calving grounds. Calves that were not killed immediately by lynx bites to the throat, died subsequently of lesions in the throat area.

The potential role of the white-tailed deer Odocoileus virginianus as lynx prey is an important consideration in a possible lynx restoration effort in Adirondack Park. Apparently, the lynx rarely preys on the white-tailed deer. Seton (1929) writes: "We have heard of one or two accounts of the Canadian lynx having killed a deer; we are somewhat skeptical in regard to this being a general habit of the species---." In Minnesota, Berg (1982 pers. comm.) found a lynx-killed deer in the Beltrami Lakes section of northern Minnesota. The deer carcass had tooth marks in its throat and lynx tracks around it. Berg (Op. Cit.) also said that he knew of one reliable report by a trapper of a lynx-killed deer.

The recent study of Parker et al. (1982, unpub. M.S.) is of particular interest regarding lynx predation on deer. The plateau, approximately 1200 feet (360 m) in elevation, is occupied by white-tailed deer during the snow-free months of May to December. Deer move off the plateau to the slopes and lowlands during the winter, returning to the plateau again in May (Parker et al. Op. Cit.). The lynxes telemetered in the study remained on the plateau throughout the year, essentially dependent on hares as prey. The occurrence of deer remains in lynx scats was 9% in summer and 5% in winter (According to the authors, the 5% winter value is traceable to deer used as bait).

Assessment of Habitat and Prey Base in Adirondack Park

In this section, I shall consider various factors as they relate to lynx survival in Adirondack Park, specifically topography, snowfall, vegetation and prey availability. The reader should refer to Map No. 1 in conjunction with overlay Maps No. 2 and/or No. 3, while reading the text.

The area in Adirondack Park where lynx survival appears to have the highest probability is shown in Map overlays No. 2 and No. 3 (Use overlays in conjunction with Map No. 1). This area, termed the Potential Lynx Restoration Area (PLRA), is outlined on the basis of historical lynx distribution, snow cover, vegetation, prey availability, potential human exploitation and potential competition with the bobcat.

The PLRA coincides closely with the area designated by Stout (1958, Atlas of Forestry in New York) as the High Peaks Subregion of the Adirondacks (Use Map No. 3 in conjunction with Map No. 1). The High Peaks Subregion is described by Stout (Op. Cit.) as follows: "This heavily wooded mountainous area has at least 40 peaks that rise above 4000 feet (1200 m). In fact, it is the largest block of land in New York State having an average elevation of over 3000 feet (900 m). This distinctive feature alone sets it apart from bordering subregions of the Adirondacks." It is apparent (Maps No. 1 and 3) that the PLRA boundary generally follows the 2000 ft. (600 m) contour outlining the High Peaks block of land (Maps No. 1 and 3). Hence, most locations in the PLRA lie well above the latter elevation.

Severe winters and short summers affect the High Peaks area enclosed by the PLRA. The mean annual snowfall in the PLRA as interpreted from the maps (Maps No. 1 and No. 2) ranges from approximately 80 in (203 cm) to more than 190 in (483 cm). On the slopes of Mt. Marcy (elev. 5344 ft., 1619 m), winters begin in September and end in June (Adams et al. 1920). In the High Peaks subregion as a whole, the growing season is merely 80 to 90 days long and snow remains on the peaks well into May each year (Stout 1958).

There is currently no good vegetation type map available for the Adirondack High Peaks region. Fortunately, this lack of quantitative information is not a serious problem from the standpoint of this report because the High Peaks region is botanically quite homogenous. A forest type map for the Adirondack region is given by Ferree and Davis (1954). This map shows the High Peaks area primarily under spruce-fir cover, with minor inclusions of birch and other hardwoods. However, the latter map is probably of questionable value because it shows spruce-fir as the dominant forest type for the Adirondack region as a whole.

Ferguson and Mayer (1970) have designated northern hardwoods as the dominant forest type in the Adirondacks. My visual inspection of satellite data (Geographic Information System of the Adirondack Park Agency, Landsat data displayed as color graphics on a video monitor) showed large, homogenous blocks of conifer dominating the High Peaks region, with minor inclusions of mixed wood and hardwood at lower elevations. Landsat data clearly show conifer vegetation patterns. However, at this writing, the latter have not been correlated with quantitative vegetation surveys in the High Peaks area. According to R. Curran (1982, pers. comm.), stands designated in the Landsat system as "spruce fir" in the High Peaks have an approximate composition of 80% conifers.

Following is a brief characterization of High Peaks vegetation, according to various sources. Along the High Peaks periphery, the northern hardwood forest grows upward, including principally sugar maple Acer saccharum, yellow birch Betula lutea and American beech Fagus grandifolia, with various admixtures of red maple Acer rubrum, black cherry Prunus serotina, striped maple Acer pennsylvanicum, white ash Fraxinus americana, red spruce Picea rubens, eastern hemlock Tsuga canadensis and eastern white pine Pinus strobus. The northern hardwood forest gradually gives way to an increasing admixture of conifers and at the 2500 ft. (750 m) level, approximately 95% of the forest cover consists of red spruce and balsam fir (Ketchledge 1967, 1970). Where the forest has been disturbed by wind or fire, aspens Populus sp. appear at lower elevations and paper birch at higher elevations. Occasional stands of black spruce and tamarack Larix laricina are scattered throughout (Ketchledge 1970). On the slopes of Mt. Marcy (and presumably at equivalent elevations elsewhere in the High Peaks), red spruce disappears at an elevation of 4250 ft. (1300 m); the forest is composed almost entirely of balsam fir at higher elevations up to timber line at 4900 ft. (1500 m) (Adams 1920). Some paper birch is found as stunted growth up to the very highest elevations. Adams (1920) gives the composition of high elevation fir forest as

85% balsam fir, 10% paper birch and 5% red spruce. Above 4500 ft. (1360 m), stunting of trees is noticeable and becomes increasingly evident as the timber line is approached (Adams 1920).

It is apparent that High Peaks vegetation is typical of boreal coniferous forest, as noted by Shelford (1963). Elsewhere, lynx range today is largely coincident with boreal forest. Strong conifer components are characteristic of lynx habitat, whether the conifers tend to grow as mature blocks (jackpine in northern Minnesota, Mech 1982 pers. comm.), in stands with admixtures of hardwood and open ground (Saunders 1963, Nellis and Keith 1968, Berrie 1974, and Parker 1980) or in scattered island-like stands in open country (inferred from photos in Bergerud 1971; Koehler et al. 1979). The coincidence of conifers with lynx habitat appears to be largely a function of conifer habitat selection by their principal prey, the snowshoe hare (as noted previously).

The stunting effects of low temperatures, wind, snow and ice on vegetation at high elevations in the PLRA is a positive force in terms of lynx prey production. Stunted conifer forest tends to remain in the size classes which are optimum for snowshoe hare production on a relatively continuous basis. This optimum size range has been measured at 8.6 ft (2.6 m) to 15 ft (4.5 m), with stands of marginal quality ranging upward in height to 47 ft (14.2 m) (Brocke 1975b). These measurements were made at an elevation of 1800 ft (550 m) where mean snow depth in mid-March is approximately 3 ft (1 m). To compensate for greater snow depths at higher elevations, 1 m or more can be added to the tree heights given above. Adams (1920) states: "At 4250 feet the average mature firs approximate 40 to 45 feet by 8 to 10 inches in diameter at breast height; at timber line, they do not exceed 7 to 12 feet in height by 5 inches (average about 3) in diameter. The change is not uniform and stunting not very noticeable below elevations of about 4500 feet.--- Younger trees however are found throughout. Reproduction is abundant in all openings." My personal subjective impressions from trips to the

High Peaks region are that at elevations above approximately 2500 ft (760 m), hare habitat is common and at elevations above 3000 ft (900 m) hare habitat is essentially continuous. I estimate conservatively that 60% of the PLRA consists of snowshoe hare habitat.

An assessment of the lynx carrying capacity of the hare prey base in the PLRA is given below, obtained by converting hare pellet counts at high elevations to corresponding hare densities and relating these densities to published lynx densities. Snowshoe hare pellet counts (410 quadrats, 1 m^2) for various elevations from 2360 ft (715 m) to 4800 ft (1454 m) are given in Table 2. It should be noted that although specific locations are given in Table 2, pellet counts were made in groups ranging from 3 to 10, in 1 to 10 sites respectively for one elevation, or a range of elevations in the general area of the given location. For example, in the case of Whiteface Mountain, 8 quadrat groups (80 quadrats) were spaced over a 600 ft. (180 m) range in elevation (Table 2). Evidence of hare populations was consistently found in conifer habitat at lower elevations and in essentially all forests at higher elevations (above approximately 3000 ft, 900 m). Hare pellets were found at the highest elevations sampled, namely 4800 ft (1450 m) on Whiteface Mountain. On two occasions in summer, I have seen snowshoe hares above the tree line on Whiteface Mountain, apparently using scattered conifers as cover. The unweighted mean of 6 pellet count means given in Table 2 for high elevations is $21.9/m^2$.

The results of snowshoe hare pellet counts (100 quadrats) in the Adjidaumo census area are given in Table 3. The mean of sample means is 30.0 pellets/m^2, which represents a hare population density (See Table 4) of 200 hares/m^2 or 75.7 hares/km^2. As pellet counts in the High Peaks were of winter pellets, representing the pre-breeding (March) population, conversion factors for population levels at other times of the year are given in Table 5. On the basis of Tables 4 and 5, hare population densities were calculated for the 6 high elevation locations for July, October and December. These hare population

Table 2. Snowshoe hare pellet counts at selected high elevations in the Adirondacks. (Winter pellets, May and early June).

Location	Elevation of pellet samples ft (m)	Pellet Count pellets/m^2, $\bar{X} \pm S E$ (n)[1]
1. Goodnow Mountain	2690 (815)	33.1 ± 8.4 (10)
2. Santanoni Mountain	2700-3000 (818-909)	17.0 ± 2.5 (10)
3. Kempshall Mountain	2360-2800 (715-848)	34.3 ± 6.1 (5)
4. Seward Range	3000-3900 (909-1182)	7.4 ± 3.4 (5)
5. Marcy-Skylight Mountains	4350 (1318)	17.2 ± 6.6 (3)
6. Whiteface Mountain	4200-4800 (1273-1454)	22.6 ± 4.7 (8)

[1] n is the number of means. Each mean represents 10 quadrat samples.

Table 3 . Snowshoe hare pellet counts in the Adjidaumo hare census area. Ten quadrats (1 m^2) were tallied in each of 10 locations between May 23 and May 26, 1978. The population estimated by removal (ending April 1) was 50 hares.

Location	Pellet Count Pellets/m^2 $\bar{X} \pm$ S E (n)
1	22.3 ± 13.9 (10)
2	20.7 ± 12.8 (10)
3	11.9 ± 7.2 (10)
4	24.3 ± 13.6 (10)
5	15.9 ± 6.7 (10)
6	68.7 ± 44.9 (10)
7	44.4 ± 22.3 (10)
8	34.6 ± 30.2 (10)
9	29.6 ± 16.3 (10)
10	28.1 ± 15.9 (10)

$\bar{X}$ (SE) of sample means = 30.0 (5.2)

Table 4. Conversion factors relating the mean pellet count (from Table 3) to the snowshoe hare population density on the Adjidaumo hare census area.

Parameter	System of Measurement	
	English	Metric
Hare population estimate	50	50
Total area, Adjidaumo	0.25 mi^2	0.66 km^2
Mean pellet count	30/m^2 (metric)	30/m^2
Hare density	200 hares/mi^2 of hare habitat	75.7 hares/km^2 of hare habitat
Hare density per pellet counted	6.66 hares/mi^2	2.52 hares/km^2

Table 5. Computed values from a snowshoe hare population model, showing the annual cycle beginning with a pre-breeding population of 100 animals. (From FINAL REPORT, W-105-R, Jobs IX 1-3, p. 31). Factors relating monthly population levels to the March population level are based on the model.

Month	Population	Factor
March	100	1.0
April	94	0.9
May (Litter 1)	173	1.7
June (Litter 2)	283	2.8
July (Litter 3)	314	3.1
August	278	2.8
September	246	2.5
October	219	2.2
November	205	2.0
December	192	1.9

Table 6. Computed snowshoe hare densities for hare habitat at high elevation sites in the Adirondacks. Densities were estimated from hare pellet counts given in Table 2 and conversion values given in Tables 4 and 5.

Location	Elevation of sites ft (m)	Estimated hare densities, hares/mi^2 (hares/km^2)			
		July[1]	October[2]	December[3]	March[4]
1. Goodnow Mountain	2690 (815)	683 (258)	485 (183)	418 (158)	220 (83)
2. Santanoni Mountain	2700-3000 (818- 909)	351 (133)	249 (94)	215 (82)	113 (43)
3. Kempshall Mountain	2360-2800 (715- 848)	708 (268)	502 (190)	433 (163)	228 (86)
4. Seward Range	3000-3900 (909-1182)	152 (58)	102 (41)	93 (36)	49 (19)
5. Marcy-Skylight Mountains	4350(1318)	355 (134)	252 (95)	217 (82)	114 (43)
6. Whiteface Mountain	4200-4800 (1273-1454)	466 (176)	331 (125)	285 (108)	150 (57)
Mean	-	453 (170)	321 (121)	277 (104)	146 (55)

[1]Density computed by multiplying March density by 3.1 (See Table 5).

[2]Density computed by multiplying March density by 2.2.

[3]Density computed by multiplying March density by 1.9.

[4]Density computed by multiplying pellet counts in Table 4 by 6.66 hares/mi^2 or 2.52 hares/km^2.

densities are given in Table 6.

Currently, the best data available relating snowshoe hare densities to lynx densities are those of Brand et al. (1976) for Alberta. The latter authors compare lynx densities per 100 km^2 of lynx occupied area, with hare densities per 100 km^2 of hare habitat. In order to transfer the lynx-hare density relationships for Alberta to the PLRA, one must assume that the proportion of hare habitat in the Alberta lynx range is equivalent to that proportion in the PLRA. As mentioned above, I estimate that the proportion of hare habitat in the PLRA is approximately 60%. This is probably a conservative estimate. By contrast, proportions of various vegetation types in the 130 km^2 Alberta Lynx study area of Brand et al. (1976) is as follows: 33% improved pasture and cropland, 33% aspen and poplar, 15% spruce forest, 11% brush, marsh and open water. Hence, snowshoe hare habitat probably constitutes less than 60% of lynx occupied range. For these reasons, I believe that the potential lynx densities estimated for the PLRA from the data of Brand et al. (1976) are probably conservative.

The data of Brand et al. (1976, from their Table 1, p. 419) have been adapted and transferred to Table 7. Lynx and hare densities are given in columns A and B. The "ratio" of lynx to hare densities is given in column C. It should be noted that this is not a simple ratio because lynx density is stated in terms of lynx-occupied range and hare density in terms of hare habitat. The mean "ratio" of 2543 hares/lynx is given in column C. Assuming that the proportion of hare habitat within lynx range for the PLRA and Alberta are equivalent, potential lynx density estimates for the PLRA based on hare prey densities have been computed as in the following example: Assume a "ratio" of 2543 hares/lynx (from Table 7, column C, mean of 8 years), and a mean Adirondack hare density of 10,400 hares/100 km^2 of hare habitat (from Table 6. December density of 104 hares/km^2 (10,400 hares/100 km^2) is used because Brand

Table 7. Ratio of Lynx to hare densities (December) in Alberta, based on the data of Brand et al. (1976, Table 1, p. 419).

Year	Column A Lynx/100 km^2	Column B hares/100 km^2 of hare habitat	Column C Ratio Col. B/Col. A[1]
1964-65	8.5	13,700	1,611
1965-66	3.8	7,900	2,079
1966-67	2.3	8,000	3,478
1967-68	6.9	18,500	2,681
1971-72	10.0	49,900	4,990
1972-73	7.7	20,000	2,597
1973-74	3.8	6,900	1,815
1974-75	3.1	3,400	1,097
Mean	5.8	16,037	2543/1
Range	2.3 - 10.0	3400 - 49,900	1097 - 4990

[1] It should be noted that this ratio relates lynxes per 100 km^2 of area occupied by lynxes to hares per 100 km^2 of hare habitat.

Table 8. Lynx population densities and lynx population estimates for the PLRA, based on hare prey carrying capacity in the Adirondacks, and lynx-hare ratios reported for Alberta by Brand et al. (1976)[1]

Hare densities Adirondack Locations	Computed Lynx Population: Lynxes/100 mi² (Lynxes/100 km²)	Computed Lynx Population: Computed Lynx Population for PLRA
1. High density Kempshall Mt. 16,300 hares/100 km² of hare habitat	16.6 (6.4)	111
2. Low density Seward Range 3600 hares/100 km² of hare habitat	3.6 (1.4)	24
3. Mean density 6 Adirondack locations 10,400 hares/100 km² of hare habitat	10.6 (4.1)	71

[1]The mean value of 2543 hares per 100 km² of hare habitat/1 lynx per 100 km² of lynx occupied area taken from Table 7 was used. These data are based on Brand et al. 1976.

Table 9. Lynx densities reported in the literature, with corresponding estimates of the lynx population in the PLRA[1]

Authority (Geographic Area)	Density Level	Density: Lynxes/100 mi^2	Density: Lynxes/100 km^2	Computed Lynx population for PLRA[1]
Bergerud 1971 (Newfoundland)	Low	10	3.9	67
	High	20	7.7	134
Brand et al. 1976 (Alberta)	Low	6	2.3	40
	High	26	10.0	174
Mech 1982 unpub. (Minnesota)	-	15	0.6	10
Parker et al. 1982 unpub. (Cape Breton Island)	-	52	20.0	348
Saunders 1963 (Newfoundland)	-	50	19.3	335

[1] The Potential Lynx Restoration Area (PLRA) in the Adirondack High Peaks Region has an area of 671 mi^2 (1738 km^2)

et al. 1976, relate lynx densities to December hare densities). Then, 10,400/2543 = 4.1 lynxes/100 km^2. The total estimated population of the PLRA (1738 km^2, 671 mi^2) is 71 lynxes. This and other lynx population estimates for the PLRA are given in Table 8.

Lynx population density estimates from published and unpublished sources are given in Table 9. These values have been used to compute potential lynx populations for the PLRA, ranging from 10 to 348 (Table 9, populations computed on the basis of land area). The values of Mech (Table 9) have been computed by us using his raw telemetry data for nothern Minnesota. The latter values are uncharacteristically low, probably because they represent a transitory population of immigrants from Canada. The values of Parker et al. (1982 unpub.) are the highest reported anywhere for the lynx and may not represent a long-term level for Cape Breton Island.

In sum, the lynx population density that can be attained in the PLRA is largely in the realm of speculation, at this writing. However, if man allows the lynx to survive, I believe that the species can attain a population of at least 70 animals in the PLRA, on the basis of data and computations given above.

SECTION 3. INTERSPECIFIC COMPETITION.

The results of various studies suggest that the bobcat and the lynx may compete where their ranges overlap because (1) both species use conifer or mixed conifer-deciduous cover in more northern areas (Rollings 1945, Pollack 1949, Progulske 1952, Erickson 1955, Saunders 1963, McCord 1974, Koehler et al. 1979, Berg 1979, Parker 1980, May 1980, Parker et al. 1982) and (2) both species feed on snowshoe hares (Hamilton and Hunter 1939, Rollings 1945, Pollack 1951, Westfall 1956, Saunders 1963, Stevens 1966, Nellis et al. 1972, Brand et al. 1976, Koehler et al. 1979, Brand and Keith 1979, and Parker 1980).

Additionally, the bobcat has been observed to replace the lynx, where ranges of the two species overlap. For example, Squires (1946) noted the following for New Brunswick: "It seems probable that during the last hundred years, the positions of the two lynxes (i.e. the bobcat and the lynx) in our fauna have been reversed; that the Canada lynx was formerly so much more common that it was the only one that came to the attention of many of the writers, whereas of late years it has become almost extinct in the Province while the wildcat is now abundant." A parallel reversal apparently occurred in the Adirondacks, for Merriam (1882) wrote: "The Wild Cat is for some reason, an extremely rare animal in the Adirondacks. It may be that our climate is too severe for it, since it is much more common farther south." In Canada DeVos and Matel (1952) observed that the bobcat has penetrated into most sections of the range vacated by the lynx. They felt that competition between the lynx and the bobcat may exist. More recently, Parker et al. (1982) completed a study on lynx ecology on Cape Breton Island, Nova Scotia. They stated: "Prior to the ingress and colonization of bobcats throughout the lowlands of Cape Breton Island in the past 25 years, lynx were common over much of the island. Concurrent with the colonization of the lowlands by bobcat, lynx densities declined until they are now common only on the highlands, the one area where bobcats have yet to become established."

Clearly, potential competition between the lynx and the bobcat is an important consideration in any attempt to restore the lynx in Adirondack Park, an area where the bobcat is resident. To shed light on this subject, L. Fox (1982, Final Report, W-105-R, Study XII, Jobs 1-4) sought answers to four questions, specifically (1) is there evidence that the bobcat is under stress in the climatically severe Adirondack environment, as may be indicated by e.g. unusual predatory behaviour in winter such as a shift to deer prey? Such a shift would suggest that the lynx could possibly compete where deer are locally scarce or absent. (2) Is there evidence that the bobcat uses lower Adirondack elevations where winter snow conditions are less severe? Such an elevational preference of the bobcat would indicate the potential presence of a niche for the lynx at higher Adirondack elevations. (The factors addressed by the latter two questions are, of course, related as deer tend to yard at low elevations in winter). (3) Do Adirondack bobcat populations show decline/s correlated with severe winters? And (4) Is the bobcat locally scarce in the Adirondacks? Wherever it is scarce, lynx survival (in suitable habitat) may be enhanced.

Data on bobcat condition as reflected by femur fat indices (Fox Op. Cit., Figs. 3 and 4) show that Adirondack bobcats are more stressed than southern New York bobcats. The mean percent dry weight of femur bone marrow (1978, 1979 and 1980) ranges between 48% and 58% for Adirondack bobcats, compared to a range of 73% to 82% for southern New York bobcats (Fox Op. Cit., interpreted from Fig. 4). The most important prey item was the white-tailed deer, while lagomorphs were second. Deer remains were found in 32% of all stomachs examined (n = 169) and comprised 35.7% of the total weight. Most deer killed by bobcats are small; 10 of 13 carcasses visited by snow trailed bobcats were young of the year (Fox Op. Cit.).

Although the data are limited, Fox (Op. Cit.) believes that large prey or cached prey may be critical to winter survival under Adirondack conditions. Supporting this hypothesis is the observation that three telemetered bobcats known to have fed on deer during the winter of 1979-79 survived, whereas two telemetered bobcats that died were not known to have fed on deer. Additionally, a significant difference was detected in the femur fat index of 79.8 for two bobcats feeding on deer in the Adirondacks during late winter versus the average femur fat index of 47.4 for 13 bobcats not known to feed on deer (Fox Op. Cit.). These data, particularly for the Adirondack region, suggest that the bobcat adapts to stressful winter conditions by feeding on deer. Other studies for the northern sections of its range support the findings of Fox (Op. Cit.) namely Hamilton and Hunter (1939), Marston (1942), Westfall (1956), Erickson (1955), Progulske (1952). Fox found that lagomorphs tended to be the most important food item for the summer months. Fox's data suggest that competition between the bobcat and potentially reintroduced lynx would be minimized by the bobcat's apparent obligate preference for deer prey in winter (to compare predatory behavior of the lynx, see Section 2 of this report).

According to the data of Fox (Op. Cit.), bobcats tended to select lower elevations within their home range (Table 10). Bobcat No. 306 was the only one of 10 telemetered bobcats that used the mid-elevations, ranging from 610 to 760 m (2000 to 2500 ft.). The others generally used elevations below 610 m (2000 ft.) although data points for some animals were not significantly different from random locations within their home range areas (Table 10). In sum, it appears that in general, bobcat competition would be minimal for reintroduced lynxes at elevations above 200 m (2000 ft.) in the Adirondacks.

According to limited information in the literature, the lynx tends to use

Table 10. Summary of habitat and elevation selection by Adirondack bobcats, as determined by telemetry. The Chi square statistic was used to test comparisons of observed with expected areas of cover type and elevation used by bobcats. Data were collected by Fox (1982); the reader should refer to the latter final report for procedures.

Bobcat No. and Sex	Elevational Preference: Preferred Elevation	Elevational Preference: Avoided Elevation	Cover Type Preference, Annual: Preferred	Cover Type Preference, Annual: Avoided	Cover Type Preference, Winter: Preferred	Cover Type Preference, Winter: Avoided
105 Male	<610 m* (2000 ft.)	>610 m*** (2000 ft.)	Mixed*** Cut***	Hardwood *** Large***	Mixed***	Hardwood *
306 Male	210-762 m* (2000-2500 ft.)	NS	Hardwood ** Cut**	Softwood** Large***	Mixed*** Cut*	Large*
51 Male	NS	NS	-	-	-	-
54 Female	<610 m* (2000 ft.)	>610 m*** (2000 ft.)	Softwood *** Mixed *	Hardwood * Small*	Softwood* Mixed *	NS
454 Female	NS	NS	Mixed ***	NS	NS	NS
67 Female	NS	>518 M*** (1700 ft.)	-	-	-	-

Significance -
Values of Chi square: P≥ 0.05*
P≥ 0.01**
P≥ 0.005***
NS = Not Significant

higher elevations along the southern fringes of its range. This is probably a behavioral response to the availability of snowshoe hare prey, and possibly a consequence of exploitation by man and competition from the bobcat at lower elevations. Parker et al. (1982) state the following on the basis of their lynx study on Cape Breton Island, Nova Scotia: "Whether the decline in lynx densities was coincidental with the dispersion of bobcats (mentioned above in Section 2) or a direct result of that phenomenon is uncertain, although the evidence suggests the latter. Bobcat tracks were rare on our study area (namely the plateau, approximately 360 m, 1200 ft. in elevation) and normally restricted to the slopes of the plateau or near the escarpment. We suggest that deep winter snow cover is the reason bobcats have not yet colonized the plateau." The latter authors conducted limited experiments with the paws of lynx and bobcat carcasses to determine the supporting capacity of the paws. They found that lynx paws supported approximately two times the weight of bobcat paws under identical snow conditions (Parker et al. 1982).

In Colorado, a study to determine the status of the lynx (Halfpenny and (16) Miller, 1981) found that lynx activity was generally confined to elevations above 2730 m (9000 ft.). The latter authors state: "The elevational distribution of lynx in Colorado, past and present, appears to be above 2730 m (9000 ft.). Only 4 exceptions of 44 records and reports for which elevations are known occurred at lower elevations. While these exceptions are notable, there is little reason to believe lynx in Colorado existed to any great extent outside the elevational zone of spruce-fir forests (Halfpenny and Miller 1981). In the White Mountains of New Hampshire, an area which is ecologically identical with (17) the Adirondack High Peaks region (PLRA), a small population of lynxes still survives in the zone of stunted spruce-fir forest at elevations above 760 m (2500 ft.) and only rarely have lynx tracks been found (in snow) below that elevation (Lanier 1982, pers. comm.). It should be emphasized that the elevational preference of the lynx is probably a function of its close ecological association with spruce-fir forest and snowshoe hare prey, as I have implied previously. Where forest types are not divided along an elevational gradient, and where both the bobcat and lynx exist, the lynx tends to be found in boreal forest. For example, in the Beltrami Lakes section of Minnesota where both species are sparsely distributed, the lynx is associated with the more mature boreal type of forest, while bobcats are associated with deciduous-coniferous forest, whether it is disturbed or not (Berg 1982, pers. comm.). According to Berg (Op. Cit.), the boundary for resident lynx range in northern Minnesota is also the boundary for deep snow.

In the Adirondacks, information on the annual bobcat harvest, including data on the declining ratio of bobcats to coyotes taken annually by trappers between 1945 to 1980 (Fox 1982) suggests (1) that bobcats were not historically abundant in the state, (2) that apparent abundance of bobcats in the 1950s may represent an exception to the long term population level, (3) that populations have declined in recent years, and (4) that there has been a shift in the recent distribution of bobcats from centers of abundance in the central Adirondacks to current centers of abundance in the Indian River Lakes ecological zone (in the northwestern Adirondack region). Presumably the latter shift in population is out of an area of climatic severity, which experienced a significant decline in deer populations following the winters of 1970 and 1971 (For detail, the reader should refer to the report of Fox Op. Cit.).

Data for annual bobcat harvest densities show that bobcat harvests are low within the PLRA (Fig. 1). The mean of mean harvest density of 12 towns which are partially included in the PLRA is 0.11 bobcats/100 km^2 ± 0.02 ($\overline{X}$ ± SE, data for 1977 to 1982). The mean of mean harvest densities for 104 Adirondack towns

Fig. 1. Average bobcat harvest density (From Fox 1982. Final Report, W-105-R, Study XII, Jobs 1-4), showing the mean number of bobcats pelt tagged per 100 km^2 in each town during the period 1977 through 1982. Boundaries of the PLRA are shown. Harvest density within the PLRA is compared to that of the Adirondacks as a whole in the text.

outside the PLRA is 0.37 ± 0.03 ($\bar{X}$ ± SE). The difference between means is highly significant ($P < 0.0001$, Mann-Whitney U Test, $U = 213.5$, $z = 3.72$). Regarding the High Peaks area, Fox (Op. Cit.) states: "The Adirondack high peaks deserve special mention in relation to bobcat management. The harvest of bobcats from this area is and has been historically low. Reports of high bobcat densities in the Boreas Ponds area were unsubstantiated during two fall months of trapping and track searches of the area failed to reveal these animals. Of the carcasses we examined from this area, all were under two years of age, suggesting that they may have been animals that recently dispersed into the area. Telemetry data suggest that bobcats in the Adirondacks generally use lower elevations. For these reasons, we do not believe bobcats should be given a high management priority in the Adirondack high peaks area."

In sum, data from the bobcat study (Fox 1982) suggest that potential competition between the lynx and bobcat would be minimal at elevations above 600 m (2000 ft.), especially in the PLRA. Specifically, telemetered bobcats tended to confine their activities to elevations below approximately 600 m (2000 ft.). Bobcat harvest data indicate that bobcats are scarce within the PLRA, and probably absent from elevations above 760 m (2500 ft.). Food analysis and telemetry results show that bobcats are stressed by Adirondack winters, tending to prey on deer during the winter season. The inference that Adirondack bobcats depend on deer prey in winter is supported by harvest data (Fox 1982) indicating a decline in the central Adirondack bobcat population, especially in recent years. This decline coincides with the depression of deer populations in the central Adirondacks, following the severe winters of the early 1970s. It appears that lynx-bobcat competition for snowshoe hare prey in winter would not be critical at the lower elevations occupied by the bobcat. Whether there would be direct aggression and consequently mutual exclusion between the two species where the ranges of individual animals overlap is open to speculation. No hard data currently exist on this topic.

Finally, there is the question of potential competition between the lynx and other vertebrate predators. Interspecific competition between predatory species is difficult to observe under the best conditions, and few data exist on this point for any vertebrate predators. In Alberta lynx range, a shift to snowshoe hare prey away from other species has been reported for the great horned owl Bubo virginianus, red-tailed hawk Buteo jamaicensis (McInvaille and Keith 1974) and the coyote Canis latrans (Brand et al. 1976). But there is no suggestion that these species competed with the lynx for hare prey. If competition occurred, it was more likely during the low in the snowshoe hare cycle.

In the Adirondacks, the possibility exists that the coyote may indirectly favor potentially reintroduced lynxes by competing with the bobcat for deer prey. There is currently no direct evidence for such competition. However, the recent increase in coyotes, accompanied by a coincident decrease in bobcats in the Adirondacks (see bobcat-coyote harvest ratios, Fox 1982) supports the inference that such competition may have occurred.

It is unlikely that lynxes introduced into the PLRA would encounter any substantial interspecific competition within that area. The High Peaks spruce-fir forest is generally frequented by few wildlife species (Adams et al. 1920). The marten Martes americana is probably the only species which deserves consideration as a competitor. Throughout many sections of their range in North America, the marten and lynx are characteristic inhabitants of boreal coniferous forest (Shelford 1963). In the Adirondacks, the marten is closely associated with spruce-fir forest wherever it occurs, with the strongest population centered in the High Peaks region (Gebo 1976). The principal prey of Adirondack martens includes the boreal redback vole Clethrionomys gapperi and the red squirrel

Tamiasciurus hudsonicus (Gebo 1976). As noted in Section 1, the lynx is known to have occurred in the High Peaks during the late 1800s. Additionally, Adams et al. (1920) make note of Colvin's (1880) observation of lynx tracks near Lake Tear. The marten has probably always inhabited the High Peaks and there is little reason to doubt that the two species coexisted there until the late 1800s.

SECTION 4. VULNERABILITY TO HUMAN EXPLOITATION.

Research on lynx biology and behavior has been largely conducted in Canadian range where populations are extensive and cyclic. There is little information about lynx biology and behavior in small, isolated populations as the Adirondack population would be, were it to become established. Therefore, available information on the lynx must be interpreted with caution and conservatism.

The lynx appears to have behavior traits which make it particularly vulnerable to man. Seton (1909) wrote: "This animal is very easily caught by any of the usual forms of furtaking." On Cape Breton Island, Nova Scotia, the lynx is much more easily trapped than the bobcat (Parker 1982, pers. comm.) and unlike the bobcat, is often not fearful of man. Indeed, it is often so mild mannered that trapped animals can be handled without tranquilization (Parker Op. Cit.). Commenting on a lynx invasion of Minnesota in the early 1970s, Mech (1973) wrote: "Most of the lynxes reported have been relatively unafraid of human beings, lending farther credence to the hypothesis that they have ventured into settled areas from the Canadian wilderness. They have been approached to within 5 ft. (1.5 m) on occasion and have attacked dogs and domestic fowl in daylight and in front of human beings. Generally, lynxes that have been examined have had little or no tooth wear and appear to be in excellent physical condition."

On Cape Breton Island, Nova Scotia, the lynx population is essentially limited to Cape Breton Highlands National Park, with limited road access. Parker et al. (1982) estimated that a minimum of 11 lynxes used their telemetry study area (60 km^2, 23 mi^2). Allowing for unidentified lynxes, they estimate a lynx density of 20 lynxes/100 km^2 (52 lynxes/100 mi^2). A total of 13 lynxes were removed from their study area by public trapping the following winter.

Assuming that the population was stable, trapping removed 65% of the population (Parker et al. Op. Cit.), suggesting that these lynxes were very susceptible to trapping pressure. According to the latter authors, their trapping pressure was higher than normal and their estimated lynx density is among the highest recorded anywhere (See Table 9, Section 2).

The lynx harvest and causes of lynx mortality in Minnesota from 1930 through 1976 were analyzed by Henderson (1980). Her paper is of considerable interest, even though the majority of lynxes taken in Minnesota are invaders from Ontario and Manitoba during years of cyclic lynx abundance. During that period, her estimates of the total annual lynx harvest range from 0 (1950, 1975 and 1976) to 691 (1973), with a 47 year annual mean of 177 lynxes, and a total of 8342 lynxes taken over 47 years. Over this same period, pelt values ranged from $0.89 (1939) to $162.00 (1976) and bounty values ranged from $7.55 (1953) to $15 (1964), the last year when bounties were paid. Henderson (Op. Cit.) estimates that trapping accounted for 81.4% of known lynx mortality during cyclic lows and 57.9% of known lynx mortality during cyclic highs.

Data were collected on lynx occurrences by the Minnesota D. N. R. and L. D. Mech during a period of lynx irruption from 1971 to 1974 (Henderson 1980). Of a total of 167 lynxes known to have been killed by man, 4.2% were highway kills. The cause of death for 121 of the remaining animals was learned as follows (Henderson Op. Cit.): 48% were trapped, 15% shot by grouse hunters, 18% shot around residences and the remainder shot by deer hunters and others. During the period when these statistics were being collected (and before) the lynx was an unprotected species. In 1975, the status of the lynx was changed from an "unprotected species" to one with a legal season. During the 1977-78 season, lynx could be taken from December 1 to January 31 only, throughout the state by gun, bow or trap; there was a season possession limit of 5 lynxes per person and all lynxes had to be tagged and registered with the Minnesota DNR (Henderson Op. Cit.). It should be noted that the DNR's harvest strategy was to protect the resident lynx population along the northern fringe of Minnesota (actually largely protected by inaccessibility) and utilize lynxes moving into the state during cyclic highs. In other words, the strategy has not been one of expanding lynx range southward, which seems impractical because of range accessibility. In the 1979-80 season, the registered total harvest was 40 (Berg 1982, pers. comm.). In the 1981-82 season, most of the eastern Minnesota range was closed to lynx harvest.

The overwhelming influence on lynx distribution in Minnesota is trapping, in the opinion of Mech (1982, pers. comm.). At the Feb. 1982 price of up to $300 per lynx pelt, trappers will kill essentially every lynx that is accessible, even though the current season (1981-82) is only 10 days in Minnesota. Illegal trapping is not uncommon. Lynxes have not become established in land penetrated by roads (essentially most of Minnesota) even though lynx invasions occur regularly. If it weren't for trapping, lynxes would have become established in the currently logged boreal zone; accessible by roads, but where there are few if any bobcats (Mech Op. Cit.).

A case of an apparent overharvest and consequent decline of a small lynx population occurred in New Hampshire. The New Hampshire lynx population is contained in an area of approximately 1900 mi^2 (4940 km^2) in the White Mountain National Forest (interpreted from Siegler 1971). The trend in harvest densities, computed from the data of Siegler (1971) are given in Table 11. By comparison, the bobcat harvest density for 114 northern New York towns for the years 1977-78 to 1981-82 is 0.35 ± 0.03 bobcats taken/100 km^2 ($\overline{X}$ ± SE). An approximation of Adirondack bobcat density for the period is 2.3 bobcats/100 km^2 (Fox 1982). It is clear that this population was exploited almost to the vanish-

Table 11. Lynx harvest densities in New Hampshire, computed from the data of Siegler (1971). Harvest densities are expressed in terms of lynx range given by Siegler in Fig. 1 of his report.

Period	Lynxes Harvested	Mean Annual Take	Harvest/100 km^2 of lynx range
1931-35	108	21.6	0.44
1936-40	65	13.0	0.26
1941-45	7	1.4	0.03
1946-50	26	5.2	0.10
1951-55	10	2.0	0.08
1956-60	9	1.8	0.04
1961-65	5	1.0	0.02
1966-70	0	0.0	0.0

ing point. Apparently, a few lynxes still exist at this writing (perhaps five animals) in a 10 to 15 mi^2 corridor between two peaks (Lanier 1982, August, pers. comm.). An attempt was made to protect the species at a very late date. According to Siegler (Op. Cit.): "In 1965 we were able, however, to convince the Legislature that the Canada Lynx was a rare and endangered species. Since then, this animal is off the wanted list. --- Due to our concern for this animal, we negotiated an agreement with the Supervisor of the White Mountain National Forest in 1964 to deny trapping permits for the taking of lynx. This is still in effect." At the current price of lynx pelts, it is probable that the occasional lynx caught in sets for other species was not reported. In my opinion, it is remarkable that this lynx population has done as well as it has under the circumstances.

The overharvest of lynxes on occasion in Canada has been recognized (DeVos and Matel 1952). Attempts to correct overharvest by regulation have met with varying degrees of success. For example, the latter authors state (DeVos and Matel Op. Cit.): "Some provinces have realized the possibility of overtrapping and have established closed seasons. Unfortunately, a closed season cannot prevent the accidental trapping of lynx, but it may result in some decrease in the number caught.--- Lynx trapping was closed in Ontario during the trapping season 1951-52. The season was not very effective as the accidental catch was high (182 as compared to a legal catch of 462 in 1950-51). It has been suggested that a quota system be established in part of the province to remedy this condition." Related problems in the regulation of the bobcat season to influence harvest are discussed by Fox (1982). The bobcat, like the lynx, is a species frequently caught in trap sets for other mammals. Closing the season, without any other special provisions to encourage lynx population growth may create its own special problems. In Colorado, the lynx was classified as endangered with the following result (Halfpenny and Miller 1981): "Farther documentation of lynx occurrence will be extremely difficult. Paradoxically, part of the reason for this is because of legislation and statutes intended to protect the species. Nearly all recent (post-1969) evidence of lynx has resulted from trapping and hunting. Since 1973, however, lynx have been classified as endangered and the taking of a lynx can result in a fine of one thousand dollars and or 30 days imprisonment---. Therefore, it is unlikely that even lynx taken accidently will be reported."

Wherever the lynx occurs in North America, it appears to be vulnerable to human exploitation. Given the long tradition of public trapping and hunting on the continent, and a tendency by a significant fraction of the public to break wildlife laws, the demise of the lynx is virtually assured where road access is good. It is clear that the lynx has managed to survive only in those areas that are minimally accessible by road or are topographically rugged. Such areas function as refugia and still harbor lynx populations, as for example Cape Breton Highlands National Park, the Boundary Waters Canoe Area, high elevations in the White Mountains and Colorado Rockies, and the Canadian boreal forest wilderness. From the standpoint of inaccessibility, conditions in the PLRA would favor lynx restoration (See Maps No. 1 and 3). Almost the entire PLRA is Forest Preserve land classified as Wilderness by the Adirondack Park Agency. No roads for motorized vehicles are permitted in this classification; access is via established hiking trails only. The area is topographically rugged and the snows come early, discouraging most trappers. Deer and grouse densities are low in most sections of the PLRA, especially at higher elevations. Hence, hunters pose a minimal threat to reintroduced lynxes unlike the Catskill area where a significant number of bobcats are taken incidentally by deer hunters (Fox 1982). In short, if lynxes were to be introduced, the biggest management challenge would be to minimize the impact of trapping within the PLRA.

SECTION 5. SURVIVAL AND RESTORATION OF THE LYNX _Lynx lynx_ IN EUROPE.

Superficially, the European Lynx _Lynx lynx_ resembles its North American counterpart. However, there are important differences. The European species weighs about 22 kg. (24 kg. mean weight, for males and 20 kg. mean weight for females), which is approximately twice the mass of _Lynx canadensis_. While the snowshoe hare is the principal prey of the latter species, the European lynx feeds on a wide variety of species including roe deer, red deer, chamois, wild boar, European hare, snow hare _Lepus timidus_, grouse and other species (Kempf 1978). The diet of the European lynx reflects the great adaptability of this species to local prey availability, ranging from a diet of 72% snow hares in Finland to 52% roe deer in eastern Europe (Kempf 1978).

Another important difference is that the lynx is presently the only large wild predator in most of its European range (Cop 1977, Schröder 1981 pers. comm., Schwarz 1981 pers. comm.), a range historically shared with other large predators. Hence, the lynx experiences little competition for prey and space, except from man. However, there are enough similarities between these two species to warrant a brief consideration of the recent recovery and restoration of the European lynx. The following summary is based on the literature, unpublished notes and my observations in eastern Bavaria.

The lynx was largely eliminated from most of Western Europe, except for isolated pockets (Kratochvil and U. and H. Wotchikowsky 1978). With the benefit of legal protection, the lynx has made dramatic natural recoveries during the last two decades, expanding its range in Norway, Sweden, Finland, Yugoslavia and sections of eastern Europe (Kratochvil and U. AND H. Wotschikowsky 1978).

Reintroductions of the lynx have been attempted in various European locations formerly occupied by the lynx namely in Italy, Austria, France, Switzerland, Yugoslavia and West Germany. Two lynx reintroductions have been successful (Schröder 1981 pers. comm.) namely (1) in Switzerland in an area with a fairly dense human population, and (2) in Yugoslavia where excellent population expansion has occurred. In Yugoslavia , 3 male and 3 female lynxes were initially released. This nucleus increased to about 16 animals in 3 years, occupying an area of about 230 mi^2 (60,000 ha). Lynx kills in the area included 44 roe deer and 12 red deer (Cop 1977). The Yugoslavian reintroduction was successful apparently because of good planning and an attempt to develop broad popular support through a media campaign. (Cop 1977).

Reintroductions that were unsuccessful include one at Gran Paradiso National Park in the western Alps of northern Italy and one in the Nationalpark Bayerischer Wald in Bavaria, West Germany. The former attempt, first planned in 1971 (Holloway and Jungins 1973), subsequently failed for the following reasons (Schroder 1979, pers. comm.): (1) Alpine valleys were densely peopled, interfering with lynx survival; (2) there was a general lack of roe deer prey, the principal prey of the European lynx. Although the lynx also preys on cham- and ibex (present in the area), these species are more difficult to capture; (3) released lynxes moved as much as 60 km, suggesting the lack of some requirement in the habitat (Schröder 1981, pers. comm.).

The second case of apparent failure occurred in the Nationalpark Bayerischer Wald, a moderately large park in eastern Bavaria, West Germany, adjacent to the Czechoslovakian border. I visited this area on October 7, 1981 with Dr. Wolfgang Thiele, Assistant Director of the park and Herr Schwarz, the forester-biologist charged with recording and verifying lynx observations. This area, north of the village of Zwiezel, is ecologically very similar to the Adirondack region. The soils are acid, forested with a mixture of deciduous species, including beech and maple, as well as conifers such as spruce and fir.

A history with some detail of the Bavarian lynx reintroduction is as follows: In 1970, 9 lynxes of undetermined sex and age were purchased and illegally released in the Nationalpark Bayerischer Wald (termed the Park from here on) by a private conservation group. As the release had not been legally executed, the State of Bavaria could not openly support the reintroduction. The State could not give the lynxes legal protection, nor could it launch an education program to minimize illegal lynx killing. However, the State was not opposed to the reintroduction and assigned forester Schwarz to observe and record the fate of the lynxes.

Soon after their release, the lynxes moved 25 km to new range centering on Mount Falkenstein (Fig. 2) within the Park, approximately 1300 m in elevation. The top of this rugged mountain resembles many Adirondack peaks, although the conifers are not as stunted because of less severe winter conditions and lesser snow depths. It is interesting that this mountain was the last known German location occupied by lynxes 150 years ago (apparently the conservation group which made the release was unaware of this fact). A similar pattern of movement by reintroduced lynxes to their historical stronghold has been observed in Switzerland (Schwarz 1981, pers. comm.).

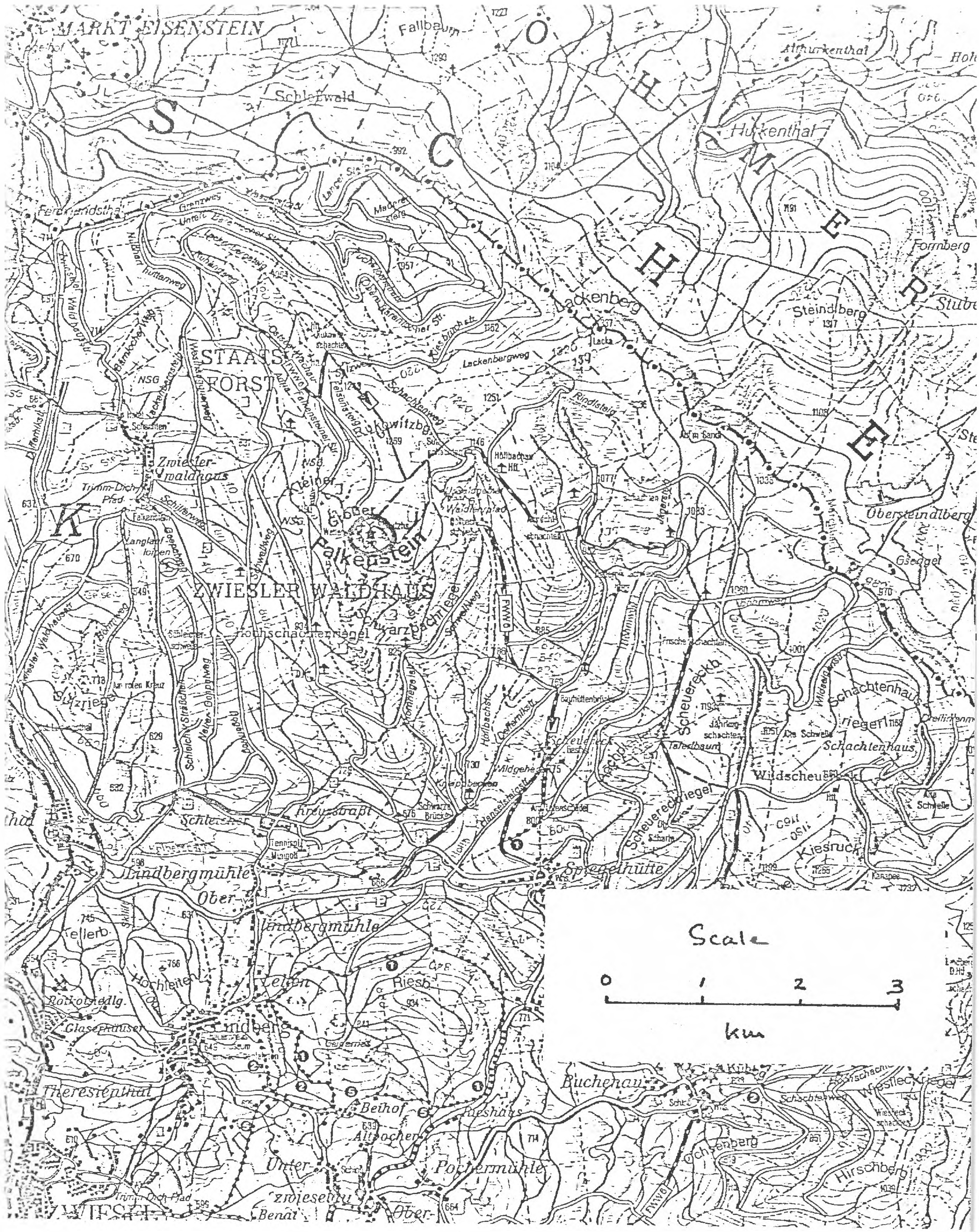
The released lynxes tended to concentrate their activities in the rocky intermediate elevations of Mount Falkenstein between 800 m and 1100 m, making hunting forays to lower elevations (Schwarz, 1981, pers. comm., observations based on snow tracks). Lynxes often hunted well below 800 m on the lower slopes, concentrating their predation around roe deer feeding stations in winter. It should be noted that the mountainsides are laced with truck trails, used for logging operations (Fig. 2). Villages surround the mountain and the Park; commercial and recreational use of the area is heavy.

A chronology of events in the Bavarian lynx reintroduction is given in Table 12. Evidence of reproduction was observed in 1974, 1975, 1977 and 1978 (Table 12). Although there were 12 sightings of lynxes in the 1978-79 season (Schwarz 1982, letter to the writer), the number of yearly sightings has declined steadily since the mid-1970s, Schwarz was of the opinion that this lynx colony, currently estimated at less than 5 animals, was below the threshold

Table 12. Chronology of events in the Bavarian lynx reintroduction, according to the notes and personal account of Mr. Schwarz. Nine lynxes were released in 1970.

	Observations and Comments	
Year	Evidence of Reproduction	Evidence of loss
1971	---	Adult lynx killed in Park; had commonly frequented a roe deer feeding station.
1972	---	1. Young lynx killed by auto. 2. Lynx killed by hunter outside Park.
1974	1. Two young lynxes seen by Schwarz in Park. 2. Two young lynxes caught in a chicken coop and released.	1. Lactating female killed by auto. 2. Female killed outside Park by hunter in Czechoslovakia.
1975	Two young lynxes seen in Park.	Badly injured lynx was found which had tried to kill a red deer stag. This animal probably died.
1977	Three young lynxes were seen.	A starved lynx was found next to a ski run.
1978	1. Three young lynxes seen with female. 2. Two young lynxes seen with female (probably the same family).	--- ---

Figure 2. Location of the reintroduced lynx population in eastern Bavaria. The population was centered on Mount Falkenstein and extended to the more densely populated valley below, and into Czechoslovakia (top of map).


MARKT EISENSTEIN
Fallbaum
Schleewald
Hurkenthal
Lackenberg
Steindlberg
Formberg
Ferdinandsthal
Grenzweg
Lackenbergweg
STAATS FORST
Zwiesler-waldhaus
Trimm-Dich-Pfad
Großer Falkenstein
ZWIESLER WALDHAUS
Hochschachtenriegel
Schwarzbachriegel
Rindlstein
Auf'm Sand
Obersteindlberg
Gsteigel
Scheuereckb.
Scheuereckriegel
Schachtenhaus
Wildscheuer
Kiesruck
Spiegelhütte
Kreuzstraßl
Schleicher
Lindbergmühle
Ober-
Kellerb.
Hochleiten
Rotkotnedlg.
Glashäuser
Lindberg
Theresienthal
Riesb.
Beihof
Rieshaus
Altbacher
Unter
Pochermühle
Buchenau
Ochsenberg
Hirschberg
Wieslec-Kriegel
Benat
Ober-
Scale
0
1
2
3
km
S
C
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R
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Ö
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K

Figure 3. Sticker to encourage lynx restoration, distributed by Die Wildbiologiske Gesellschaft München. Literal Translation: "Let the lynx return".


wiederkommen

required for survival.

Probably the most important prey species in the lynx's diet in eastern Bavaria are roe deer and red deer. Lynx kills found and verified by Schwarz (1981 pers. comm.) included 7 red deer (usually fawns or yearlings) and 33 roe deer in one year. In the winter of 1980-81, 5 red deer kills were found in addition to roe deer. These were reported kills; no effort was made to search for lynx kills. Schwarz estimated that the annual kill of 5 lynxes in the mid-1970s was approximately 100 deer (largely roe deer).

The principal reason for the apparent decline of the reintroduced lynxes was deliberate killing of lynxes by hunters in the late 1970s.(Schwarz 1981, pers. comm.). The problem stems from the lynx's perceived predation on deer. As the lynx is the only predator of large size and the evidence of its kills distinctive (tooth marks on the throat), lynx kills are rarely misidentified. In the early years following lynx reintroduction, there was generally a high level of cooperation by local hunters in reporting lynx kills (Schwarz 1981, pers. comm.). With the progression of time, cooperation in reporting kills declined and apparently, illegal killing of lynxes increased. According to Schwarz (pers. comm. 1981), the decreased level of cooperation was due to a large extent to the economics of the Bavarian hunting system and leasing of hunting tracts. Under the Bavarian system the hunter is allotted a fixed number of deer to be shot under his shooting plan. However, each lynx kill is equivalent to a hunting kill and is deducted from the allowable harvest. This not only reduces the legal harvest for the hunter-lessee, but as each lease is expensive ($20,000 to $30,000 is not unusual), a lynx-killed deer represents a large economic loss to the hunter. An obvious and illegal solution was not to report lynx kills and illegally kill lynxes. In Schwarz's opinion, the latter occurred with increasing frequency in recent years, judging from anonymous reports and reports of third parties. A possible solution to this problem is payment to hunters for losses incurred by lynxes. Such a system has been instituted elsewhere in Europe to offset stock losses attributed to predation by the European brown bear.

Under the circumstances, it is remarkable that this reintroduced lynx population survived as well as it did. On the positive side, the lynxes benefited from (1) a concentrated food source, (2) lack of competition from other predators, (3) apparently good habitat on and around Mount Falkenstein, and (4) some restraint of hunters in killing lynxes during the early 1970s. On the negative side, the following factors apparently caused the decline of the reintroduced lynx population in eastern Bavaria:

1. There was (apparently) no preconveived plan to reintroduce ideal social groupings or sex ratios.
2. A plan was not in place to monitor lynx movements, habitat choices, and range dimensions through telemetry.
3. As the reintroduction was illegal, the State could not confer legal protection to the lynxes.
4. As the reintroduction was illegal, the State or private conservation groups could not mount a media campaign to foster lynx survival.
5. As the reintroduction was illegal, a legal mechanism to economically reimburse hunter-lessees for deer losses was not in place.

Finally, some observations of Dr. Wolfgang Schröder on reintroduction procedures which have proved to be successful in Europe (Schröder 1981, pers. comm.):

1. In successful reintroductions, 3 to 4 pairs of lynxes, including pregnant females, have proven to be enough if losses are minimal during the first year. Potential losses have to be taken into account; highway losses for example have averaged around 20 percent.
2. Lynxes for reintroduction have been successfully produced in colonies enclosed under semi-wild conditions in Sweden. Under

these conditions, it is important that the mother has the opportunity to teach the young how to hunt.

3. The public should be informed about a particular reintroduction through a media campaign. However, such campaigns should not impart too much information.

4. In Europe, the key to successful reintroduction is to involve the hunting public and elite in backing up the program. When conservation groups alone are the principal support, conflicts have developed between the hunting segment and conservationists (usually identified as preservationists in the U.S.).

5. Formation of an international coordination group with representatives (including Ministers) from all participating countries has proven successful.

SECTION 6. SYNTHESIS: RESTORATION OF THE LYNX IN ADIRONDACK PARK.

The central purpose of this study is to provide information that can serve as a basis for deciding whether lynx restoration in Adirondack Park is feasible. In the previous five Sections, a background of information was presented. In this Section, I shall offer my assessment of the feasibility of lynx restoration in Adirondack Park and briefly consider some biological dimensions of such a restoration.

There is one important question which is not clearly answered by the foregoing Sections, namely: Why did the lynx disappear from the Adirondack region in the late 1800s? Previous to this study, I believed that trapping alone could not have eliminated the lynx from the Adirondacks. It seemed that some other agent was responsible, possibly interspecific competition with invading bobcats. The following hypothetical scenario seemed likely: the bobcat, following hard on the heels of man, moved into the logged Adirondack forest, surviving on a newly created winter prey supply, the white-tailed deer (i.e. in numbers that could sustain bobcats). Even though it was not well adapted to a boreal environment, the bobcat could survive by its altered predatory behavior. As a consequence of its invasion, it displaced the lynx through interspecific aggression.

In his study on bobcat ecology, Fox (1982) has provided data supporting the first portion of the postulated scenario. However, his data also indicate that the bobcat probably never penetrated into the higher Adirondack elevations and therefore could not have displaced the lynx there. What agent eliminated the lynx from the Adirondack high country? On the basis of information presented above, I believe that trapping was responsible. It is clear that the lynx is extremely vulnerable to trapping and could have been eliminated by skillful trappers. During the last century, Adirondack woodsmen were a tenacious lot who derived their livelihood from commercial trapping and hunting, as well as guiding. These men were effective beyond the level of most trappers and hunters today, partly because they were not constrained by regulations. Hence they eliminated species such as the wolf and cougar, greatly decreased white-tailed deer populations in the early 1900s and practically eliminated the beaver from the Adirondacks. In view of the near-extirpation of the lynx in recent times by trapping in the rugged White Mountains, it is conceivable that trappers of the late 1800s eliminated the lynx in the Adirondacks. (24)

If lynx restoration were attempted in the Adirondack High Peaks region, what indications are there that the species would not be extirpated again from New York State? Of course, this possibility exists. However, I believe that there are a number of changed conditions in the socio-economic context which augur well for successful restoration. They include a movement away from a subsistence economy, more responsible behavior by hunters and trappers, the potential support of conservation organizations and a public that is more environmentally sensitive than ever before.

Synthesis

On the basis of information presented in Sections 1 to 5, I believe that restoration of the lynx is feasible in Adirondack Park, specifically in the area identified as the Potential Lynx Restoration Area (PLRA) in the High Peaks region (See Maps No. 1, 2 and 3. The area of the PLRA is 1738 km^2 or 671 mi^2). Specific reasons for my conviction that restoration is feasible are as follows:

1. The lynx was apparently resident in the eastern Adirondacks including the PLRA (High Peaks area) during the last century (See Sect. 1). The High Peaks area has remained relatively unaffected by man, compared to other sections of the Adirondacks. Hence, the potential problem of a changed habitat is not an issue (25)

in this case.

2. Environment, habitat and prey are ideal for lynxes, judging from the results of studies conducted elsewhere in North America. The mean elevation of the PLRA exceeds 900 m (3000 ft.); the PLRA is subject to long winters and heavy snowfall. Boreal spruce-fir forest is dominant (See Sect. 2). The snowshoe hare density is comparable to average hare densities in continental lynx range. The carrying capacity for the PLRA is estimated to be at least 70 lynxes, which is an acceptable lynx population level, in my opinion.

3. Data from the Adirondack bobcat study show that potential competition between bobcats and lynxes in the PLRA (mean elevation > 900 m, 3000 ft.) would be minimal. Bobcat activity was generally confined to elevations below 760 m (2500 ft.). Additionally, trapping harvest data indicate that bobcats are scarce in the PLRA (probably absent from higher elevations). There are few field observations relating to lynx-bobcat competition. However, a Nova Scotia study found that lynxes occupied a relatively inaccessible plateau while bobcats remained in adjacent lowlands. The chances for competition between other species in the PLRA, such as the marten, appear to be minimal (See Sect. 3).

4. The lynx is extremely vulnerable to human exploitation. It is easily trapped and appears to have been eliminated by trapping in most accessible areas of its former range. Survival of a restored lynx population would be enhanced by the 26 lack of access in the PLRA. This rugged area includes the largest continuous block of Forest Preserve Lands in Adirondack Park classified as Wilderness. Motorized traffic is excluded from these lands by definition (See Sect. 4). Established hiking trails provide the only access to the interior. In New Hampshire, inaccessibility of high elevation forest land in the White Mountain National Forest appears to have protected a small nucleus of surviving lynxes.

5. Some lynx restoration programs have been successful in Europe. Lessons

learned from both successful and unsuccessful European attempts can be applied to good advantage in the Adirondacks (See Sect. 5). Additionally, the expertise and personnel exist within the Bureau of Wildlife, N.Y.S. Department of Environmental Conservation to effectively implement a lynx restoration effort. The Bureau's existing liaison with trapper groups, conservation organizations, other public agencies and the public in general is more than adequate to encourage public cooperation.

It is not within the realm of this report to cover details of the implementation of lynx restoration, however, some biological dimensions of a restoration attempt are briefly outlined below.

Restoration: Some Biological Dimensions

It is clear that isolated lynx populations exist today in the Rocky Mountains and in the Northeast. Some of these populations, like the one in the White Mountain National Forest of New Hampshire, may be doomed (See Sect. 4). Others, like the population on Cape Breton Island, seem to be thriving. What is the minimum size for a lynx population in terms of population health, growth, and long-term survival? What is a minimum population in terms of genetic viability?

The genetic integrity of small populations is discussed by Miller (1979). Miller states that reduced variability is caused by (1) inbreeding, (2) genetic drift and (3) the "bottleneck" and "founder" effects. (The latter describes genetic changes which arise when a population is reduced to a fraction, or when a few individuals establish a new population). Miller (Op. Cit.) supports the view long held by biologists that inbreeding and bottleneck effects are negative to the genetic health of the population because they decrease heterozygosity. Inbreeding is known to cause neonatal deaths and increased frequency of malfunctions. Obviously, inbreeding is not popular among animal breeders who wish to save as many animals as possible. However, there is a new school of thought that inbreeding can be adaptive and a positive evolutionary force (Shields 1982). There is increased evidence from the field that inbreeding is a normal strategy among many species (Shields 1982, pers. comm., e.g. for the wolf and white-tailed deer). Miller (1979) cites an example of reduced heterozygosity of the northern elephant seal Mirounga angustirostris which was reduced to a remnant population of less than 100 animals, but now numbers 30,000 individuals. By contrast, the southern species Mirounga leonina shows high heterozygosity (one wonders why a population growth of 100 to 30,000 should be maladapted!). Miller himself gives the example of the golden hamster Mesocricetus annatus that was probably reduced to a single pair, yet no deleterious effects of this bottleneck are known. Recently, Lavigue et al. (Unpub. M.S.) measured the genetic variability in the Atlantic harp seals Pagophilus groenlaudicus. They found that this species exhibits a high coefficient of inbreeding (0.979) and low measures of heterozygosity. Harp seal populations are not known to have experienced a genetic bottleneck. Concerning the bottleneck and adaptability, Franklin (1980) states: "Even in the most extreme situation, when a population has been founded from a single pair, three quarters of the additive variance remains, which means that on the average, there is still an opportunity for an appreciable response." To maximize adaptive capacity of the reintroduced stock, lynxes for reintroduction should be as closely related as possible to the original stock, collected from an ecologically similar area (Shields 1982, pers. comm.). The subspecies canadensis (Hall and Kelson 1959) from Ontario or Quebec is probably the best stock. (While Newfoundland may have lynxes to spare, the subspecies on the island, namely subsolansis is different from the Adirondack race, namely canadensis). All sorts of combinations of numbers, sex and age have been tried in mustelid reintroductions (Berg 1981). In Europe, three to four pairs of lynxes have been successful in reestablishing a population, if losses are minimized during the first years (Schröder 1981, pers. comm.). A sex ratio of two females to one male has been suggested for a New York lynx reintroduction by Mech (1982 pers. comm.) and Berg (1982 pers. comm.). In my opinion, an appropriate combination for a single group, possibly introduced in two successive years is eight pregnant females and four males, introduced a few weeks prior to parturition.

We (Lloyd Fox and the author) have attempted to model the population growth of a hypothetical lynx reintroduction. The models are of very limited value because the basic data needed for modelling are scarce in some categories and absent in others. The problem is that most available data are for cyclic lynx populations, rather than stable ones. For example, Brand and Keith (1979) studied a lynx population in decline; thus many of their values are inapplicable for a stable population. For example, their observed survival rates are so low (Table 8, Op. Cit.) that they predictably cause a modelled population to decline. We present the models here for the limited insight they offer.

Various parameters assumed for the models are given in Table 13. The adult annual survival rate of 0.789 was computed from a graph based on the estimated lynx age distributions given by Brand and Keith (1979, Table 7). All other survival rates given in Table 13 are subjective estimates. Reproductive rates for all models are based on the data of Parker et al. (1982). A computer program was developed by L. Fox using the Leslie Matrix (Lescore Program). No losses to emigration were assumed. All reintroduced lynxes were assumed to be two years old; lynxes were reintroduced in groups of 12 including eight pregnant females and four males. Hence, the effective genetic strength per introduced group is approximately equivalent to eight lynx pairs.

The results are given in Table 13. Model A shows a slightly greater growth rate than Model B, reflecting the assumed greater yearling survival rate, but

Table 13. Assumptions and results for models of reintroduced lynx populations. Assumptions are based on published information and subjective estimates (see text).[1]

Model	Year of Introduced Group[2]	Survival rates		Total population for year			
		Yearlings	Adults	4	6	8	10
A	1	0.65	0.65	25	31	38	45
B	1	0.40	0.789	26	30	35	38
C	1 and 2	0.40	0.789	48	60	72	86
D	1 and 3	0.40	0.789	47	56	66	74

[1] Reproductive rates for all models are:
0.34 females/yearling female/year and 1.27 females/adult female/year.
Kitten survival rate for all models is 0.50.

[2] Lynx groups introduced consist of 4 adult males and 8 pregnant adult females, all 2 years old.

apparently compensated in part by reduced adult survival rate. Introducing groups of lynxes in the first and third years appears to be preferable (Model C), although the population growth rate of Model C is not much greater than that of Model D. In general, the results of these models have limited predictive value because the actual age specific survival rates are not known for the PLRA.

A list of reintroduction procedures which may maximize the success of a lynx restoration effort are given below. These are inferred from the recommendations of Berg (1981), the European experiences given in Section 5, and other sources.

1. Lynxes should be trapped in the same general area to preclude outbreeding depression. Female lynxes should be trapped after the general period of local impregnation and introduction might best be conducted shortly before parturition.
2. To insure the good condition of introduced lynxes, trappers should be carefully selected. Box trapping is the method of choice, although frequently checked leghold traps or foot snares may produce acceptable results.
3. Staging areas at both ends of the trip should be established where captured lynxes are well fed and cared for. Transportation should be as rapid as possible. Lynxes should be held in dark, comfortable cages to minimize activity.
4. Lynxes should be "slow released" to acclimate them to release sites. Release areas should have a supply of snowshoe hare carcasses scattered in the immediate vicinity. Feces and urine from holding cages should be collected and identified as to individual. These can be scattered (as compatible with known social behavior patterns) in release sites.

5. Release sites for individual females and for individual males should be adequately spaced; overlap of male and female ranges is not a problem. Apparently female lynxes tolerate range overlap (Mech 1980), unlike Adirondack bobcats (Fox 1982).

6. Predetermine criteria for success and monitor the reintroduction using telemetry and lynx sign. Integration of a contracted research effort to evaluate and report the results of the restoration effort is advisable.

7. Movements of lynxes introduced first should be closely monitored. The second introduction in a succeeding year should be implemented in the general area where the original lynxes concentrate most of their activity. Reintroduced European lynxes have been found to move to new areas of their choice. Obviously, care should be taken in successive reintroductions (by checking field sign) to minimize crowding.

RECOMMENDATIONS

On the strength of the information and the analysis presented above, I recommend the following to the New York State Department of Environmental Conservation, Bureau of Wildlife:

1. Implement a lynx restoration program in the Adirondacks on the basis of this report. Details of this program might be jointly developed by Bureau biologists of the Endangered Species Unit, Furbearer Unit and Adirondack Regions.

2. Contract a lynx restoration research program to be conducted jointly with the D.E.C. implementation program. Such a research program will contribute crucially to the implementation program itself and provide vitally needed scientific information on lynx restoration.

3. Solicit the full cooperation of the New York State Conservation Council, Adirondack Furtakers, New York State Trappers Association and other appropriate conservation groups. Conduct a public campaign of education by all possible media outlets including the Conservationist, newspaper articles, radio and T.V. spots and bumper stickers, etc. The lynx is a relatively uncontroversial predator, compared to most other predatory species. I believe that a lynx restoration effort by DEC would be favorably received by the public in general, as well as by trappers, hunters and conservationists, both in New York State and throughout the nation. Indeed, I believe that the proposed lynx restoration program would enhance the DEC's image in the public eye, whether the effort succeeds or fails.

4. My limited perspectives preclude offering detailed recommendations on regulations. However, a few comments are in order. Past experience (cited in Section 4) has shown that highly restrictive and punitive regulations are counterproductive, alienating segments of the public and stopping the flow of information. General closure of the High Peaks region to trapping may not be advisable. A possible alternative is to conduct trapping in the PLRA by permit and registered traplines. It may be possible to regulate the intensity of trapping by this procedure. There are pros and cons to declaring the lynx an endangered species. Whether it is declared endangered or not, a small reward for turning in carcasses of accidentally trapped lynxes may be effective. A time limit for submission of carcasses should be liberal. Beyond the time limit, prosecution can be sought. Trapper organizations will probably cooperate fully if the possibility for a limited lynx season in the future is left open. Ear tattooing of released lynxes is advisable to discourage pelt sale and encourage carcass submission.

5. It would be advisable to restore lynxes using 2 separate releases. The question is, should these releases occur in Year 1 and 2 of the program, or in Year 1 and 3? An advantage of the latter approach is that more information can be obtained on the survival and breeding of the first group before the second group is released. An advantage of releases in Year 1 and 2 is that the integrity of frameworks for trapping, holding, moving and releasing can be more easily maintained. On balance, I would recommend releases in 2 successive years of the restoration program.

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