INFORMATION TO USERS

This manuscript has been reproduced from the microfilm master. UMI films the text directly from the original or copy submitted. Thus, some thesis and dissertation copies are in typewriter face, while others may be from any type of computer printer.

The quality of this reproduction is dependent upon the quality of the copy submitted. Broken or indistinct print, colored or poor quality illustrations and photographs, print bleedthrough, substandard margins, and improper alignment can adversely affect reproduction.

In the unlikely event that the author did not send UMI a complete manuscript and there are missing pages, these will be noted. Also, if unauthorized copyright material had to be removed, a note will indicate the deletion.

Oversize materials (e.g., maps, drawings, charts) are reproduced by sectioning the original, beginning at the upper left-hand corner and continuing from left to right in equal sections with small overlaps. Each original is also photographed in one exposure and is included in reduced form at the back of the book.

Photographs included in the original manuscript have been reproduced xerographically in this copy. Higher quality 6" x 9" black and white photographic prints are available for any photographs or illustrations appearing in this copy for an additional charge. Contact UMI directly to order.

UMI

A Bell & Howell Information Company
300 North Zeeb Road, Ann Arbor, MI 48106-1346 USA
313/761-4700 800/521-0600

Reproduced with permission of the copyright owner. Further reproduction prohibited without permission.

LYNX AND COYOTE DIET AND HABITAT RELATIONSHIPS DURING A LOW HARE POPULATION ON THE KENAI PENINSULA, ALASKA

A

THESIS

Presented to the Faculty
of the University of Alaska Fairbanks
in Partial Fulfillment of the Requirements
for the Degree of

MASTER OF SCIENCE

By

Winthrop R. Staples III, B.A.

Fairbanks, Alaska

December 1995

UMI Number: 1376793

UMI
300 North Zeeb Road
Ann Arbor, MI 48103

LYNX AND COYOTE DIET AND HABITAT RELATIONSHIPS DURING A LOW HARE POPULATION ON THE KENAI PENINSULA, ALASKA

By

Winthrop R. Staples III

RECOMMENDED:

S.F. MacLean

E.H. Follmann

Theodore N. Bailey

Frederick C. Dean
Advisory Committee Chair

R. Terry Bowyer
Department Head

APPROVED:

Paul B. Reichardt
Dean, College of Natural Sciences

R. Kan
Dean of the Graduate School

Oct 27, 1995
Date

ABSTRACT

Food habits and habitat use of lynx and coyote were compared 1987-1991 on the Kenai Peninsula, Alaska when the snowshoe hare population was low (< 0.5 hares/ha). During snow seasons, lynx fed primarily on hares (64% total items), whereas coyotes relied heavily on moose carcasses (42% total items). Diet overlap was 42% and hare use overlap was 16%. Habitat use overlap was 92%, but coyotes used roads more than lynx. Both carnivores selected 1947 burn and avoided 1969 burn and large expanses of mature forest. I conclude that there was exploitation competition for food between these predators, because both used the same habitats and hares, a major food, were scarce. The coyote, however, may be using resources that were previously used by red fox, which have been reduced to low levels. Lynx displayed little fear of humans and were vulnerable to shooting incidental to hunting and depredation events.

TABLE OF CONTENTS

LIST OF FIGURES

Figure **Page**

LIST OF TABLES

LIST OF APPENDICES

Appendix **Page**

ACKNOWLEDGMENTS

I dedicate this work to the memory of David Burnett Dunn, an extremely ethical and dedicated wildlife biologist who worked on the 1992-1994 phase of the Kenai lynx study. This study was funded by the U.S. Fish and Wildlife Service and supported by managers D. W. Doshier and M. B. Hedrick of the Kenai National Wildlife Refuge. The overall lynx study was conceived and directed by T. N. Bailey, who provided instruction in field techniques, and continual advice and encouragement. E. E. Bangs provided excellent training in trapping theory and techniques. B. Richards and S. Richards provided invaluable volunteer veterinary care of injured study animals, necropsies of study animals, recommendations for reducing capture injuries and advice about immobilization drugs and their use in field situations. I extend a special thanks to pilot W. W. Larned who did most of my flying for aerial locations and mortality recoveries. I also thank pilots R. A. Richey and R. K. Johnson for their assistance. My army buddy C. Kelso deserves credit for much of my success in the field because of his advice in the "field crafts". Field assistants on the project were A. Loranger, I. D. Martin, L. Tutterow, T. B. Hall, L. Juul, T. V. Schmacker, E. W. Weiss, A. Crampton, R. McAvinchey, L. Jozwiac and P. Buckelew. Data on snowshoe hare capture were collected for this project by S. Lindahl, S. Ribbe, S. Najera, S. Harris and C. Pendergrass. J. C. Malloy of the University of Montana analyzed hare grid data and determined density estimates reported in this paper. I also thank E.

O'Guinn for trap repair/modification and vehicle-maintenance support. D. King and R. Reeves contributed greatly through their volunteer hound capture of study lynx and the use of their hounds "Digger", "Susie", "Andy" and "Lisa". I also thank the Soldotna section of the Alaska Department of Fish and Game, specifically D. Johnson, C. C. Schwartz, T. Spraker and K. J. Hundertmark, for their cooperation, assistance and relaying of observations on resident lynx and depredation complaints. I thank B. Boyle, H. Saccone and B. Platte of the Region 7 Headquarters of the U.S. Fish and Wildlife Service for their training and assistance in regard to the ARC\INFO GIS system. I extend my appreciation and respect to Kenai Peninsula trappers and predator callers, who used excellent technique and restraint while complying with the lynx trapping closure during the Kenai Lynx Study. I also thank the residents of Sterling and Soldotna, Alaska, for reporting lynx observations and their patience during depredation periods. Specifically, I thank Kenai residents Mr. and Mrs. Dornberger, the Poage family, Mr. and Mrs. Burns, Mr. and Mrs. Rhoades and Mr. and Mrs. Bowman for their hospitality and cooperation during our investigation of their depredation events. I also wish to acknowledge R. B. Weeden, D. R. Klein and D. R. Guthrie for their contributions to the formation of my wildlife ethic and desire to search for "grand themes" in the natural world.

Finally I wish to thank the members of my graduate committee Frederick C. Dean, Erich H. Follmann, Stephen F. MacLean and Theodore N. Bailey for their patience, advice and review of this thesis.

1. INTRODUCTION

Fossil remains of coyote (*Canis latrans*) have been found at Rancholabrean era (8,000-500,000 years ago) sites in Alaska and Alberta (Kurten and Anderson 1980, Nowak 1978). Nowak (1987), however, has written that these populations were small and highly cyclic and that coyotes were distributed mainly in the western one-half of North America between the end of the Rancholabrean era and the colonization of the continent by Europeans. Young (1951) stated that the coyote was strictly an animal of the open plains prior to alteration of ecosystems in North America by Europeans. In historical time coyotes were first reported in southeastern Alaska in 1889 (Sherwood 1981), in south-central Alaska in the 1920's (Young and Jackson 1951) and on the Kenai Peninsula in 1925 (Thurber and Peterson 1991). Lynx (*Felis lynx*) and coyote therefore may not have evolved the dietary niche separation observed between bobcats (*Felis rufus*) and coyote in the American southwest (Small 1971, Litvaitis 1981).

A study of northern bobcat-coyote niche relationships in Maine, an area recently colonized by coyotes, suggests that this felid-canid pair may compete for food in relatively simple northern ecosystems when resources are limited (Litvaitis and Harrison 1989). Snowshoe hares (*Lepus americanus*) comprise a major portion of lynx and coyote diets in subarctic ecosystems (Saunders 1963, van Zyll de Jong 1966, Nellis et al. 1972, Todd et al. 1981, Parker et al. 1983, Thurber and Peterson 1992). This suggests that exploitation competition for prey may exist between these predators during periods of low hare densities.

Management strategies for lynx now involve setting seasons in accordance with regional abundance of snowshoe hare (Stephenson 1987). Former studies dealing with food habits of lynx and population characteristics have been conducted only in inland sub-arctic ecosystems. Detailed studies of lynx food habits have not been conducted in more complex coastal sub-arctic ecosystems like the Kenai Peninsula. Although coyotes have colonized large areas in Canada, Alaska and the northern lower 48 states in the last century, no studies have been done to determine their effect on sympatric populations of lynx.

Wolves (*Canis Lupus*)(Peterson et al. 1984) and caribou (*Rangifer tarandus*) (Davis and Franzmann 1979) were extirpated from the Kenai Peninsula, Alaska in the early 1900's. Other wildlife populations on the insular Kenai Peninsula also may be similarly vulnerable to overharvest or increased natural mortality. Because of reduced lynx numbers during periods of low hare abundance (Nellis et al. 1972), lynx may be particularly vulnerable to severe population reduction or extirpation due to overharvest, other mortality factors or competition from coyotes on the Kenai Peninsula.

A long-term study of lynx ecology on the Kenai National Wildlife Refuge (KNWR) located on the Kenai Peninsula, Alaska was initiated in 1983 by Bailey et al. (1986). They determined that lynx had been overexploited on the Kenai Peninsula during the 1970's and that the lynx population did not recover despite abundant prey and habitat during the 1983-84 high in hares. Lynx were vulnerable to trapping in accessible areas. Mortality of radio-collared lynx, mostly due to trapping, was

90% during 1982-84. Bailey concluded that trapping may need to be curtailed for up to 5 years in highly accessible areas to protect viable breeding populations of lynx during periods of low hare densities.

The Kenai lynx study was continued by Kesterson (1988) from September 1984 to May 1987. He reported that lynx numbers increased 4-fold, even during a period of declining hare densities, after a trapping closure beginning in the winter of 1984-85. He also determined that home range size of male and female lynx decreased as lynx densities increased. Lynx appeared to prefer mid-successional habitat in areas burned in 1947 and to avoid areas of mature forest. Analysis of a sample of 40 scats showed that lynx primarily consumed hares during the 1984-87 winters, a period when snowshoe hares were relatively abundant.

In January, 1988, I began further studies on the KNWR to monitor lynx density, recruitment and mortality and to determine how dependent Kenai lynx are on snowshoe hares during a hare population low. I also documented the food habits of Kenai coyotes to determine if coyote use of local food resources reduces the ability of the Kenai Peninsula to support lynx. My fourth objective was to determine habitat use of sympatric lynx and coyotes and how this might affect possible competition for food.

2. STUDY AREA

The 23,310 km^2 Kenai Peninsula is located 40 to 240 km south of Anchorage, Alaska and is connected to the mainland by an isthmus only 16 km wide (Bangs et al. 1982) (Fig. 1). The major topographic features of the Kenai Peninsula were described by Schwartz and Franzmann (1991).

The presence or absence of continuous snow cover > 10 cm deep approximately defines two biologically important seasons on the Kenai Peninsula. Schwartz and Franzmann (1992) reported that snow cover occurs from November through April (snow season). Although snow is often present in October and May, it is usually shallow or spotty and does not appear to reduce mobility or access to small mammals from May through October (snow-free season). Differences in the availability of a number of prey types also coincide approximately with the presence or absence of snow cover. Hares and spruce grouse mate in May and are more vulnerable to predation than during the previous months. Additionally, carnivores have easy access to vulnerable young hares, red squirrels (*Tamiasciurus hudsonicus*), grouse, small mammals and migratory birds from June through October.

The 675 km^2 study area is located in the northern Kenai Lowlands immediately north of the community of Sterling. The study area is composed mainly of the Swanson River Canoe System, a recreational area with 5-100 m of relief (Spencer and Hakala 1964) and many ponds and lakes. Two roads provide ground access to the study area. Swanson River Road, a 27.4-km-long unimproved gravel road, runs north-south through the western portion of the study area. Swanson River Road is

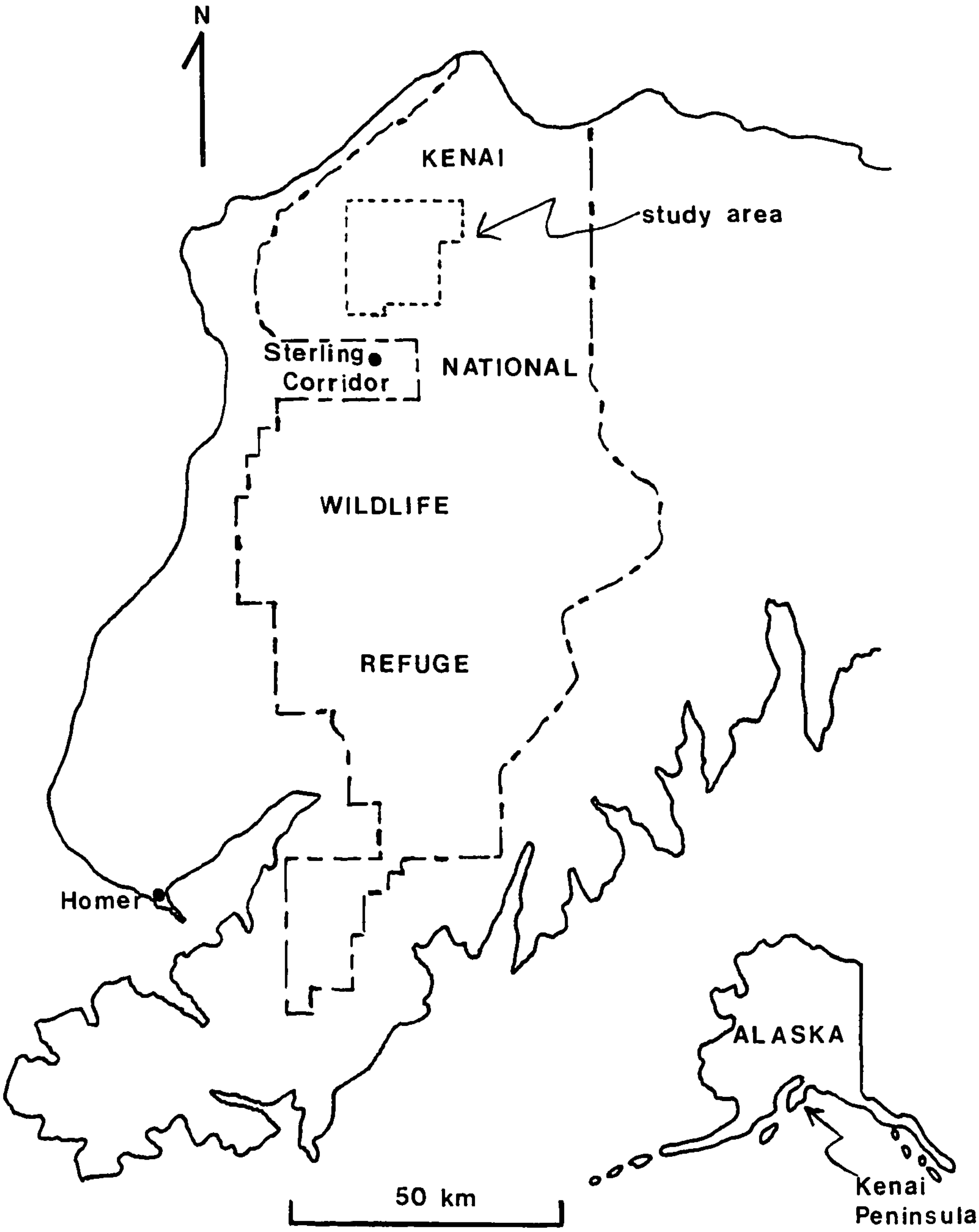

Figure 1. Kenai Peninsula and location of the Kenai National Wildlife Refuge, Alaska.

heavily used by recreationalists and workers, who operate the Swanson River Oil Field located in the northwestern quadrant of the study area. The 20.2-km long Swan Lake Road runs east-west through the northern portion of the study area and is used by recreationalists and refuge personnel. Road traffic on Swan Lake Road is light during the winter months.

The study area is composed of the 1947 burn (44%), the 1969 burn (22%), unburned areas (31%) and areas of 1947 burn crushed in 1976-77 (4%) (Fig. 2). The 1947 burn is located in the east-central region of the study area. The 1969 burn, located in the western edge of the canoe system, is separated from the 1947 burn by a large unburned area that extends from the northern study area boundary to within 0.5 km of the southern boundary. Two areas of the 1947 burn (totaling 27 km^2) on which vegetation was mechanically crushed in 1976-77 (Oldemeyer and Regelin 1984) are located in the northeastern quadrant of the study area. These areas were treated with LeTourneau tree crushers to improve habitat for moose. The machines rolled over and broke off at ground level existing 1947 burn regrowth. Unburned areas are located on hills and ridges and occur within the perimeters of both burns and the crushed areas.

Classification types of forest vegetation are from Viereck et al. (1992) unless otherwise noted. Unburned forest (80+yrs.) on the uplands is dominated by a Closed to Open Mixed Forest of white spruce (*Picea glauca*), paper birch (*Betula resinifera*) and quaking aspen (*Populus tremuloides*). Wetter slopes and depressions in upland unburned stands are vegetated with black cottonwood (*Populus trichocarpa*) and thinleaf

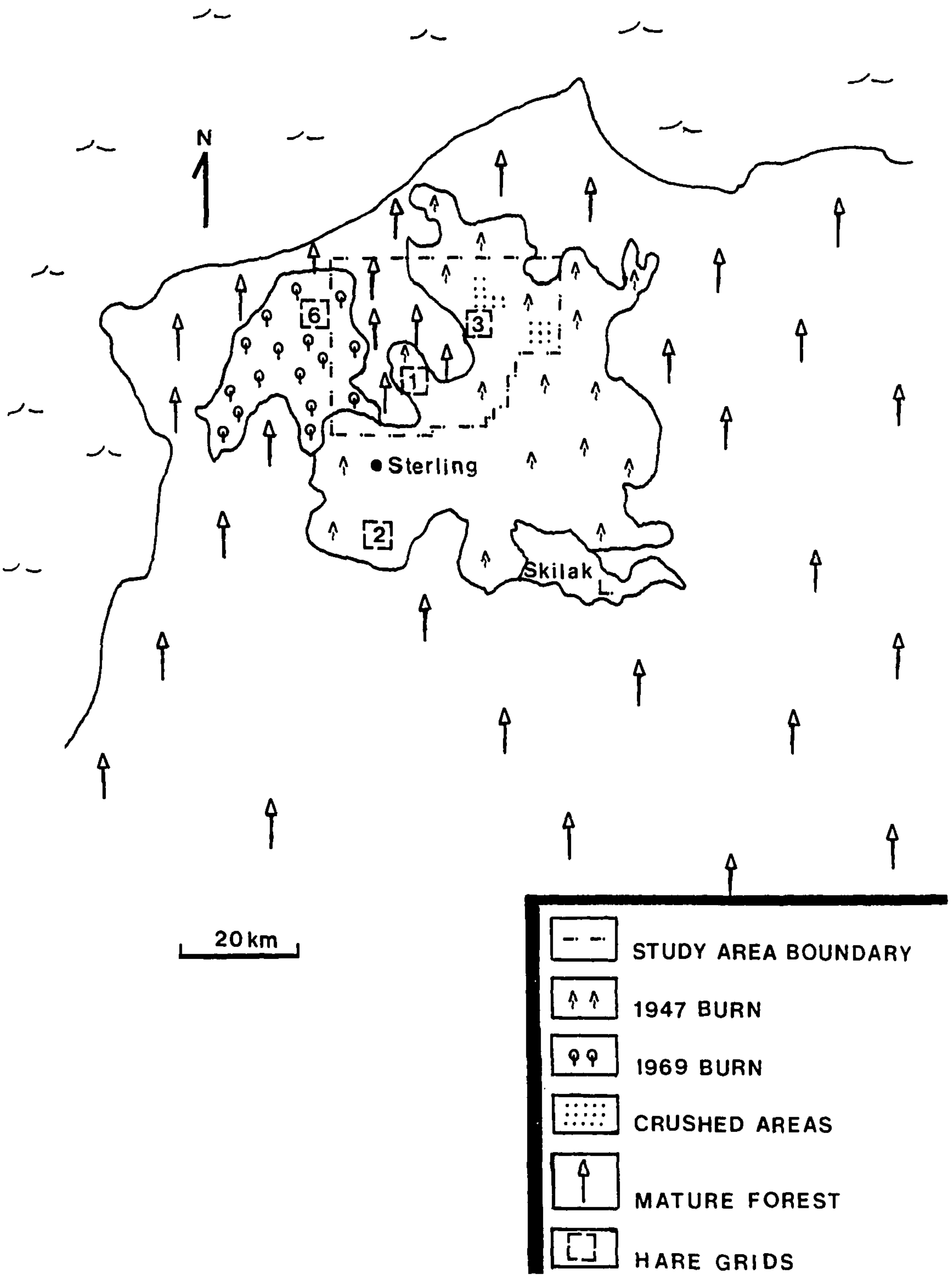

Figure 2. Location of the study area, major burns and hare grids on the Kenai National Wildlife Refuge, Alaska.

alder (*Alnus tenuifolia*). Unburned poorly drained areas are dominated by Closed, Open and Woodland Needleleaf (conifer) Forests of black spruce (*Picea mariana*). Browse for moose (*Alces alces*) and hares is limited (4.3 kg/ha, 90 years post burn) in unburned Kenai peninsula forest (Schwartz and Franzmann 1989). Escape and thermal cover for hares is also scarce and restricted to dense stands of black spruce and alder.

The dominant vegetation type in the 1947 burn is a Closed Mixed Forest of white spruce, black spruce, paper birch, quaking aspen, and black cottonwood. In 1985 most trees in this burned area were 3-5 m in height (Bangs et al. 1985). The relatively small size of broadleaf trees in this burn is apparently from browsing during high to moderately high (3.6-1.3/km^2) moose densities in 1970-82 (Schwartz and Franzmann 1989). Much of the regrowth broadleaf component of the 1947 burn has now either grown out of reach of hares and moose or has been killed by over-browsing. Browse availability, therefore, appears to be much less than the 397 kg/ha^2 (30 years post burn estimate) reported by Schwartz and Franzmann (1989). Although browse availability appears to be reduced in this area, much thermal and escape cover for hares exists under black and white spruce. Poorly drained areas in the 1947 burn are vegetated with Closed, Open and Woodland Needleleaf Forests of black-spruce regrowth. The 1947 fire was a cold fire so the 1947 burn contains many remnant stands of unburned forest (Schwartz and Franzmann 1991).

The 1969 burn is dominated by a Closed to Open Broadleaf Forest of birch, aspen, and willow (*Salix barclay* and *S. bebbiana*) averaging 2-3 m in height. High moose densities (3.7/km^2) observed in 1986-87 (Alaska

Department of Fish and Game [ADF&G], unpublished data) appear to be responsible for the low height of trees in this recent burn. The 1969 fire was a hot fire and consequently the 1969 burn has less unburned remnant forest than the 1947 burn (Bangs et al. 1985) and is characterized by low frequency of regrowth of white and black spruce (Oldemeyer and Regelin 1984). Browse density in the 1969 burn is greater than in the 1947 burn (Schwartz and Franzmann 1989), but there is little thermal or escape cover for hares because of the low density and small size of spruce in this area.

The crushed areas (17-18 yrs.) located in the northeast quadrant of the study area are largely vegetated with a Mixed Woodland Forest. Crushed areas are typified by lower stem densities of broadleaf species than are usual in the 1969 burn. Saplings of white and black spruce in crushed areas are generally too small (1-2 m) to provide significant thermal or escape cover.

Open wet areas in the study area, most often associated with ponds and lakes, are covered with Wet Graminoid Herbaceous and Dwarf Scrub vegetation types. Vegetation in these open wet areas is dominated by graminoid species and dwarf arctic birch (*Betula glandulosa*). I will refer collectively to these areas as wetland habitat hereafter.

The lightly developed Sterling Corridor is located on the southern border of the primary study area. This corridor extends from 2-4 km north and south of the Sterling Highway and Kenai River (Fig. 3). Most of this area is still forested; buildings, roads and maintained open lots cover only a small portion of the land. Most of the development in this area is residential and is serviced by dirt roads. All habitat

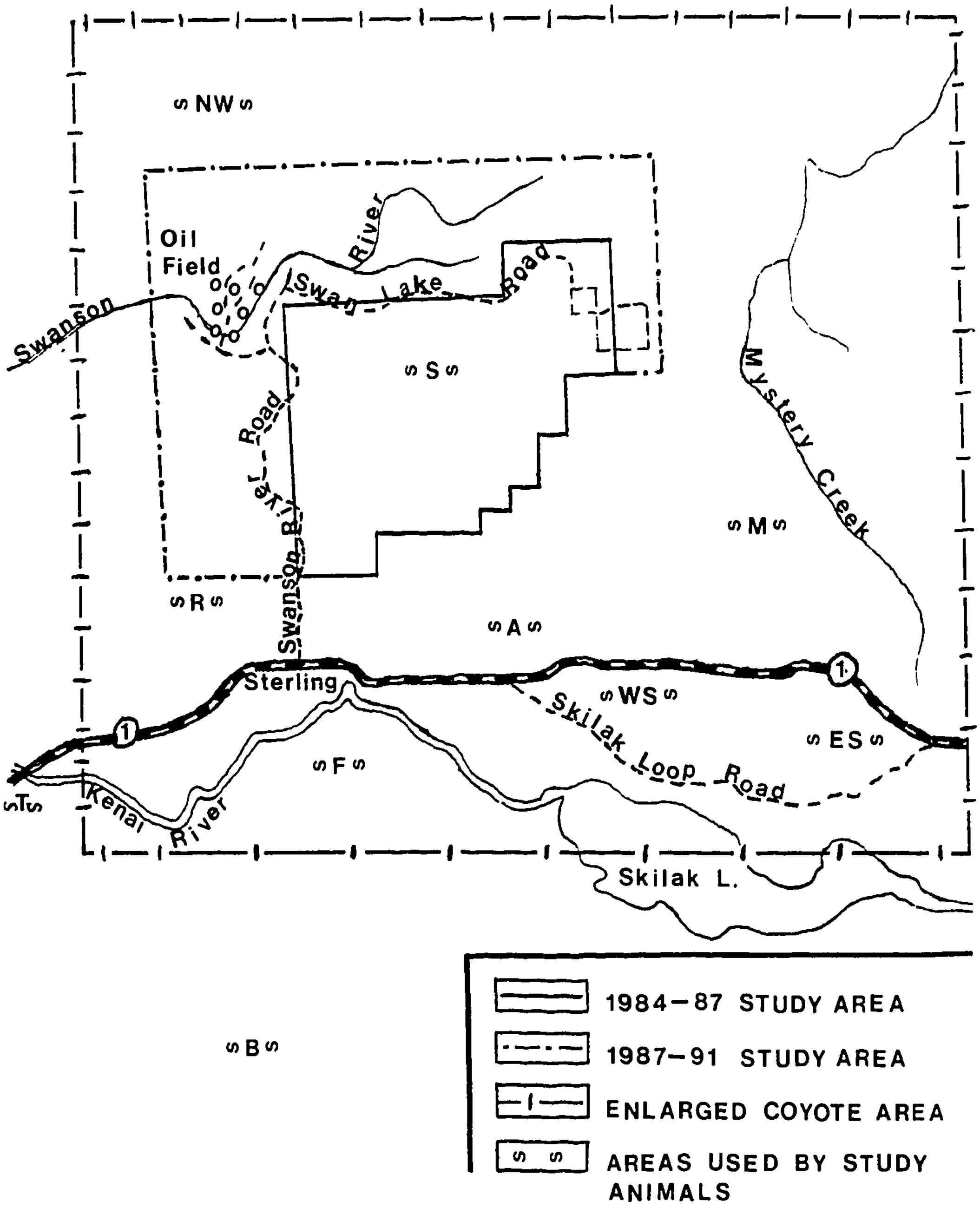

Figure 3. Location of 1984-87, 1987-91 and enlarged coyote study areas and areas used by lynx (~uppercase letters~) on the Kenai Peninsula, Alaska.

types discussed previously, as well as riparian habitat along the Kenai River and many intermediate stages of early succession caused by clearing of land for house and road construction, firewood collection, and agriculture, are present in the corridor. Browse is locally more abundant in recently disturbed corridor areas than in the primary study area.

3. METHODS

3.1 Prey Abundance

Refuge staff and summer volunteers determined densities of snowshoe hares by mark-recapture trapping of hares and by counting hare pellets in four 360 x 360 m grids (Bailey et al. 1986), Kesterson (1988). Three hare grids were located in the study area (Fig. 2): 1 in the 1969 burn (grid #6) and 2 in the 1947 burn areas (grids #1 and #3). A fourth grid (grid #2) was located 8 km south of the study area in a location burned in 1947.

Hares were censused from June-August by live trapping in double-door cage traps with dimensions of 23 x 23 x 81 cm. Grid areas were trapped for 3 weeks during the same time periods each summer. Forty-nine traps were arranged in 7 x 7 grids (total grid dimensions 360 x 360 m). Plot centers were located 60 m apart and permanently marked with steel stakes. Traps were set within 5 m of plot centers. Captured hares were marked with monel ear tags (National Band and Tag Co., Newport, Kentucky) and recorded as either adults or young of the year (Trapp 1962, Keith et al. 1968). Program CAPTURE, Model M(O), (White et al. 1982) was used to estimate the density of hares in the study areas. This model estimates the number of live adults at the end of the trapping period. The ratio of juveniles to adults captured in Grid 2 in late summer was applied to estimates of adult densities to calculate post-reproductive densities in each grid. A more detailed description of the assumptions of this model was reported by Kesterson (1988).

Permanent pellet plots were centered in each of the 49 trap plots for hares. Pellet plots were located by placing a 1-m^2 frame on plot center marking stakes. All pellets in each plot were counted and removed between May and August of each year (1983-1990).

Spruce grouse (*Canachites canadensis*) have been identified as alternate prey of lynx (Nellis et al. 1972, Brand et al. 1976, Kesterson 1988) and coyote (Thurber and Peterson 1992). Refuge staff conducted 5-10 early morning surveys from late September though October (Ellison 1974) in 1987 through 1990 to assess trends in populations of spruce grouse. Surveys were conducted by slowly driving along the Swanson River (18.2 km) and Swan Lake roads (20.6 km) and counting all grouse observed.

Microtines are also alternate prey of lynx (Kesterson 1988) and coyote (Todd et al. 1981, Thurber and Peterson 1992) in northern areas. A crude index of microtine and shrew abundance was determined by snap-trapping in October of 1988-1991 and concurrently with summer capture efforts for hares from 1989-1991. Museum Special snap traps with attached shrew wires (Bangs 1979) were baited with a mixture of peanut butter, rolled oats and bacon grease. Small mammal trapping involved placing 1 snap trap at each of the 49 hare grid stations for 3 to 11 nights. In October 1988 trapping of small mammals was conducted by placing traps one to a station at 10-m intervals along four 400-m linear transects through the 1969 burn, 1947 burn, and unburned and crushed areas. In October 1989-1991, trap transects used were 75 m long with a trap placed every 5 m. Eight of these trap transects were arranged through each of the 1947 burn, crushed and unburned habitat types.

3.2 Food Habits

Lynx scats were collected from captured animals, by snow tracking and by searching trails used by lynx each spring from January 1988-June 1990. Saunders (1963) reported that lynx scats often occur on an elevated spot such as a log, stump, rock or moss hillock, and that 2 or more lynx scats of different ages are occasionally found in the same location. Similar defecation behavior also was observed by Kesterson (pers. commun.) on the Kenai Peninsula and sites where several individual lynx scats are found are called "lynx supersets" by Kenai trappers. I collected additional scats by examining elevated locations in areas used by lynx and by revisiting sites where ≥ 2 lynx scats occurred.

Scats associated with tracks or obtained from trapped animals were labeled as confirmed in identity. If scats exhibited the distinctly segmented morphology described by Halfpenny (1986) and Kesterson (pers. commun.) and were at locations that were either (1) elevated, (2) sites of previous lynx defecation or (3) sites where 2 or more scats were found, they were labeled as suspected lynx scat. Fresh suspected scats were subjected to a third identification criterion, the mild musky odor characteristic of lynx scats.

Criteria for assigning suspected lynx scats to appropriate seasons were derived by observing confirmed winter scats in the field through mid-summer. Defecation dates of lynx scats were determined by surface texture, color, hydration and presence or absence of algae or moss. Confirmed and moist dark scats were classified as fresh and assigned a defecation date and season. Dark-colored, washed-out looking scats in the snow column or scats located up to 30 days after snow-melt were assigned to the previous winter season. White, light-gray scats or those with small amounts of algae or moss found 1 to 14 days after snow melt were assigned to the previous snow-free (summer) season. Light-colored scats located >14 days after snow melt and scats with large amounts of algae or moss were collected if conditions at the site indicated that an accurate estimate of season could be made. Scats found that could not be assigned accurately to a season were not collected. Light-colored scats of lynx were not collected during the first year of the study. All lynx scats except those left in place for observations of aging and color change were cleared from trails during the snow-free season each year to simplify aging of scats collected from the same places during subsequent years.

Coyote scats were collected from gravel roads and sections of main trails near roads from January 1988 to June 1990. Because roads and main trails were searched daily, mostly fresh, wet scats or scats associated with tracks were collected. Coyote scats were distinguished from lynx scats by their long cylindrical shape (Halfpenny 1986) and a strong acrid smell.

To avoid mis-identifying wolf scats as coyote scats, I did not collect coyote scats when tracking conditions were poor and wolves were known to be present near roads. Due to intensive management of Kenai wolves by the U.S. Fish and Wildlife Service (USFWS) and the ADF&G, radio collars were maintained in most wolf packs. Radio-collared animals in the 3 wolf packs using the study area were monitored daily.

Thurber and Peterson (1992) noted that wolves avoided heavily used roads on the KNWR. Because wolves are known to avoid canoe-system roads often used by recreationalists during the summer season and wolf tracks are large and easily observed in snow and moist soil, it was unlikely that wolf scats were mis-identified as coyote scats.

Lynx and coyote scats were frozen at -30° C and then steam sterilized for 30 minutes at a pressure of 1 atmosphere prior to examination to avoid infection with cysts of *Echinococcus granulosus*. Instruments and work surfaces were washed with a strong bleach-soap solution as recommended by Bowyer et al. (1983).

Scats were first soaked in warm tap water, and amalgamated matter was reduced to 1-2 mm in size with forceps. Prey remains were washed with an aerated stream of water in a number 20 (0.75 mm) mesh screen until clean. Detailed identification was begun by viewing hair samples of different prey items with a 15-30X binocular microscope. Although steam sterilization eliminates some characteristic scale configurations on hair and ruptures the medulla of hollow hairs, I assumed that the relatively small number of mammalian species (n = 10) in the study area allowed identification of species by hair size, color and banding patterns.

The nonhair fraction was then re-examined for remains of species not yet detected. Hair, teeth, claws, beaks, feathers, egg shell and bone were identified by comparison with reference material. No attempt was made to differentiate between remains of red-backed (*Clethrionomys rutilus*) and tundra (*Microtus oeconomus*) voles. Plant parts and seeds were identified by comparison to reference material and the publication by Martin and Barkley (1961). Food identifications and estimated percent volume of solid-scat residue were recorded. Unidentified remains and the nonhair/nonfeather remains were dried and stored for further analysis and reference.

Percent occurrence of foods in scats was calculated based on both the total number of scats and the total number of food items in scats for the carnivore species or season considered. Statistical tests were performed only on proportions derived for total food items. Differences in food habits between seasons, years and between lynx and coyotes were tested using the Chi-square statistic and the Kruskal-Wallis test on counts of food items (Freund 1984).

The measure of resource use overlap developed by Anthony and Smith (1977) was used to determine similarity of coyote and lynx diets. The percentages of common use for different foods were summed to calculate the dietary overlap percent of these two species. If percent of total food items occurring in the scats of 2 predators are 90% and 50% for food A (overlap = 50%) and 10% and 50% for food B (overlap = 10%) the "simple overlap" for the two predators is 60%.

Lynx and coyote kill and scavenging observations were made while snow tracking, locating radio-collared animals and investigating sightings by the public. Observations of lynx and coyote food habits in the Sterling Corridor were recorded because of the proximity of this lightly developed residential area to the study area and the likelihood that this distinctly different ecotone might be an important source of resources to populations of these highly mobile carnivores. Free-roaming and poorly penned domestic rabbits and fowl were vulnerable to dogs, cats, coyote, lynx and numerous avian predators. Therefore, numbers of animals taken at depredation sites were difficult to determine because of the possibility that several predators were taking livestock more or less simultaneously. Reported kills of domestic animals were recorded as one kill per residence. Repeated depredations at a single residence at different times were counted as separate kills.

3.3 Animal Capture

I captured coyotes with No. 3 Victor Soft-Catch coil spring traps. Refuge staff also captured some coyotes incidentally when trapping for wolves with no. 4 Newhouse long-spring foot-hold traps during April-June. Trap sets were constructed by first placing a large amount of coyote or wolf scat along the side of a road or trail. Boiled, waxed traps were handled with gloves and buried in front of scat baits in the manner described for coyote by Jamison (1983). Trap sets were checked once or twice each day, and scat baits were rescented every 3 days.

Coyotes in traps were initially immobilized with 60-80 mg of ketamine hydrochloride or tiletamine:zolazepam administered intramuscularly using a jabstick syringe. Additional doses of 10-40 mg were given as necessary to maintain anesthesia. We aged coyotes by tooth wear and body weight and recorded sex, age, weight and standard body measurements (body length, neck, girth and shoulder height). Coyotes with paw lacerations were administered 1 ml of procaine penicillin and antibiotic ointment was applied to injured areas. Coyotes were ear tagged, fitted with 300-g radio collars (Telonics Inc., Mesa, Ariz.) and released.

I trapped lynx using No. 3 Victor Soft-Catch traps from March through June. Refuge staff also captured lynx incidentally during wolf/coyote capture efforts from April-August. We suspended trapping efforts when temperatures were < -18° C. To prevent injuries to lynx I cleared all obstructions from a 2-m radius around trap sites, attached double swivels and shock absorbing springs to traps, and firmly attached traps with short lengths (< 15 cm) of chain to trees or stakes. When I anchored lynx traps with stakes, I used chains terminating with grapple drags to insure that large animals capable of pulling up stakes did not escape with traps attached to their feet.

Several different techniques were used to capture lynx. I used baited cubby sets (Hawbaker 1974) with bird wing, aluminum or silver mylar long range visual attractors. Commercial lures using wildcat scent also were employed in conjunction with bait and scat attractors. Starting in May I discontinued the use of meat bait to reduce the probability of capturing black bears (*Ursus americanus*). During May and June stuffed snowshoe hare, red squirrel and grouse skins were used as bait. I also used simulated caches constructed of piles of sticks with protruding fur, feet and feathers to attract lynx to traps. To attract wary or previously-captured lynx, lynx or broken coyote scat was placed on a rock or log close to sites of lynx defecations. I also trapped at carcasses used by lynx and attempted to capture lynx in modified wire live traps (185x51x67 cm)(Tomahawk Live Trap Co., Tomahawk, Wis.). We outfitted remote sets with trapsite transmitters (Telonics Inc., Mesa, Ariz.) and physically checked these sets every 3-5 days. We examined lynx sets without transmitters once each day. We also captured lynx by treeing them with trained Walker hounds in late October and early November of 1990.

Trapped lynx were initially immobilized with 60 mg ketamine hydrochloride injected with a jabstick syringe. Additional hand-injections of 10-40 mg of ketamine hydrochloride were administered to maintain anesthesia. Treed lynx were immobilized with darts fired from a Cap-chur long range projector rifle (Palmer Chemical and Equipment Co., Inc., Douglasville, Ga.) and the Telinject Vario IV blowpipe 11 mm rifle (Telinject U.S.A. Inc., Newhall, Calif.). Initial doses of 200-400 mg of ketamine hydrochloride were used to immobilize lynx pursued by dogs. Because of the need for extreme accuracy due to the small size of lynx, both darting systems were used with Aimpoint (Aimpoint, Herndon, Va.) and Pro-point (Tasco Sales, Inc., Miami, Fla.) illuminated red dot optical sights. Barbs on Cap-chur darts were removed or bent over and rubber shock absorbers placed over needles to reduce trauma from dart impact and to limit dart penetration to 6 mm. Very low velocity (brown wad) Cap-chur charges and .22 caliber short black powder blanks (Winchester Western) were used to propel Cap-chur darts. We used tree climbing spikes to climb trees to recover immobilized lynx caught in tree branches. Immobilized lynx that fell from trees were caught in 2x2 m nylon cargo nets.

During spring, 1988, immobilized lynx were also hand-injected with 30 mg promazine. To reduce recovery time and the risk of injury after release the use of tranquilizers was discontinued on lynx after 1988 unless they were injured, had seizures or appeared highly stressed.

After 1988 injections of 25 mg of acepromazine were administered when a tranquilizer was needed. Lynx were sexed, ages were estimated by tooth characteristics and weight, and body measurements of neck circumference, girth, shoulder height and body, tail, ear and canine length were recorded. For purposes of age determination all lynx were assumed to be born in early June. Lynx estimated to be 0-15 months old were recorded as kittens, and from 16-30 months old were recorded as sub-adults. We captured no lynx younger than 6 months old. Healthy lynx were ear-tagged, fitted with 300 g Telonics radio collars and given 1-ml injections of vitamin B. Lynx with paw lacerations or dart wounds were given 1 ml injections of procaine penicillin. Dart wounds made by Cap-chur darts were irrigated with mastitis penicillin ointment. Paw lacerations were covered with anti-biotic ointment. Injured lynx were treated by a local veterinarian and rehabilitated at the KNWR Headquarters in Soldotna.

3.4 Habitat Use

Availability of habitat types in the study area was determined by transferring boundaries of burns, bogs and open water from 1:31,680 and 1:15,840 infa-red aerial photos to 1:63,360 U.S. Geological Survey maps of the study area. The resulting polygons were digitized into a PC ARC/INFO (Environmental Systems Research Institute, Inc., Redlands, Calif.) Geographic Information System.

Radio-collared study animals were located from either a Piper PA-18 or Cessna 206 aircraft flying at an altitude of 166 m in the manner described by Mech (1983) from November 1987-September 1991. Locations were obtained during daylight hours. Habitat types at visual estimates of study animal locations were recorded immediately by the aerial observer. The corresponding location on a 1:63,360 U.S. Geological Survey scale map was then estimated and marked on a map carried in the aircraft. Township system coordinates were later determined for marked locations, but these coordinates were not used to find habitat use for habitat analysis.

Wielgus and Bunnell (1994) studying grizzly bear (*Ursus arctos)* habitat selection determined that visual estimates of radio-collared animal locations by aerial observers can be accurate to within 1 ha. Recent efforts by KNWR staff to determine aerial location accuracy by comparing Universal Transverse Mercator coordinates obtained by Global Positioning System (GPS) instruments at transmitter sites and in locating aircraft have resulted in average error estimates of 100 m or approximately 3 ha (Jozwiak, unpublished data). Assigning a coordinate value to a visual estimate of a transmitters location on the landscape, however, involves additional sources of error regardless of whether a map or GPS device is used to estimate the resulting x, y coordinates. The ratio of radio location error values of either 1 ha or 3 ha to the mean study area stand size of 89.1 ha indicates low potential error rates for misclassification of habitat types (White and Garrot 1986). White and Garrot (1986) indicated that misclassification of habitat use due to location errors lowers the power of statistical tests to detect habitat selection, but asserted that because, in reality, only part of the telemetry locations are in error the ability of a statistical test to detect selection is hampered but not eliminated.

Ground locations were obtained by triangulating with a hand-held, H-antenna (Telonics Inc., Mesa, Ariz.). At least 3 azimuths taken at locations where the directionality of received signals could be accurately determined were used to plot locations on 1:15,840 aerial photos. Azimuth variation between experienced field assistants using the same antenna and Silva Ranger compass was $\leq$ 2 degrees. The center points of triangles resulting from plotting 3 bearings were assumed to be the position of the study animal. Locations from plot triangles with a maximum dimension over 240 m and ground fixes obtained from a distance of >2.4 km were not used. The predominant burn type in a 50-m radius around the estimated location of an animal (micro-habitat) was recorded. The burn type of the major burn, unburned forest or crushed area (macro-habitat) within those boundaries estimated locations of points fell also were recorded. The township system coordinates of each plotted point were then estimated using 1:63,360 U.S. Geological Survey maps.

The accuracy of ground locations was certainly less than locations obtained from the air because of obstructive vegetation and terrain and because animals often were moving and all azimuths used for plotting locations could not be taken simultaneously. I did not formally test the accuracy of ground locations because of the high variability and unpredictability of potential sources of error. I believe that the high activity rates and movement rates of animals during this period were the greatest source of error. Plots made on 1:15,840 aerial photos of signals received from dead or trapped study animals and lynx feeding on carcasses, however, often resulted in locations accurate to within 100 m. I reduced misclassification of habitat use at animal locations by not using data from azimuths yielding large plot polygons (> 5 ha) and plot polygons that contained more than one habitat type. Because of relatively large average stand sizes, and because only one habitat type was usually present in plot and error polygons, I believe that habitat type misclassification for ground locations was low.

The activity state of animals monitored from the ground was also estimated. Activity (stationary, active or uncertain) was determined by fluctuation of signal volume after listening to signals for 2 minutes. Accuracy of activity observations was not tested, but observations of moving and stationary study animals and radio-collared dogs suggested that walking or running movement was easily detected. Hunting activity of lynx, however, was probably underestimated because cats spend much time standing or sitting while hunting.

There is a large literature concerning bias in analysis of resource use caused by inaccurate estimations of resource availability (Johnson 1980, White and Garrott 1990, Morrison et al. 1992). Because Johnson (1980) demonstrated how inclusion of resources not used by or available to study animals can distort results, I excluded ponds, lakes and open wetlands (areas I assumed not to be used) from available habitats. I assumed that all remaining habitat types were available to my study animal population. This assumption was certainly violated on an individual basis because of the limited distribution of some rare habitats (crushed types, remnant mature forest in the 1969 burn) and the territorial behavior of these two carnivores. Habitats comprising most of the study area (1947 burn, large expanses of mature forest and the 1969 burn), however, have wide distributions in the Swanson River Canoe System area and were available to the majority of my study animals.

To gain the maximum information from data, I chose eight combinations of micro- and macro-habitats for initial habitat-use analysis. These micro/macro habitat combinations were 1947 burn/1947 burn, 1947 burn/crushed, mature/1947 burn, mature/crushed, crushed/crushed, mature/mature, mature/1969 burn and 1969 burn/1969 burn. Preference calculations, however, are sensitive to sampling error for rare or seldom used resources (Lechowicz 1982), and an increased risk of Type II errors exists when many habitat types are used for analysis of resource selection (Alldredge and Ratti 1986). To minimize the effect of these errors, I also examined habitat use by consolidating habitat types and considering only the 4 major types of burns (Macro-habitats) at relocation points. Using only major burn types helped me to increase sample sizes for it also allowed me to use aerial locations for which only the major habitat type was recorded.

Habitat selection was first determined for the entire study area using relocations made from aircraft. Because of previously noted difficulties associated with accurately determining habitat preference, I decided to replicate tests of habitat use using animal locations determined by ground-based directional antennae. Habitat for locations determined from the ground were analyzed by comparison with habitat available within 2,400 m of roads. I also analyzed lynx habitat use in the smaller area used during the 1984-87 study, so that a direct comparison of habitat use between the two study periods could be made.

I began analysis of habitat preference by dividing percent use (r) by the percent available habitats (p) in the study area. This calculation yields the simple Ivlev's forage ratios (Lechowicz 1982). Ratios over one (use higher than availability) indicate preference and ratios under one (use less than availability) indicate avoidance. I then calculated the Vanderploeg and Scavia's Relativized Electivity Index (E*), which is based on this ratio of resource component use to availability (Vanderploeg and Scavia 1979):

$$E^* = [W_i - (1/n)]/[W_i + (1/n)] \quad \text{where,} \quad W_i = \frac{r_i/p_i}{\Sigma\, r_i/p_i}$$

and n = number of resource types

Lechowicz (1982) reported that this index allows valid rank-order comparisons of resource use between areas with different availabilities. He also reported that the E* index is vulnerable to sampling error for rare resources as the number (n) of resource types increases. Thus, I had to interpret E*-values contradicting simple forage ratios by considering the effect of rare habitat availability and the effect of low values of 1/n on index calculations when eight habitat types were used.

After reviewing the comments of Aldredge and Ratti (1986) and White and Garrott (1990) regarding the relative merits of different statistical techniques for analysis of habitat selection, I also chose the Friedman's test procedure as explained by Conover (1980) to further test for differences between all available habitats and their use. This test statistic is based on rankings of the difference between resource availability and use for individual study animals. This introduces a measure of variability in habitat use by individual animals into the test statistic. In addition, the validity of the test result for the population can be evaluated by inspecting tables of the preference ranks of individual animals to see how much the preferences of individual animals differ. I then performed a multiple comparisons test (Conover 1980) using the availability/use rankings computed for the Friedman's test to determine which habitat types were used significantly more or less than available. Data on habitat use of animals that contributed proportionately few locations were excluded from Friedman's and multiple-comparisons tests to avoid problems associated with equal weight assumptions of these tests (Alldredge and Ratti 1992).

To determine if there was a difference in habitat use between the previous (1984-87) and my study period, and between lynx and coyotes, habitat use count data were arrayed on a contingency table and tested for independence with the Chi-square statistic at $\alpha = 0.05$. The Z-test for the difference between two proportions (Freund 1984) was used to determine which habitats contributed the most to the rejection of null hypotheses of Chi-square tests. The Wilcoxon test (Conover 1980) was used to determine if there was a significant difference between preference values calculated for area habitats between the 1984-87 and 1987-91 time periods and between habitat preference values calculated for the entire study area and the road buffer area.

To obtain a measure of similarity of habitat use by lynx and coyote, I again calculated resource use overlap by using equations described by Anthony and Smith (1977).

4. RESULTS

4.1 Lynx Population Characteristics

Nineteen lynx were captured a total of 32 times in the study area between March 1988 and September 1991. One adult female that used the central portion of the study area during this period was not captured. Five additional lynx were captured 7 times in the adjacent Soldotna, Funny River and Mystery Creek areas. Trapping effort for lynx totaled 9,113 trap nights and resulted in 29 captures. Capture effort using hounds during October and November 1990 totaled 126.3 person days (Bailey 1991) and resulted in 10 captures. One person day of effort equaled an 8 hour work day by a field worker. A capture summary with areas used by lynx and their fates is included as Appendix A. The estimated number of lynx residing in the study area, determined by snow tracking and captures ranged from 0.7 to 1.8/100 km^2 (Table 1).

Three year-old kittens (one 7.8 kg resident male, one 7.0 kg dispersing male, and one 6.3 kg dispersing female) were captured during spring 1988. The two males survived their second winter and were recruited into the study area population; the female starved during November 1988.

During spring 1989, 2 year-old kittens (2 resident males) were captured in the study area, and 1 year-old male kitten was captured in a Soldotna residential area. All 3 kittens were small (4.8, 5.5 and 6.0 kg), and were much more afraid of capture personnel and less aggressive than kittens captured in spring of 1988. Each of the two resident

Table 1. Estimated number of lynx using the study area during 4 snow seasons on the Kenai National Wildlife Refuge, Alaska, 1987-1991. Numbers of resident lynx without radio collars are in parenthesis.

Snow Season	Adult Males	Adult Females	Sub-adult Males	Sub-adult Females	Kitten Males	Total Lynx	Lynx/ 100 km^2
1987-88	3(2)	7(6)	0	1	1(1)	12(9)	1.8
1988-89	3	5(1)	3(1)	0	2(2)	13(4)	1.9
1989-90	5	4(1)	1	0	1(1)*	11	1.6
1990-91	3	2(1)	0	0	0	5	0.7

*= Kitten's sex unknown

kittens were missing the end of one ear and both of these kittens starved during June and July of 1989. The 6.0 kg male was captured twice while preying on domestic rabbits in Soldotna. He was rehabilitated until he weighed 9.5 kg and exhibited more aggressive behavior, and then released in a remote area in early September 1989. He survived for 4 months but starved in January 1990.

Kitten production and survival into the autumn was low for the rest of the study. One kitten was tracked in the study area during the winter of 1989-90 but not captured. No kittens were detected or captured in the study area after February 1990.

The body condition of females appeared to deteriorate during winter 1988-89. Adult female F29 starved to death in January 1989. Five adult females captured during the spring of 1988 averaged 9.89 kg (*SD* = 1.09), but during spring 1989 four adult females captured averaged only 8.64 kg (*SD* = 0.67). A small sample t-test did not detect a significant difference between the 2 years ($t = 0.91$, $P = 0.36$), but I believe females were in poorer condition during spring of 1989, as judged by protrusion of vertebrae and bones of the pelvic girdle.

Confirmed and suspected mortalities of lynx between March 1988 and September 1991 totaled 13 of 24 radio-collared lynx. In summary 7 lynx (2 adult females, 2 sub-adult females, 1 sub-adult male and 2 male kittens) starved. Three lynx died from capture-related causes and 3 lynx were illegally killed (1 confirmed, 2 new radio collars ceased operating in areas where other lynx were illegally killed). Two unmarked adult male lynx that did not use the study area were killed by vehicles on the Sterling Highway south of Mystery Creek. In addition, trappers incidentally killed 3 lynx during the 1987-88 through the 1990-91 trapping seasons, but none of these animals was thought to reside in the study area. Lynx appeared to be vulnerable to mortality due to shooting during the study, because lynx did not flee in 92 of 105 instances when they were encountered by humans at close range (Appendix B).

No adult male lynx died of natural causes during the study period. Adult males appeared to be in better condition than females (less protrusion of vertebra and bones of the pelvic girdle).

Home ranges of lynx were not calculated, but field observations and inspection of maps and relocation coordinates were sufficient to indicate lynx spatial response to decreasing hare densities. Of 13 monitored adult lynx, 9 (F29, M55, F56, M57, M58, F61, M62, M65, F67) remained in the same general area throughout the study. Three of 13 adult lynx (M30, F41, M64) departed areas they had occupied for > 1 year and moved 10-15 km south of the study-area boundary before again restricting their movements to a general area. One adult female (F60) made a series of seasonal movements to areas outside the study area to exploit locally abundant food resources during the snow-free (salmon streams) and snow (Sterling Corridor) seasons but returned to the study area during alternate seasons. Two female lynx (F60 and F61) made long range exploratory movements around the Kenai Peninsula after losing litters during the summer of 1988, but returned to the study area by autumn.

4.2 Coyote Population Characteristics

Twenty-nine coyotes (15 males and 14 females) were captured in the study area and in adjacent areas between April 1988 and August 1990 (Appendix C). Fifteen of these coyotes (4 males and 11 females) were fitted with radio collars. A minimum of 2,062 trap nights were expended during this period.

The number of coyotes fitted with radio collars was not sufficient to enable estimation of the number of coyotes using the study area each year. Yearly capture success per 100 trap nights was recorded as a crude population index. Capture success during the snow-free season along Swan Lake Road was 2.0 (352 total trap nights) in 1988, 1.5 (345 total trap nights) in 1989 and 0.6 (552 total trap nights) in 1990. Coyote numbers also appeared to drop on Mystery Creek Road during this period for coyote capture success was 0.8 (382 trap nights) in 1988, 0.9 (219 trap nights) in 1989 and 0.0 (213 trap nights) in 1990. It did not appear that coyotes became wary of our trap sets because three coyotes were recaptured; no traps were dug up by coyotes, and no increase in the number of capture misses or "snapped traps" was observed. Predator callers hunting in the study area reported that coyotes were less numerous in the winter of 1990-91 than previously.

Because of the difficulty of distinguishing pup from adult coyotes while snow tracking and the small number of coyotes outfitted with radio collars during 1989 and 1990, I am unable to report meaningful information about the reproductive performance of coyotes during the study period.

Seven of 15 coyotes died between April 1988 and February 1991.

During the 1988-89 snow season, none of 11 coyotes died. During the snow season of 1989-90 6 of 11 coyotes with operational radios on 29 December 1989 died: 2 (18%) were shot by hunters, 1 (9%) was killed in a vehicle collision, and 3 (27%) were killed by wolves. The stomachs of 2 wolf-killed coyotes contained moose, and the third coyote's remains were found 18 m from a partially consumed moose. Mortality estimates for the 1989-90 snow season are conservative because 1 additional coyote was shot in October, 1989 and 4 coyote radio transmitters failed between 29 December 1989 and 23 January 1990.

Wolf predation on coyotes also was detected during the 1990-91 snow season despite the lack of operational radios on Kenai coyotes. A reliable observer reported finding a coyote killed by wolves south of the study area near the Kenai River (Jim's Landing) in mid-November 1990. Also the scattered remains of an unmarked coyote were located in the study area near a moose carcass fed on by wolves on 6 February 1991.

Trappers were also a significant source of mortality on Kenai Peninsula coyotes during the study. Trappers reported killing an additional 106 coyotes on the refuge during the 4 trapping seasons from 1987-88 to 1990-91.

4.3 Prey Abundance

Numbers of snowshoe hares declined dramatically and remained at low levels during the study (Table 2). Because program Capture, Model M(O) (White et al. 1982) does not detect density differences accurately below 0.5 hares/ha, only numbers of individual juvenile and adult hares

Table 2. Snowshoe hare captures and estimated densities over time on the Kenai National Wildlife Refuge, Alaska, 1983-1990.

Grid	Year	Adult	Juvenile	Hares/ha*	Pellets/m^2
1	1983	23	11	11.0	65
	1984	34	20	12.3	51
	1985	30	10	4.4	52
	1986	23	8	3.8	28
	1987	10	2	0.5	14
	1988	4	5	-	11
	1989	2	2	-	5
	1990	2	1	-	1.9
2	1983	27	76	3.0	60
	1984	47	79	5.1	35
	1985	48	27	3.2	44
	1986	19	15	1.4	20
	1987	16	15	0.2	9
	1988	2	2	-	7
	1989	1	2	-	2.1
	1990	1	0	-	2.6
3	1986	20	13	0.4	
	1987	13	11	0.5	20
	1988	5	7	-	10
	1989	5	4	-	3.2
	1990	4	1	-	4.1
6	1989	1	0	-	7.5**
	1990	0	1	-	3.1

* = estimated using program Capture, Model M(O)

** = pellets cleared for the first time

captured are listed after 1987. Numbers of adult hares captured on grids 1 and 2 in 1947 burn areas were highest in 1984 at 34 and 47 adults, respectively. In 1987 adult hares captured on grids 1, 2 and 3 numbered 10, 16 and 13 individuals. Numbers of adult hares captured on these grids declined to 2, 1 and 4 individuals by the summer of 1990. Counts of hare pellets recovered from hare grids declined from 50 and 35 pellets/m^2 in grids 1 and 2 during 1984 to 1.9 and 2.6 pellets/m^2 in grids 1 and 2 by 1990. Grid 6 located in the 1969 burn yielded 1 adult in 1989 and 0 adults in 1990.

Numbers of spruce grouse appeared to increase on the refuge during the study period (Table 3). No grouse were seen on Swanson River and Swan Lake roads during October 1987, but sightings increased to 0.197 and 0.188 grouse/km on these roads by October 1990.

Examination of data from summer (hare grid) and autumn small mammal trapping suggests that microtine densities differed between seasons. I, therefore, only report October 1988-91 capture success for red-backed voles, tundra voles, and masked shrews (*Sorex cinereus*). Numbers of red-backed voles trapped in the study area varied greatly between years (Table 4). During summer and autumn of 1988 and 1991 visual observations alone indicated that red-backed voles were very numerous, and trapping yielded 27.9 and 10.9 voles/100 trap nights, respectively. During 1989 and 1990, however, trapping success dropped to 2.7 and 4.7 voles/100 trap nights respectively.

In October 1988 small mammal trapping was conducted in 7 major burn/vegetation types; the greatest number of red-backed voles was captured in a 1947 Burn area vegetated with birch and spruce regrowth.

Table 3. Early morning, roadside spruce grouse surveys on the Kenai National Wildlife Refuge, 1987-1990.

Year	Route	Length (km))	Number Surveys	Total Grouse	Grouse/ Survey	Grouse/ Survey/ km
1987	Swanson River Rd.	27.4	6	0	0.0	0.0
	Swan Lake Rd.	20.2	6	0	0.0	0.0
1988	Swanson River Rd.	27.4	10	2	0.2	0.0
	Swan Lake Rd.	20.2	10	22	2.2	0.1
1989	Swanson River Rd.	27.4	7	9	1.3	0.0
	Swan Lake Rd.	20.2	7	25	3.6	0.2
1990	Swanson River Rd.	27.4	5	27	5.4	0.2
	Swan Lake Rd.	20.2	5	19	3.8	0.2

Table 4. Small mammal trapping effort and captures by year on the Kenai National Wildlife Refuge, Alaska, 1988-1991.

Year	Total Trap Nights	Total captures/100 trap nights		
		Red-backed Voles	Tundra Voles	Masked Shrews
1988	840	27.9	1.2	3.5
1989	1080	2.7	0	1.2
1990	1079	4.7	0	1.6
1991	1073	10.9	0.4	5.9

The fewest voles were captured in more open wetland and upland grassy areas (Table 5).

4.4 Lynx Diet in the Study Area

Percent occurrence of hare, red squirrel, and microtine rodents in confirmed and suspected lynx scats were similar (X^2 = 1.02, 2 *df*, *P* = 0.60). Thus, three years of food habits were pooled as snow and snow-free seasons for statistical analysis. Percent occurrence of food items in lynx scats, however, are reported by season for each year in Appendix D.

Few (*n* = 14)lynx scats were collected between late June and October due to the lack of tracking snow, cessation of trapping efforts and the failure of lynx to revisit winter latrines during the warmer months. Data on lynx food habits for the snow-free season, therefore, reflect primarily May and June.

Snowshoe hares were the most important food of Kenai lynx during the study period (Table 6). Hare remains occurred in 91.3% of 161 snow season and in 66.7% of 42 snow-free season scats. Based on total food items, the percent of hare remains for snow and snow-free seasons was 63.6% and 37.8%, respectively.

Within season comparisons of prey items in lynx scat using Chi-square values indicate that hare use was significantly higher than all other major food categories except red squirrel during the snow seasons (Table 7). Hare use, however, was not significantly higher than use of squirrels and voles for snow-free seasons.

Table 5. Small mammal captures in 7 burn/vegetation types during 120 trap nights on the Kenai National Wildlife Refuge, Alaska, 18-21 October 1988.

	Captures /100 trap nights		
Burn & Species	Red-backed Voles	Tundra Voles	Masked Shrews
1947 Burn (birch/spruce)	61.7	0	7.5
Unburned Mature (birch/spruce)	43.3	2.5	2.2
Unburned Mature (black spruce)	41.6	0	3.3
Crushed (birch/spruce)	20.8	0.8	4.2
1969 Burn (alder)	18.3	0	4.2
1947 Burn (open wetland)	7.5	1.7	0
1947 Burn (grass)	1.7	3.3	2.5

Table 6. Food items identified in 203 lynx scats collected in the Kenai National Wildlife Refuge, Alaska, 1988-1990, 3 years data pooled.

	Snow Seasons		Snow-free Seasons	
Food Item	%Freq. Total Scats n = 161	%Freq. Total Items n = 231	%Freq. Total Scats n = 42	%Freq. Total Items n = 74
Snowshoe Hare	91.3	63.6	66.7	37.8
Spruce Grouse	9.9	6.9	11.9	6.8
Red Squirrel	14.9	10.4	50.0	28.4
Moose	6.8	4.8	0	0
Vole	13.0	9.1	26.2	14.9
Shrew	0	0	2.4	1.4
Mallard	0	0	2.4	1.4
Unidentified Bird	1.2	0.9	7.1	4.1
Salmon spp.	0.6	0.4	0	0
Unidentified Fish	0.6	0.4	0	0
Grass	1.9	1.3	2.4	1.4
Porcupine	0.6	0.4	0	0
Ermine	0.6	0.4	0	0
Unidentified Mammal	1.9	1.3	7.1	4.1

Table 7. Within season comparison of major food categories in lynx scats from the Kenai National Wildlife Refuge, Alaska, 1988-1990 using Chi-square values (test criterion $X^2_{.008} = 7.13$ used for $\alpha = 0.05$ due to correction for 6 simultaneous tests).

	3 Snow Seasons	3 Snow-free Seasons
Hare-Squirrel	87.04**	0.73NS
Hare-Birds	99.30**	7.61*
Hare-Vole	93.01**	6.56*NS
Squirrel-Birds	0.60NS	3.23+NS
Squirrel-Vole	0.08NS	2.53+NS
Birds-Vole	0.10NS	0.0NS

** P<0.0001 * P<0.008 *NS P>0.01 +NS P>0.05 NS P>0.1

Snow tracking 61 km confirmed heavy use of hares during the snow season. Ten of 16 kills located while snow tracking in the study area were snowshoe hares (Table 8).

Although biased by a variety of sightability variables, total prey related observations (total pursuits, kills, and prey watching observations made by refuge staff and the general public in the study area) also indicate that hare were the primary prey of lynx during the study period (Table 9). Thirty-three of a total of 55 related observations of small game involved snowshoe hares.

Red squirrels were the second most important food of Kenai lynx during the study period. The stomachs of 2 lynx road-killed during the snow-free season also contained red squirrel remains.

Spruce grouse were the third most important food of lynx. Grouse may have been more important during the snow-free season than scats suggest, because an appreciable percentage of the unidentifiable feather fragments observed in the snow-free season scats may have been grouse.

Voles also appeared to be a substantial part of lynx diets particularly during the snow-free seasons. No attempt was made to differentiate between remains of red-backed and tundra voles in scats, but only 14 (3.1%) of 445 voles killed during 4,072 October trap nights were tundra voles.

Moose remains occured in 7% of snow season scats, but in no snow-free season scats. Six lynx fed on 7 different moose carcasses and on 2 wolverine trap sites baited with moose carrion in the study area (Appendix E). Lynx appeared to have exclusive use of these 7 carcasses even though coyotes were present in the immediate vicinity. Two were

Table 8. Lynx kills found during snow tracking 61 km on the Kenai National Wildlife Refuge, Alaska, 1988-1990.

Snowshoe Hare	10	62%
Red Squirrel	3	19%
Spruce Grouse	1	6%
Vole	2	13%
Total	16	

Table 9. Total small game related observations of refuge staff and the general public (kills, pursuits, prey watching) in the study area on the Kenai National Wildlife Refuge, Alaska, 1988-1990.

	Observations	Percent Total
Snowshoe Hare	33	61%
Red Squirrel	14	25%
Vole	2	4%
Spruce Grouse	2	4%
Red-breasted Merganser	1	2%
Harlequin Duck	1	2%
Three-toed Woodpecker	1	2%
Total	54	

identified as male adults, 2 were adult females, 1 was a male kitten with his mother, and the sex of 1 adult lynx was not determined. Lynx fed on moose carcasses for periods of 3 to 21 days. Male lynx M65 fed for 16 days on 3 different carcasses between 1 January and 10 February 1990. No wolves or wolf sign were found in the vicinity of moose carrion fed on by lynx.

Lynx appeared to leave moose carcasses for 3 reasons. First, the lynx seemed to have an aversion to spoiled meat. At the 2 wolverine trap sites female lynx ate little and departed within a day. The moose bait encountered by lynx females between 29 March and 4 April had been unfrozen for about 2 weeks and may have been spoiled or tainted. Lynx rehabilitated at the Kenai National Wildlife Refuge headquarters refused to eat older frozen food items and became ill on two occasions when fed tainted meat. Second, 3 moose carcasses with much good meat remaining were abandoned when they became frozen. Two male lynx, however, who were possibly very hungry when they discovered frozen carcasses, were able to rasp frozen meat off of carcasses with their claws. Third, 2 lynx departed carcasses when all muscle tissue had been consumed. No lynx were observed to consume large moose bones and heavy hide as coyotes and wolves often did at old kill sites.

Masked shrew, mallard (*Anas platyrhynchos*), salmon (*Oncorhynchus*), porcupine (*Erethizon dorsatum*), ermine (*Mustela erminea*), unidentified fish, unidentified mammals and bluejoint reed grass (*Calamagrostis canadensis*) occurred in a small percentage (6 %) of lynx scats. In addition, the remains of a three-toed woodpecker (*Picoides villosus*) eaten by a lynx were discovered in the study area.

Visual observations during the warmer months when few scats (n = 42) were collected suggest that aquatic birds were preyed upon in snow-free season. Lynx M71 was observed bounding into a pond after harlequin ducks (*Histrionicus histrionicus*). Lynx F60 was seen "watching" red-breasted mergansers (*Mergus serrator*), and lynx M57 and F58 were often located on the banks of a pond containing breeding ducks. Outside the study area, F60 was observed killing a large gull (*Larus)* on the banks of the Kenai River, a nonstudy lynx was observed pursuing a mallard 200 m from downtown Soldotna, and remains of a lynx-killed mallard were located 15 km east of the study area.

Comparison of lynx scat data by season after consolidation into 6 major food categories (Table 10) indicate that lynx diet varied significantly between the snow and snow-free seasons ($X^2 = 21.88$, $P < 0.001$); use of snowshoe hares decreased, and use of red squirrels increased significantly during the snow-free season.

Lynx made heavy use of small game kills. At 5 of 12 hare kill sites lynx consumed the entire carcass except the cecum, 1 or 2 paws and a small amount of fur. At 4 of the 12 hare kill sites lynx cached parts of the carcass by pulling snow over the remains and returned to eat all edible portions. Lynx cached hare hind legs at the 3 remaining kill sites, but we did not determine if lynx returned. Lynx consumed all parts of red squirrels except the tips of their tails and stomachs containing plant matter. Whole duck and grouse carcasses, including most feathers, were eaten immediately after the kill. Two of three voles were totally consumed. The stomach of the third vole was full of plant matter and was not eaten.

Table 10. Pairwise seasonal comparisons of consolidated lynx food categories using Z-values, Kenai National Wildlife Refuge, Alaska, 1988-1990 (test criterion $Z_{.008} = 2.40$ used for $\alpha = 0.05$, one-tailed test, due to correction for 6 simultaneous tests).

	3 Snow seasons	3 Snow-free seasons	
	%Freq. Total Items N = 229	%Freq. Total Items N = 74	Z-test Statistic
Snowshoe Hare	64.2	37.8	3.91*
Birds	7.9	12.2	1.15NS
Red Squirrel	10.5	28.4	5.71*
Vole	9.1	14.9	1.41NS
Other Vertebrates	7.0	5.4	0.69NS
Grass	1.3	1.3	2.39*NS

*P<0.0001 *NS P > 0.008 NS P>0.10

Hunting strategies used by lynx during the study period are described in Appendix F.

4.5 Lynx Diet in the Sterling Corridor

Previous studies did not suggest, and we did not predict, that lynx would use unique food resources in the lightly developed residential areas and the Kenai River riparian habitat 3 to 13 km south of the study area. Although I was not able to quantify environmental variables in the Kenai River Corridor area, I report these data because use of this area by lynx and coyotes may be important to a large fraction of the populations of these two species on the Kenai Peninsula.

Our observations and confirmed reports from Kenai residents indicate that lynx preyed on coho salmon (*Oncorhynchus kisutch*), pink salmon (*O. gorbuscha*), mallards and gulls (*Larus*) in the Kenai River drainage area. Lynx, however, were only reported to feed on the abundant salmon resource on 2 occassions. Lynx pursued voles in hayfields and snowshoe hares in regrowth habitat created by construction activity and previous agricultural efforts. Lynx also preyed on domestic rabbits, fowl and cats and fed on food scraps placed near houses. Finally lynx were observed feeding on road killed moose and small game along the Sterling Highway (Route 1). See Appendixes G and H for detailed accounts of lynx hunting, scavenging and depredation behavior in the corridor area.

4.6 Coyote Diet in the Study Area

Data from confirmed and suspected coyote scats were pooled for analysis of food habits because percent occurrence of major prey species in both scat categories were similar (Table 11). Chi-square comparison of counts of moose, microtine rodent and hare, the 3 prey most often consumed by coyotes, indicate no significant difference between prey occurrence in confirmed and suspected coyote scats (X^2 = 0.79, 2 df, P = 0.67). Percent occurrence of food items from coyote scats for each season are recorded in Appendix I.

Moose carrion was the most common food item in the diet of coyotes during the study period. Moose remains occurred in 70.4% (n = 179) and 52.5% (n = 183) of coyote snow and snow-free season scats.

Moose accounted for 43.6% and 23.4% total food items during the snow and snow-free seasons, respectively. Tracks and sightings of coyotes scavenging moose carrion also indicated that moose was important in coyote diets during both seasons. Coyotes were detected feeding on 15 moose carcasses in the study area and on 11 additional carcasses in areas adjacent to the study area. Fifteen of 26 carcasses were wolf kills, 8 moose died of starvation and the cause of death of 3 moose was not determined. On 6 occasions coyotes were ≤ 200 m of wolves feeding on moose carcasses.

Vole remains were the second most common item found in coyote feces. They occurred in 27.9% of snow season scats and in 68.9% of snow-free season scats, and accounted for 17.3% and 30.7% of the identified food items for the snow and snow-free seasons. During the 1988 snow-free

Table 11. Food items identified in 362 coyote scats collected in the Kenai National Wildlife Refuge, Alaska, 1988-1990.

	3 Snow Seasons		3 Snow-free Seasons	
Food Item	%Freq. Total Scats N = 179	%Freq. Total Items N = 289	%Freq. Total Scats N = 183	%Freq. Total Items N = 409
Snowshoe Hare (*Lepus americanus*)	25.7	15.9	47.5	21.2
Spruce Grouse (*Canichites canadensis*)	7.3	4.5	8.6	3.9
Spruce Grouse egg	0	0	1.5	0.7
Red Squirrel (*Tamiasciurus hudsonicus*)	2.8	1.7	3.8	1.7
Moose (*Alces alces*)	70.4	43.6	52.5	23.4
Vole (*Clethrionomys & Microtus spp.*)	27.9	17.3	68.9	30.7
Loon egg (*Gavia immer*)	0	0	0.5	0.2
Merganser Egg (*Mergus serrator*)	0	0	0.5	0.2
Unidentified Egg	0	0	0.5	0.2
Mallard (*Anas platyrhynchos*)	0	0.2	0.5	0.2
Great Horned Owl (*Bubo virginianus*)	1.1	0.7	0.5	0.2
Unidentified Bird	2.2	1.4	11.5	5.1
Salmon (*Oncorhynchus spp.*)	14.5	9.0	8.7	3.9
Grass (*Calamagrostis spp.*)	3.9	2.4	6.0	2.7
Beaver (*Castor canadensis*)	3.4	2.1	1.1	0.5
Caribou (*Rangifer tarandus*)	0.6	0.4	0	0
Porcupine (*Erethizon dorsatum*)	1.1	0.7	4.9	2.2
Unidentified Mammal	0.6	0.4	0	0
Blue Berries (*Vaccinium uliginosum*)	0	0	3.8	1.7
Low Bush Cranberry (*Vaccinium vitis-idaea*)	0	0	0.5	0.2
Prickly Rose (*Rosa acicularis*)	0	0	0.5	0.2
High Bush Cranberry (*Viburnum edule*)	0	0	0.5	0.2

season, when vole numbers were high, vole remains occurred in 85.3% of 109 scats. During the 1989 snow-free season, when vole densities were much lower, vole remains were detected in 49.3% of scats ($Z = 4.86$, $P < 0.0001$).

Remains of snowshoe hare occurred in 25.7% of coyote scats collected during snow seasons and in 47.5% of scats collected during snow-free seasons, and composed 15.9% ($n = 289$) and 21.2% ($n = 409$) of total identified items for snow and snow-free seasons, respectively.

Salmon bones and scales were detected in 14.5% of snow season and in 8.7% of snow-free season scats, accounting for 9.0% and 3.9% of the prey items found for snow and snow-free seasons. Visual observations confirmed that salmon were important in the diet of coyotes. Coyotes killed live salmon and retrieved recently deceased spawned-out salmon from the Swanson River and its tributaries. Coyotes also chased bald eagles (*Haliaetus leucocephalus*) off of fresh kills and scavenged salmon remains under eagle roosts. On 2 occasions, snow tracking sign indicated that coyotes dug up and consumed old salmon remains including dried up skin and bones.

Coyote diets also included spruce grouse and other birds. During snow seasons 7.3% of coyote scats contained grouse remains, and 3.3% contained remains of other bird species. During snow-free seasons 10.1% of coyote scats contained grouse remains, and 14.0% of scats contained unidentifiable bird and other bird species remains. Three percent of snow-free season scats contained shells of grouse and other bird eggs.

Coyote scats contained small quantities of several other species of birds, mammals and plants (Table 11). In addition, coyotes residing in the study area killed ermine on two occasions but did not consume them. Field observations also revealed that a coyote killed and ate a white-winged crossbill (*Loxia leucoptera*) and 2 young great-horned owls. Coyotes also scavenged Dolly Varden trout (*Salvelinus malma*), ice fisherman's bait and decayed remains of hunter-killed ducks.

Within-season comparisons of major food categories in coyote scats indicated that coyotes used moose carrion significantly more than hares or voles during snow seasons. During snow-free seasons, coyotes used birds significantly more than salmon (Table 12).

Comparison of seasonal coyote scat data consolidated into 8 major food categories indicate that snow season coyote diet differed significantly from snow-free season diet (X^2=50.70, 7 *df*, P<0.001). While use of hares and birds increased during snow-free seasons, only coyote use of voles increased significantly during snow-free seasons. Coyote use of moose and salmon was significantly lower during snow-free seasons (Table 13).

Tracking sign indicated that coyotes returned repeatedly to moose carcasses and eventually consumed all muscle, viscera, hide and smaller bones. Small game was completely consumed including stomach and cecal contents and most hair and feathers. On one occasion, a coyote dug up and consumed a hare cecum left from an old lynx kill. Twelve coyote scats contained a large percentage of moose rumen contents.

4.7 Coyote Diet in the Sterling Corridor

Although tracks indicated that coyotes were present in or adjacent

Table 12. Within season comparison of major food categories in coyote scats using Chi-square values on the Kenai National Wildlife Refuge, Alaska, 1988-1990 (test criterion $X^2_{.005} = 7.88$ used for $\alpha = 0.05$ due to correction for 10 possible simultaneous tests).

	3 Snow Seasons	3 Snow-free Seasons
Hare-Moose	36.28*	0.35NS
Vole-Hare	0.09NS	3.39+NS
Vole-Moose	39.96*	3.79+NS
Birds-Salmon	0.80NS	12.85*

* P<0.001 +NS P>0.005 NS P>0.10

Table 13. Pairwise seasonal comparisons of consolidated coyote food categories using Z-values on the Kenai National Wildlife Refuge, 1988-1991 (test criterion $Z_{.006} = 2.50$ used for $\alpha = 0.05$, one-tailed test, due to correction for 8 simultaneous tests).

	3 Snow seasons	3 Snow-free seasons	
	%Freq. Total Items N = 289	%Freq. Total Items N = 409	Z-test Statistic
Snowshoe Hare	15.9	21.3	1.68*NS
Birds	5.9	10.0	1.99*NS
Red Squirrel	1.7	1.7	0.02NS
Moose	43.6	23.4	5.6**
Vole	17.3	30.7	4.03**
Salmon	9.0	3.9	2.78*
Other Mammals	2.1	2.2	0.59NS
Vegetation	2.4	4.4	1.81*NS

** P<0.0001 * P<0.001 *NS P>0.006 NS P>0.10

to most Kenai residential areas, coyote food habits in the developed corridor were not documented in great detail, in part because coyotes appeared to avoid proximity to human activity. With the exception of one individual (C005), coyotes fled from observers in open areas at ranges of 200-300 m and avoided the immediate vicinity of residential buildings. My field observations and reports from Kenai Peninsula residents indicate that coyotes fed on road kills, hunted voles in hayfields, depredated small domestic livestock and dogs and were often observed fishing and scavenging for salmon carcasses in the developed corridor area. Appendix J contains detailed accounts of coyote corridor hunting, scavenging and depredation behavior.

4.8 Comparison of Lynx and Coyote Diets

Diets of lynx and coyotes were significantly different during the snow season ($X^2 = 196.75$, 7 *df*, $P<0.0001$). Lynx used snowshoe hares and red squirrels significantly more and used moose, voles, and fish significantly less than coyote (Table 14).

Simple dietary overlap for coyote-lynx was calculated using percent total food items data for 3 snow seasons. The resulting overlap value was 42.4%.

Detailed statistical comparison of diets from lynx and coyote snow-free seasons is not valid because few lynx scats were collected during July-October of snow-free seasons. Visual observations of lynx hunting during the snow-free season and the increase of birds and vole remains in 42 lynx scats collected in early summer suggest, however, that lynx

Table 14. Pairwise comparisons of lynx and coyote major food categories for 3 snow seasons on the Kenai Peninsula, Alaska, 1988-1990 (test criterion $Z_{.006} = 2.50$ used for $\alpha = 0.05$, one-tailed test, due to correction for 8 simultaneous tests).

	Lynx %Freq. Total Items N=229	Coyote %Freq. Total Items N=289	Z-Statistic
Snowshoe hare	63.6	15.9	11.20***
Birds	7.9	6.6	0.56NS
Red squirrel	10.4	1.7	4.27**
Moose	4.8	43.6	11.21***
Vole	9.1	17.3	2.71*
Fish	0.9	9.0	4.09**
Other mammals	1.3	2.1	1.96*NS
Vegetation	1.3	2.4	0.93NS

*** $P<0.0001$ ** $P<0.001$ * $P<0.006$ *NS $P \geq 0.05$ NS $P>0.10$

as well as coyote consumption of these species increased during the warmer months (Table 15). Overlap in snow-free season diet was 51.4%.

The amount of snowshoe hare in coyote and lynx diets became more similar during the warmer months. Hare remains were found in 47.5% of 183 coyote and in 66.7% of 42 lynx snow-free season scats. During snow seasons hare remains occurred in only 25.7% of 179 coyote scats but in 91.3% of 161 lynx scats.

Coyote use of moose carrion and porcupine continued during the snow-free season. Road-killed porcupines were observed in the study area during both seasons. Coyote use of carrion included carcasses that were in an advanced state of decomposition. Large fly larvae were found in at least 8.2% (*n* = 183) of snow-free season scats of coyotes; no lynx scats were found containing fly larvae. Live fly larvae in advanced stages of developement were not observed in scats we collected. Neither moose nor porcupine remains occurred in 42 snow-free season scats of lynx, but lynx M30 fed on a freshly killed cow moose while hunters were butchering it on 29 September 1990.

Green grass constituted over 25% of the volume of a small percentage of both lynx and coyote scats; suggesting that this plant material was intentionally consumed. No apparent digestion of the grass occurred in either carnivore. The intestinal round worm *Toxocara cati* and unidentified tape worms were found in the small intestines of 3 lynx. Small pear-shaped worms resembling the adult form (canid host) of the tapeworm *Echinococus granulosus* were recovered from several coyote scats. Two human cases of infection with *E. granulosus*, serious enough to warrant surgery to remove hydatid cysts, occurred on the Kenai

Table 15. Percent frequency of vole and bird remains in lynx and coyote scats during 3 snow and 3 snow-free seasons on the Kenai National Wildlife Refuge, Alaska, 1988-1990.

	3 Snow seasons		3 Snow-free seasons	
	% Freq. Total Scats		% Freq. Total Scats	
	Vole	Bird	Vole	Bird
Lynx	14.9	11.2	50.0	21.4
Coyote	27.9	10.6	68.9	24.6

peninsula during the study period (Palmer 1992).

Remains of berries occured in a small percentage (5.3%) of coyote scats collected during 2 snow-free seasons. No lynx scats analyzed contained remains of berry or rose (*Rosa* sp.) fruit.

4.9 Lynx Habitat Use

Lynx showed preference (% use > % availability) for regrowth in 1947 burn areas (1947 burn/1947 burn) and remnants of mature forest in the 1947 burn (mature/1947 burn) (Tables 16 and 17). Lynx avoided both 1969 burn types, crushed (crushed/crushed) and large mature (mature/mature) forest areas. Although data from ground locations in the road buffer area do not support lynx preference for remnant mature stands in the crushed area, the larger data set for aerial locations indicates that lynx preferred the small stands of 1947 burn regrowth and mature forest in the crushed area. Despite inevitable differences in habitat quality between the entire study area and the smaller road buffer area, Wilcoxon sign rank tests comparing E* index values for aerial and ground locations were not significantly different ($T = 0.14$, $P = 0.55$) A Freidman's test applied to aerial locations confirms that lynx were selective in their use of 8 combinations of study area habitat types ($T_2 = 14.06$, $P<0.01$). Multiple comparisons test results also indicated that use of avialable habitats differed (Appendix K).

Analysis of macro habitat at 619 aerial and 373 ground locations yielded simplified tables of use; patterns of habitat use were essentially the same as reported for the micro/macro habitat analysis

Table 16. Lynx micro/macro habitat selection (520 aerial locations) on the Kenai National Wildlife Refuge, Alaska, November 1987-September 1991. Sample size in parentheses.

Habitat		Availability (%)r	Use (%)p	Forage Ratio p/r (*)	Multiple** Comparison Rank Group
Micro	Macro				
1947 Burn	1947 Burn	38.4	67.1(349)	1.75(+0.07)	A
1947 Burn	Crushed	0.3	1.0(5)	3.30(+0.38)	C
Mature	1947 Burn	5.1	18.1(94)	3.50(+0.41)	B
Mature	Crushed	0.3	0.6(3)	2.00(+0.16)	C
Crushed	Crushed	3.2	1.0(5)	0.31(-0.63)	D
Mature	Mature	31.1	10.7(56)	0.34(-0.63)	E
Mature	1969 Burn	1.4	0	0 (-1.00)	D
1969 Burn	1969 Burn	20.2	1.5(8)	0.10(-0.67)	E

* equivalent Vanderploeg and Scavia Relativized Electivity Index(E*) value in parenthesis

** Habitats with same letter do not differ (P > 0.05)

Table 17. Lynx micro/macro habitat selection in the 2400 m road buffer (319 ground locations) on the Kenai National Wildlife Refuge, Alaska, November 1987-September 1991. Sample size in parentheses.

Habitat		Availability (%)r	Use (%)p	Forage Ratio r/p (*)
Micro	Macro			
1947 Burn	1947 Burn	28.7	59.3(189)	2.07(+0.33)
1947 Burn	Crushed	0.8	1.9(6)	2.38(+0.40)
Mature	1947 Burn	5.2	10.0(32)	1.92(+0.30)
Mature	Crushed	0.5	0.3(1)	0.60(-0.24)
Crushed	Crushed	4.0	0.6(2)	0.15(-0.73)
Mature	Mature	45.1	25.1(80)	0.56(-0.30)
Mature	1969 Burn	2.8	0.3(1)	0.11(-0.86)
1969 Burn	1969 Burn	12.9	2.5(8)	0.19(-0.73)

* equivalent Vanderploeg and Scavia Relativized Electivity Index(E*) value in parenthesis

(Appendices L and M).

Seasonal comparison of habitat types of 520 lynx aerial relocations show that rank order use of 5 micro/macro habitats were the same in the snow and snow-free seasons (Table 18). Mature/1947 burn was the most preferred type followed by 1947 burn/1947 burn, all crushed and all 1969 burn habitat types.

Comparison of seasonal habitat location counts, however, resulted in a significant test statistic ($X^2 = 16.01$, $P<0.003$). Z tests indicate that differential use of mature/mature ($Z = 3.13$, $P<0.002$) and 1947 burn/1947 burn areas ($Z = 3.36$, $P<0.001$) contributed the most to the overall Chi-square statistic. Lynx were located more often in contiguous mature stands and in remnant mature stands in the 1947 burn during snow-free seasons and more often in burned areas within the 1947 burn periphery during snow seasons.

When 7 locations of females denned in mature stands (mature/mature) during June and July were removed from the data set, lynx use of mature stands was still significantly greater during the snow-free months ($Z = 2.39$, $P<0.02$).

Hares were over twice as numerous in the 1947 burn as in mature forest areas traversed by lynx during snow seasons. Lynx were snow-tracked for 23.4 km through mature/mature forest and for 28.5 km through areas within the 1947 burn periphery (1947 burn/1947 burn and mature/1947 burn). Numbers of hare trails encountered by lynx averaged 0.44/50 m in mature forest and 1.16/50 m in 1947 burn areas. ($Z = 8.28$, $P = 0.0$). Lynx averaged 0.56 hare pursuits/km (13 total pursuits) in contiguous mature forest areas and 1.02 hare pursuits/km in 1947 burn

Table 18. Lynx seasonal micro/macro habitat selection, all crushed and 1969 burn types combined, (520 aerial relocations) on the Kenai National Wildlife Refuge, Alaska, November 1987-September 1991.

Habitat		Avail-ability (%)r	Snow-free Season		Snow Season	
Micro	Macro		Use (%)p	Forage Ratio (*)	Use (%)p	Forage Ratio (*)
1947 Burn	1947 Burn	38.4	60.6(165)	1.58(+.07)	74.4(184)	1.94(+.25)
Mature	1947 Burn	5.1	20.6(56)	4.04(+.49)	15.3(38)	3.00(+.44)
All	Crushed	3.8	2.6(7)	.68(-.33)	2.4(6)	.63(-.29)
Mature	Mature	31.1	14.7(40)	.47(-.48)	6.3(16)	.20(-.74)
All	1969 Burn	21.6	1.5(4)	.07(-.90)	1.6(4)	.07(-.90)

* equivalent Vanderploeg and Scavia Relativized Electivity Index(E*) value in parenthesis

areas (29 total pursuits).

Sample sizes for kills are small, but Lynx capture success appeared to be greater in unburned mature forest areas (0.38 kills/pursuit) than in the 1947 burn (0.17 kills/pursuit). Increased capture success appeared to compensate lynx for lower hare numbers in mature forest. Lynx moved similar distances and therefore may have expended approximately the same effort per hare capture in the two habitat types. Snow-tracked lynx killed 0.21 hares/km in mature and 0.18 hares/km in 1947 burn areas.

Lynx did not kill hares at sites with dense understory vegetation. Although measurements of stem density were not taken while snow-tracking, all 10 kills were made in open understories where lynx could bound after hares in a relatively straight line. No hares were killed in dense stands of alder or in spruce/birch regrowth with estimated overhead >65%. Lynx did, however, demonstrate the ability to bound great distances (2-5 m bounds) in 1947 burn areas with 25-65% overhead cover. Lynx often managed to leap through small clumps of dense regrowth (<10-cm diameter) with stems growing only several centimeters apart while chasing hares.

Because I did not determine availability of forest stands by tree species within the major burn and contiguous mature forest areas, I attempted to determine the value of different stand types to lynx by recording the numbers of hare and squirrel trails encountered by snow-tracked lynx in areas dominated by different species.

In contiguous unburned areas alder thickets had the highest average number of hare trails per 50 m lynx trail (0.82, *SD* = 1.00) while mature white spruce had the second highest number of hare trails (0.74, *SD* = 0.95). Mature mixed white spruce/birch, old black spruce and completely deciduous mature stands had 0.57 (*SD* = 0.81), 0.51 (*SD* = 0.81) and 0.0 hare trails per 50 m respectively. Large homogeneous stands of mature white spruce and white spruce/birch were not often used by lynx. Most mature white spruce and mature white spruce/birch forest hunted by lynx was edge habitat within 100 m of alder thickets.

Hare activity in mature forests was particularly heavy under robust white spruce that had lower branches growing within 2 m of the ground and which bordered alder thickets. Hares appeared to feed on rose, low-bush cranberry (*Vaccinium vitis-idaea*) and other plants available because of the interception of snow by these edge-growing spruce. Red squirrels were particularly active in these stands of white spruce and often were the source of large numbers of spruce tips dropped on the snow (Smith 1967) upon which the hares also fed.

The second vegetation type in mature forest hunted by lynx is described as old Open Black Spruce Forest. These stands of large black spruce grew in nonpermafrost areas on lake shores and trees had a cone-shaped growth form with many branches growing close to the ground. Open areas between black spruce supported shrub growth that could have been used as browse, but due to deep snow I failed to determine what hares fed on in these stands.

Large stands of mature hardwoods in unburned areas were avoided by lynx during winter. Lynx rarely moved through homogeneous stands of mature deciduous trees (150 m trail out of a total of 61 km of lynx trail). Little winter browse, escape cover, or track of small game was observed in these areas.

Composition and use of forest stands in the 1947 burn area is complicated by the presence of remnants of the preceding mature stand types, varied species composition of regrowth stands and a considerable variation in overhead cover available in regrowth forest.

Mixed stands of spruce and birch regrowth appeared to be the vegetation type most preferred by lynx and hares. Trail segments of lynx moving through predominately mixed stands of white/black spruce and birch (17.8 km lynx trail, average overhead cover 41%) crossed an average of 2.11 hare trails/50 m. Areas with only spruce saplings were not used as much as mixed stands. Habitat used by lynx consisting of regrowth of white and black spruce (8.1 km lynx trail, average overhead cover 32%) averaged 0.92 hare trails/50 m. Also the number of hare trails encountered in both spruce and spruce/birch regrowth increased as estimated overhead cover increased (Table 19).

Hares often fed on white spruce while I saw no sign that hares browsed on black spruce. Also, I observed several "hare pockets" located on the edges of remnant mature stands that were densely vegetated with small 1-2 m white spruce that were apparently seeded by nearby mature spruce trees.

Hare use of mature forest remnants in the 1947 burn (all mature types combined) appeared to be higher than hare use of large contiguous areas of unburned forest ($Z = 2.10$, $P = 0.04$). Lynx trail segments ($n = 43$) in remnant mature stands had an average of 1.26 hare trails/50 m. An average of 0.63 hare trails/50 m of lynx trail occured on 20.2 km of lynx trail in large expanses of mature forest.

Table 19. Average hare trails per 50 m in different ranges of overhead cover in the 1947 burn on the Kenai National Wildlife Refuge, Alaska. Number of trail segments in parentheses.

Regrowth Types	Overhead Cover Ranges			
	0 - 25%	26 - 50%	51 - 75%	76 - 100%
Spruce*	0.55(84)	1.01(41)	1.43(28)	2.30(9)
Spruce/Birch**	1.50(106)	2.03(160)	2.67(58)	3.55(32)

---

* = 8.1 km total trail length

** = 17.8 km total trail length

Squirrels appeared to be more numerous in large expanses of mature forest than in the 1947 burn areas used by lynx. Squirrel trails encountered by lynx averaged 0.38/50 m in unburned mature forest and 0.25/50 m in areas within the 1947 burn periphery ($Z = 2.7$, $P = 0.007$). Low numbers of squirrel trails (0.23 squirrel trails/50 m) were encountered in burned areas of the 1947 burn, but the number of squirrel trails in remnant white spruce stands was much higher at 1.0 trails/50 m ($Z = 2.45$, $P = 0.007$).

Lynx moved on the highest terrain available in close proximity to areas used by hares. Ground level estimates of terrain type are somewhat subjective, but 45.9% of lynx trail segments were located on top of sharply defined ridges. Only 1.1% of lynx trail segments were located in low draws between hills and ridges. Higher ground often was vegetated with mature spruce and birch trees bordering alder thickets in the unburned areas and regrowth spruce and birch in the burned areas. Lynx moved along ridges bordering good hare covers, sitting frequently to look down-slope into hare habitat.

Lynx appeared to avoid crossing open areas greater than 100 m in width. While lakes and open bogs composed 20.3% of the land surfaces in the 2,400 m road buffer where most of snow-tracking was conducted, only 0.8% (550 m) of lynx trail segments crossed large open areas. On the 3 occasions that we observed sign indicating that lynx crossed sections of lakes and open bogs 150-300 m wide the lynx sat long enough on edges of open areas to change position and orientation of their hind legs 3 or more times. On one occasion I. Martin (pers. commun.) observed sign that a lynx climbed a leaning tree on the shore of a lake prior to crossing.

Lynx backtracked, looped and zigzagged in areas where many hare trails occured. Lynx also hunted ridge lines by zigzagging while moving parallel to the long axis of the terrain feature. On 1 December 1989, I tracked a lynx on a hill top approximately 300 m in diameter for 2,050 m. The lynx crossed its own track 8 times while hunting this particularly attractive (1.62 hare trails/50 m) hare cover.

Lynx tracks indicating sitting occurred in or near good cover for hares. Lynx often sat while moving through areas of concentrated hare sign, before entering a tree or brush line, on snow piled on sides of roads as well as on elevated terrain. Sitting behavior was observed 1 or more times in 137 (11.1%) of a total of 1,229 trail segments.

During our field work and aerial location of lynx we made additional observations of lynx social behavior. Interactions between lynx and scent marking behavior are described in Appendix R.

4.10 Coyote Habitat Use

Coyotes displayed strong preference for burned and unburned portions of the 1947 burn and also appeared to prefer the crushed areas (Table 20 and Table 21). Coyotes avoided large contiguous stands of mature forest and areas within the burn periphery of the 1969 burn. A Friedman's test on rankings of habitat use by individual coyotes indicated that coyotes were selective in their use of the 8 study area micro/macro burn combinations ($T_2 = 18.70$, $P = 0.0001$)(Appendix S). Low numbers of coyote locations, however, increased sampling error associated with rare

Table 20. Coyote micro/macro habitat selection (103 aerial relocations) on the Kenai National Wildlife Refuge, Alaska, May 1988-April 1990. Sample size in parentheses.

Habitat		Availability (%)	Use (%)	Forage Ratio(*)	Multiple** Comparison Rank Group
Micro	Macro				
1947 Burn	1947 Burn	38.4	53.4(55)	1.39(-0.28)	AB
1947 Burn	Crushed	0.3	0	0 (-1.00)	CD
Mature	1947 Burn	5.1	22.3(23)	4.37(+0.03)	A
Mature	Crushed	0.3	2.9(3)	9.67(+0.59)	ABC
Crushed	Crushed	3.2	9.7(10)	3.03(+0.09)	BC
Mature	Mature	31.1	4.9(5)	0.16(-0.85)	F
Mature	1969 Burn	1.4	1.0(1)	0.71(-0.52)	DE
1969 Burn	1969 Burn	20.2	5.8(6)	0.29(-0.72)	EF

* equivalent Vanderploeg and Scavia Relativized Electivity Index(E*) value in parenthesis

** Habitats with the same letter do not differ (P = 0.05).

Table 21. Coyote micro/macro habitat selection in the 2,400 m road buffer area (94 ground locations) on the Kenai National Wildlife Refuge, Alaska, May 1988-April 1990.

Habitat		Availability (%)	Use (%)	Forage Ratio(*)
Micro	Macro			
1947 Burn	1947 Burn	28.2	63.4(59)	2.25(+0.23)
1947 Burn	Crushed	0.8	1.1(1)	1.38(0)
Mature	1947 Burn	5.2	17.2(16)	3.31(+0.40)
Mature	Crushed	0.5	1.1(1)	2.20(+0.21)
Crushed	Crushed	4.0	8.6(8)	2.15(+0.21)
Mature	Mature	45.1	8.6(8)	0.19(-0.72)
Mature	1969 Burn	2.8	0	0 (-1.00)
1969 Burn	1969 Burn	12.9	0	0 (-1.00)

* equivalent Vanderploeg and Scavia Relativized Electivity Index(E*) value in parenthesis

habitats; and the high number of habitats used in the analysis resulted in some low E* values that were inconsistent with forage ratios.

Analysis of coyote habitat use by consolidating data into the 4 main (macro) habitat types reduced sampling error effects resulting from rare and numerous habitats on the E* index and the multiple comparison test (Tables 22 and 23). A Friedman's test applied to macro habitat data (aerial locations) confirmed that coyotes were selective in their use of study area habitat ($T_2 = 5.0$, $P = 0.02$). Most coyote multiple comparison test ranks of 1947 burn and crushed area use were high (Appendix T). Conversely, use ranks of contiguous unburned mature stands and the 1969 burn area were generally low.

Coyote use of macro habitats in the whole study area and in the road buffer area did not appear to be different. The Wilcoxon sign rank test applied to E* values of study area and road buffer macro habitat use detected no significant difference ($T = -0.36$, $P = 0.86$.).

Analysis of aerial relocations in the enlarged (2,586 km^2) coyote "box" around the study area allowed me to use approximately twice as many relocations as used in the analysis illustrated in Table 23, and confirmed that coyotes preferred 1947 burn areas and avoided large unburned areas (Table 24). Crushed habitats were deleted from this analysis because they comprised only 0.4% of the enlarged area but were highly available to study coyotes captured in the smaller study area. Preliminary calculations indicated that inclusion of the crushed type resulted in an extreme forage-ratio value (19.25) and accompanying distortions of E* values.

There was no significant difference in habitat use between snow and

Table 22. Coyote macro habitat selection (112 aerial relocations) on the Kenai National Wildlife Refuge, Alaska, May 1988-April 1990.

Habitat Macro	Availability (%)	Utilization (%)	Forage Ratio(*)	Multiple** Comparison Rank Group
1947 Burn	43.5	75.9(85)	1.74(+0.12)	A
Crushed	3.8	12.4(14)	3.26(+0.41)	B
Mature	31.1	5.4(6)	0.17(-0.79)	C
1969 Burn	21.6	6.2(7)	0.29(-0.67)	C

* equivalent Vanderploeg and Scavia Relativized Electivity Index(E*) value in parenthesis

** Habitats with same letter do not differ ($P > 0.05$).

Table 23. Coyote macro habitat selection in the 2400 m road buffer area (111 ground relocations) on the Kenai National Wildlife Refuge, Alaska, May 1988-April 1990.

Habitat Macro	Availability (%)	Use (%)	Forage Ratio(*)
1947 Burn	33.9	79.3(88)	2.34(+0.34)
Crushed	5.3	10.8(12)	2.04(+0.28)
Mature	45.2	9.9(11)	0.22(-0.67)
1969 Burn	15.6	0	0 (-1.00)

* equivalent Vanderploeg and Scavia Relativized Electivity Index(E*) value in parenthesis

Table 24. Coyote macro habitat selection in the "enlarged coyote" study area (201 aerial relocations) on the Kenai National Wildlife Refuge, Alaska, May 1988-April 1990. Crushed area habitats excluded from analysis. Sample size in parentheses.

Habitat Macro	Availability (%)	Use (%)	Forage Ratio(*)	Multiple** Comparison Rank Group
1947 Burn	47.8	79.6(160)	1.67(+0.33)	A
Mature	43.1	15.9(32)	0.37(-0.38)	C
1969 Burn	9.1	4.5(9)	0.49(-0.27)	B

* equivalent Vanderploeg and Scavia Relativized Electivity Index(E*) value in parenthesis

** Habitats with same letter do not differ (P > 0.05).

snow-free seasons. Chi-square tests applied to seasonal macro habitat use yielded nonsignificant statistics for aerial locations in the whole study area (X^2 = 4.18, 3 *df*, P = 0.24) (Table 25), ground locations in the road buffer area (X^2 = 0.64, 3 *df*, P = 0.89) and aerial locations in the enlarged coyote "box" area (X^2 = 3.66, 3 *df*, P = 0.30).

Despite small relocation sample sizes in the 3 areas analyzed, similar habitat preferences in the whole study area, the road buffer area and the enlarged coyote "box" area indicate that these results are valid.

4.11 Comparison of Lynx and Coyote Habitat Use

To compare lynx-coyote habitat I used only relocations from the primary study area. Because sample sizes of coyote relocations were small and therefore probability of sampling and type 2 error higher when using many habitat categories, I accepted only the results of the comparisons for the 4 macro burn types.

Habitat use of coyotes and lynx was similar. Both species preferred 1947 burn habitats (Tables 26 and 27). Overlap analysis of habitat use (Anthony and Smith 1977) of coyote-lynx resulted in high overlap values for both aerial and ground locations for all seasonal comparisons. Habitat use overlap for the whole study area was 78.7% and 92% for snow-free and snow seasons respectively. For the road buffer area overlap in coyote-lynx habitat use was 83.3% and 85.7% for snow-free and snow seasons. Chi-square tests applied to all macro habitat locations, however, also indicated a significant difference between lynx and coyote

Table 25. Coyote seasonal macro habitat selection in the whole study area (112 aerial relocations) on the Kenai National Wildlife Refuge, Alaska, May 1988-April 1990. Sample size in parentheses.

Habitat Macro	Availability (%)	Snow-free Season Use (%)	Forage Ratio (*)	Snow Season Use (%)	Forage Ratio (*)
1947 Burn	43.5	70.0(42)	1.61(-.04)	82.6(43)	1.90(+.32)
Crushed	3.8	18.3(11)	4.82(+.47)	5.8(3)	1.53(+.22)
Mature	31.1	5.0(3)	0.16(-.85)	5.8(3)	0.19(-.67)
1969 Burn	21.6	6.7(4)	0.31(-.72)	5.8(3)	0.27(-.56)

* equivalent Vanderploeg and Scavia Relativized Electivity Index(E*) value in parenthesis

Table 26. Lynx and coyote macro habitat selection in the study area (aerial relocations) on the Kenai National Wildlife Refuge, Alaska, May 1988-April 1990. Sample sizes in parenthesis.

Habitat Macro	Availability (%)	Lynx Use (%)	Lynx Forage Ratio(*)	Coyote Use (%)	Coyote Forage Ratio(*)
1947 Burn	43.5	84.4(302)	1.94(+0.46)	75.9(85)	1.74(+0.12)
Crushed	3.8	1.7(6)	0.45(-0.22)	12.4(14)	3.26(+0.41)
Mature	31.1	12.0(43)	0.39(-0.28)	5.4(6)	0.17(-0.79)
1969 Burn	21.6	2.0(7)	0.09(-0.79)	6.2(7)	0.29(-0.67)

* equivalent Vanderploeg and Scavia Relativized Electivity Index(E*) value in parenthesis

Table 27. Lynx and coyote macro habitat selection in the 2,400 m road buffer study area (ground relocations) on the Kenai National Wildlife Refuge, Alaska, May 1988-April 1990. Sample size in parentheses.

Habitat Macro	Availability (%)	Lynx Use (%)	Lynx Forage Ratio(*)	Coyote Use (%)	Coyote Forage Ratio(*)
1947 Burn	33.9	70.8(223)	2.09(+0.44)	79.3(88)	2.34(+0.34)
Crushed	5.3	2.5(8)	0.47(-0.28)	10.8(12)	2.04(+0.28)
Mature	45.2	24.1(76)	0.53(-0.22)	9.9(11)	0.22(-0.67)
1969 Burn	15.6	2.5(8)	0.16(-0.66)	0	0 (-1)

* equivalent Vanderploeg and Scavia Relativized Electivity Index(E*) value in parenthesis

habitat use (whole study area, $X^2 = 33.14$, 3 *df*, $P < 0.01$ and road buffer area, $X^2 = 21.84$, 3 *df*, $P < 0.01$).

Comparison of relocation counts of lynx and coyotes by season showed nonsignificant differences during the snow season (whole study area, $X^2 = 5.05$, 3 *df*, $P = 0.17$ and road buffer, $X^2 = 6.62$, 3 *df*, $P = 0.09$). Lynx and coyote habitat use differed more during the warmer months (whole study area, $X^2 = 30.50$, 3 *df*, $P < 0.01$ and road buffer area, $X^2 = 15.59$, 3 *df*, $P < 0.01$) (Tables 28 and 29). Lynx used large contiguous stands of mature growth more than coyotes (whole study area, $Z = 2.34$, $P = 0.02$ and road buffer area, $Z = 2.53$, $P = 0.01$) during the snow-free season. Recalculation with relocations of lynx denned in mature stands removed from the data set, yielded a marginally significant difference in use of mature forest during the snow-free season ($Z = 1.86$, $P = 0.06$). Coyotes used the crushed area significantly more than lynx (whole study area, $Z = 5.05$, $P < 0.01$ and road buffer, $Z = 3.22$, $P < 0.01$) during the warm season.

Coyote and lynx use of roads was very different. During the snow season, when tracks were easily observed, coyotes used roads on a daily basis to move long distances within the study area. Lynx, however, usually crossed roads at a right angle and did not use or follow roads for long distances. Lynx walked on roads for further than 100 m for a total of 7.6 km during 3 snow seasons. If recorded, coyote travel on study area roads during snow seasons would have totaled hundreds of kilometers. Also most coyotes captured after snow-melt were trapped on Swan Lake Road. Even though our experience indicates that lynx were very vulnerable when they encountered scat sets, only two study lynx

Table 28. Lynx and coyote snow-free season macro habitat selection (aerial relocations) on the Kenai National Wildlife Refuge, Alaska, May 1988-April 1990. Sample size in parentheses.

Habitat Macro	Availability (%)	Lynx Use (%)	Lynx Forage Ratio(*)	Coyote Use (%)	Coyote Forage Ratio(*)
1947 Burn	43.5	79.2(148)	1.82(+0.43)	70.0(42)	1.61(-0.04)
Crushed	3.8	1.6(3)	0.42(-0.25)	18.3(11)	4.82(+0.47)
Mature	31.1	17.1(32)	0.55(-0.14)	5.0(3)	0.16(-0.85)
1969 Burn	21.6	2.1(4)	0.10(-0.79)	6.7(4)	0.31(-0.72)

* equivalent Vanderploeg and Scavia Relativized Electivity Index(E*) value in parenthesis

Table 29. Lynx and coyote snow-free season macro habitat selection in the 2400 m road buffer area (ground relocations) on the Kenai National Wildlife Refuge, Alaska, May 1988-April 1990. Sample size in parentheses.

Habitat Macro	Availability (%)	Lynx Use (%)	Lynx Forage Ratio(*)	Coyote Use (%)	Coyote Forage Ratio(*)
1947 Burn	33.9	72.4(134)	2.14(+0.48)	79.6(43)	2.35(+0.34)
Crushed	5.3	1.6(3)	0.30(-0.43)	11.1(6)	2.09(+0.29)
Mature	45.2	25.4(47)	0.56(-0.16)	9.3(5)	0.21(-0.67)
1969 Burn	15.6	0.5(1)	0.03(-0.92)	0	0 (-1)

* equivalent Vanderploeg and Scavia Relativized Electivity Index(E*) value in parenthesis

were captured a total of 2 times in canid scat sets along the Swan Lake Road.

4.12 Lynx and Coyote Activity

Lynx and coyotes were active during a large percentage of observations recorded during both snow and snow-free seasons (Tables 30 and 31). Comparison of daylight activity patterns of lynx and coyotes indicates similar high activity rates for the 1989 snow-free, the 1988-89 snow and the 1989-90 snow seasons. There was, however, a significant difference between lynx and coyote activity percentages during the snow-free season of 1988 ($Z = 3.57$, $P < 0.001$), when lynx and coyote were active during 42.4% and 65.6% of observations respectively.

Table 30. Percent of active observations (0900-1500 hours) of lynx and coyotes during snow seasons on the Kenai National Wildlife Refuge, Alaska, 1988-1990. Total number of observations in parentheses.

Year	Lynx	Coyote	Comparison Z-Value
1988-1989	56.6 (173)	61.4 (88)	Z = 0.73, P = 0.47
1989-1990	77.7 (112)	65.0 (40)	Z = 1.58, P = 0.11
1988-1990 (2-Year Average)	64.9 (285)	62.5 (128)	

Table 31. Percent of active observations (0900-1700) of lynx and coyotes during snow-free seasons on the Kenai National Wildlife Refuge, Alaska, 1988-1990. Total number of observations in parentheses.

Year	Lynx	Coyote	Comparison Z-Values
1988	43.0 (200)	65.6 (90)	Z = 3.57, P = 0.0000
1989	69.3 (114)	73.0 (89)	Z = 0.58, P = 0.56
1988-1990	52.5 (314)	69.3 (179)	

5. DISCUSSION

5.1 Lynx Population Characteristics and Management Implications

Diminishing hare density during 1987-91 apparently was responsible for low reproductive performance, starvation and emigration of lynx from the study area. The kitten year class of June 1987 was the last to recruit members into the study area population. During the following years small kittens were captured or seen by local residents outside the study area, but all kittens captured after 1988 starved. Detection of these "nonviable" kittens by the public during periods when lynx daytime activity was high due to low hare densities may deceive hunters and trappers into thinking that local lynx populations can sustain harvest when lynx recruitment levels are low.

Our observations of reproductive performance of lynx on the Kenai Peninsula suggest that too much emphasis has been placed on the presence of kittens in managed populations of lynx (O'Connor 1984). At low hare densities, whether young lynx survive their first and second winters and are recruited into local populations seems to be more important to the maintenance of lynx populations than the number of kittens born, seen or trapped. Management agencies that seal and measure lynx pelts could measure kittens by month of capture and assign small kittens to a nonviable category when determining the ability of a lynx population to sustain harvest. Alternately, detection of sub-adults in yearly harvests could be used to determine if young are being recruited into populations.

Female lynx appeared to be more physically stressed than male lynx by low hare densities. Two adult females starved while no adult males starved, and adult females captured in spring also were in noticeably poorer physical condition than adult males. All lynx injured or killed as a result of capture efforts were females. Even male kittens appear to have an advantage during lean times, for 5 of 6 kittens captured in 1988 and 1989 were males. Finally, Kenai female lynx appeared just as vulnerable to trapping and depredation related mortality as male lynx. During the study period females and males were captured in approximately the same ratio and numbers of females and male lynx involved in depredation incidents were approximately equal.

Lynx responded spatially to decreasing hare density in 1 of 3 ways. Lynx either stayed in their traditional areas of activity, moved to new areas, or moved seasonally between 2 or more areas. The smaller home ranges occupied by females (Kesterson 1988) are probably adaptive for female lynx during most years. Smaller, high-quality home ranges may be needed by females to successfully raise young that are not capable of traveling long distances.

I speculate, however, that normally adaptive behavior that causes lynx females to use smaller areas may predispose female lynx to higher rates of starvation during declines in hare abundance. Adult males may be less likely to starve because their larger home ranges contain more potential prey or "hare pockets".

I believe that most adult lynx remained in their traditional home ranges despite extremely low hare density because of the natural barriers to emigration around the lowland study area. Occupation of surrounding areas by resident lynx experiencing low mortality due to the trapping closure may have also limited movement. Finally, the fact that the 1947 burn area, a large part of the study area, is probably the best hare/lynx habitat on the Kenai Peninsula, also discouraged emigration during the study period.

All radio-collared lynx that did leave the study area moved south and used the areas within a few kilometers north and south of the Kenai River suggesting that areas in the Sterling corridor had more prey and perhaps fewer resident lynx than the study area. That 3 of 7 lynx that used the corridor area were illegally killed suggests that this area has the potential to act as a "predator sink" by attracting and destroying a substantial number of lynx.

Even though the lynx trapping and hunting seasons were closed on the Kenai Peninsula and most of hunters, trappers and home owners obeyed the lynx-season closure, human-related mortality effectively doubled the mortality rate of radio-collared adult lynx. While two adult female lynx died of starvation, three lynx (one adult female and two adult males) were illegally killed in residential areas south of the study area. The lack of fear of humans by lynx that we observed during this study (Appendix B) apparently caused these animals to be vulnerable to shooting. Thus, human causes of mortality can have significant negative effects on lynx populations despite appropriate harvest regulations.

Four potential causes or categories of illegal killing of lynx were identified during the study. First, depredation conflicts in residential areas probably were responsible for 2 of the 3 illegal study lynx kills. Second, the killing of 1 lynx on a road shoulder in a residential area was probably done by a Kenai resident knowledgeable about the lynx trapping/shooting closure. This kind of illegal kill is placed in a separate category because it suggests intentional violation of harvest regulations and also violation of other fish and game regulations such as the prohibition against shooting on or across roadways. Third, deaths of lynx after the conclusion of my field work were attributed to shooting incidental to small game and moose hunting in autumn, possibly by non-Kenai residents unaware of the lynx closure. The fourth potential source of illegal lynx kills was fur trappers and dedicated predator callers. Kenai trappers and predator callers, however, killed relatively few lynx. Trappers appeared to make conscientious efforts to avoid catching lynx and the one collared lynx trapped during the study period was properly released. Trapping conditions, howerver, were poor due to deep winter snows. Increased trapper effort during the study period may have resulted in a greater incidental catch of lynx.

Improper small animal husbandry practices were responsible for most depredation incidents. Protected raptors as well as lynx are increasingly likely to be victims of owner wildlife conflicts over small domestic livestock and pets if the public is not better informed about this issue. Reintroductions of lynx in Europe have resulted in controversy between farmers and conservationists (Breitenmoser and Haller 1993). The responsibility of owners of fowl and rabbits to properly cage small domestic stock should be emphasized by management agencies. Public education and strict law enforcement should be employed to eliminate this kind of attractive nuisance in a manner similar to successful contemporary policies that have reduced bear-human conflicts in Alaska.

Given the large number of reported lynx sightings on the Kenai Peninsula during the study period, I expected a larger number of illegal kills. I suspect that a talk show interview on a local radio station, presentations in public schools and numerous conversations with residents at depredation sites and with hunters in and near the study area served to inform local Kenai residents about the lynx trapping-hunting closure. I also believe that posting copies of the state of Alaska lynx season closure at trail heads in the study area served to inform nonresident recreationalists. The continual presence of Fish and Wildlife Service vehicles in and around the study area due to our field work and public knowledge that many local lynx were radio-collared also probably discouraged illegal kills.

The 2 Kenai lynx killed by vehicles during my study and the widely publicized deaths of several reintroduced lynx in New York state (Brocke 1990) due to road traffic indicate that high speed roads can be a significant source of lynx mortality. Because no lynx were road killed on unimproved gravel roads on the Kenai Peninsula, it appears that paved roads on which vehicles can travel quietly at high speed are more dangerous to lynx than unimproved gravel roads. The effect of new roads and road improvements on local lynx populations should be carefully considered in areas where lynx populations are small or endangered.

I believe that persistence of the lynx population in and near the developed corridor is due to the light nature of development in this area as well as to public compliance with the lynx trapping/hunting closure in effect since 1984. Increasing residential development will at some point destroy enough habitat and increase hazards to lynx such as high speed road traffic and illegal shooting that lynx will no longer occur here. Additionally heavy development in the corridor south of the study area could block or inflict high mortality on animals dispersing north and south on the refuge, thus endangering the ability of the refuge to maintain viable lynx populations. Land management practices aimed at keeping development light in a few north-south corridors connecting the Kenai flats and the Benchland area should be considered.

Zigzag and looping movement patterns used by lynx while hunting indicate that lynx moved far greater distances than the straight line distance between successive telemetry locations. Seidensticker et al. (1973) observed similar movement patterns of cougar and concluded that measurements between successive locations were gross underestimates of actual distance traveled.

5.2 Coyote Population Characteristics

Reduction in our rates of trapping success indicate that there was a significant reduction in coyote densities on the Kenai Peninsula during the recent period of low hare densities. Todd et al. (1981) similarly reported that coyote numbers in Rochester, Alberta fluctuated 3-6 fold between hare high and low periods. Our observations and those of Thurber and Peterson (1992) show that wolf predation can be a significant source of coyote mortality on the Kenai Peninsula when near natural wolf densities coincide with hare lows and deep snow. Heavier dependence on moose carrion by coyotes during 1988-91 than during the previous hare low observed by Thurber and Peterson (1992) might increase coyote mortality related to wolves. Heavy dependence of coyotes on carrion also may have made coyotes more vulnerable to trapping during this period because trappers often set snares and traps near carcasses.

Wolves do occasionally kill adult lynx (2 wolf kills out of over 89 radio-collared lynx; T. N. Bailey, unpubl. data), but wolves seem to have a greater depressive effect on coyote populations on the Kenai Peninsula. Wolves killed 7 out of 32 radio-collared coyotes (22%) during the 1976-1980 and 1988-1991 coyote study periods. I speculate that the presence of wolf densities of 16.6/1,000 km^2 (1989-90)(Loranger 1991) and continued trapper harvest of coyotes on the Kenai Peninsula reduced coyote numbers and thus decreased the effects of coyotes on resources used by lynx.

5.3 Lynx Diet

Snowshoe hare populations in the study area declined to low levels during this study. Hare densities of $\leq$ 0.5 hares/ha recorded in hare grids 1 and 3 are comparable with hare low densities of 0.50 and 0.23 hares/ha measured by Keith et al. (1977) in Alberta and 0.5 hares/ha determined by Ward and Krebs (1985) in southwestern Yukon.

The most important food of lynx during snow seasons was snowshoe hare. Scat data indicated that lynx increased their consumption of alternate foods to 36.4% of total items from the 18.0% observed by Kesterson (1988). Kills of alternate prey located during my study were also higher at 37.5% compared with 2 of 22 nonhare kills (9.0%) recorded from 1984-87. Lynx in other areas also have increased their use of alternate foods including spruce grouse, caribou and red fox (Brand et al. 1976, Bergerud 1983, Stephenson 1986, Stephenson 1991) during hare lows.

Lynx were opportunistic and responded to hare scarcity by adding moose carrion, fish, porcupine and ermine to their snow-season diets and by increasing their use of voles and red squirrels. Similarly lynx in the Kluane Lake, Yukon area increased predation on red squirrels during the recent 1992-1995 hare low period (O'Donoghue and Hofer 1995). Van Zyll de Jong (1966) reported red squirrel remains in few lynx scats and concluded that the red squirrel was little used by lynx because of the red squirrel's arboreal habits and alertness. Koehler (1990), however, noted tree squirrel remains in 24% of scats collected from Washington lynx. My discovery of red squirrel remains in 50% of early snow-free season lynx scats indicates that the lynx is capable of capturing many squirrels when these rodents are available.

Moose carrion appeared to be a substantial portion of the diet of one lynx during the winter of 1989-1990. The work of Nellis and Keith (1968) and Nellis et al. (1972) during a period of low to moderate hare densities, and our own tracking observations, suggested that Kenai lynx consumed the approximate biomass equivalent of 1 hare every 2 days during the snow seasons. Captive lynx will eat the equivalent of 1 hare's biomass every day if the food is available (Parker et al. 1983). Assuming that lynx M65 consumed the biomass equivalent of 1 hare each day for the 16 days he fed on moose carcasses, approximately 18% of this animal's 1989-90 snow season diet consisted of winter-killed moose carrion.

Our observations that lynx can not tolerate spoiled meat are supported by fur farmers who report that lynx are very likely to become sick if fed spoiled feed, while fox are much more tolerant of tainted food (B. Williams, pers. commun.). Brothers (1990) also reports that avoidance of bacterial contamination of lynx feed is important to successful lynx farming. Inability of lynx to tolerate tainted meat may severely limit their use of carrion, causing it to be available to other carnivores.

During snow-free seasons, lynx responded to increased numbers of birds and the greater availability of voles by increasing their consumption of these prey. Saunders (1963), van Zyll de Jong (1966), and Brand et al. (1976) also reported increased occurrence of birds, voles and mice in lynx summer diets.

Brand et al. (1976) noted that because of the small biomass of red squirrels and grouse compared to hares, consumption of these species and carrion did not compensate completely for the low population of hares in his study area. Our observations support Brand's contention; use of voles and moose carrion in the study area did not prevent the low reproductive performance and the decrease in the numbers of resident lynx during the study period. I believe, however, that the ability of Kenai lynx to use alternate foods insured the survival of some adult lynx. I speculate that occasional multi-day use of moose carcasses did much to improve the body condition of these individuals.

During the snow season Kenai lynx appeared to encounter alternate small game prey opportunistically or in close proximity to cover for hares; therefore, the capture of these animals probably required little extra effort. The addition of the small amounts of biomass present in voles, squirrels and grouse, secured with small energy expenditures, may have been important in maintaining food intake at critical minimum levels in at least some lynx. Another explanation for the proportional increase in alternate prey in diets during hare lows may be that lynx capture of alternate prey does not increase, but numbers of hares captured decreases changing the ratio of foods consumed.

Brand (1976), however, estimated that hares continued to constitute most of the biomass (91%) consumed by lynx in his area during summer. The 38-scat sample used by Brand (1976) to compute biomass estimates contained few occurrences of the heavier alternate prey available in his area (1 squirrel and 0 grouse). My snow-free season sample of 41 scats contained 5 grouse and 11 red squirrels. Applying the same biomass values used by Brand (1976) to these snow-free season prey yielded a nonhare food biomass of 18.5%. This is a conservative estimate because I repeated the use of a low biomass estimate for a miscellaneous category used by Brand in which 8 occurrences were given the biomass value of 1,660 grams (Appendix U). My experience suggests that some of the unidentified birds and mammals in both miscellaneous prey scat samples were likely to be large nonhare prey (grouse, waterfowl, beaver, porcupine, muskrat) that are more available to lynx during summer. That no uninjured adult lynx starved during snow-free seasons, and that lynx captured in May and in October were in much better condition than lynx captured in March and April also suggests that alternate prey available in the warmer months made a significant contribution to lynx diets.

I speculate that consumption of alternate foods by lynx during periods of hare scarcity is affected by small differences in hare densities and highly variable availability of small game species and carrion. Consequently, I believe it likely that use of alternate foods and their relative importance are inherently difficult to determine and may vary greatly between years and in different geographic areas. The consumption of alternate foods may be more important to Kenai lynx than to lynx populations elsewhere because:

1. The Kenai Peninsula offers a greater variety of alternate foods than simpler ecosystems in interior Alaska and in Yukon and Alberta, Canada.
2. Kenai lynx cannot easily respond to hare scarcity by emigrating to distant areas where hare densities are greater as reported in other areas in North America (Mech 1973).

I also speculate that lynx diets in the Sterling Corridor included many snowshoe hares, because of lynx kills and pursuits of hares detected in this area. Also, ample hare habitat exists in the corridor because large undeveloped areas bordering the Sterling Highway (1947 burn and many areas disturbed by human activity) are in stages of early succession.

Wild prey associated with the Kenai River riparian zone are probably a major food resource of lynx using the corridor area. Alder and willow stands in areas adjacent to the river offer good hare habitat. Large aquatic birds, often present in both seasons, also appeared to supply an alternate source of food to Kenai lynx during periods of low hare density.

The importance of domestic animals to lynx using the corridor area appeared to depend on the individual lynx. Two lynx, an underdeveloped kitten and an injured adult male, appeared to depend totally on domestic animals. Two healthy adult lynx included domestic animals in their diets but pursued and killed snowshoe hares near residences and spent long periods away from developed areas presumably utilizing wild prey. Two additional nonstudy lynx that used the area immediately to the south of the study area seemed to use domestic animals infrequently and did not localize their movements around single residences.

5.4 Coyote Diet

Kenai coyotes obtained most of their food during snow seasons by scavenging moose carrion despite the risk of being killed by wolves. Todd et al. (1981) reported that coyotes used livestock carrion heavily and reduced their consumption of snowshoe hares during 2 cyclic hare lows in Alberta. My observations that Kenai coyotes often used wolf-killed moose parallel those of Paquet (1992), who reported that Manitoba coyotes routinely fed on wolf kills. He also reported that 11 of 23 wolf-killed coyotes were found within 200 m of carcasses used by wolves. Crawford (1976) also described use of wolf kills by coyotes in Alberta indicating that this risky behavior is common in northern areas.

I believe that the low use of hares by coyotes during snow seasons was a functional response to hare scarcity and the relative unavailability of the remaining hares due to deep, soft snow in areas of good hare cover. Murie (1940), Ozoga and Harger (1966), Bekoff and Wells (1981) and Roy and Dorrance (1985) observed that mobility of coyotes was restricted by deep snow. Murray and Boutin (1991) reported that coyotes compensated for their relatively high foot-loads and were able to maintain hares as an important part of their winter diet by using lower elevations and trails, and by initiating chases of hares at shorter distances. Hares, however, were abundant on their Yukon study area (3.4 hares/ha) suggesting that this hare population was more continuously distributed across the landscape (Keith and Windberg 1978, Wolff 1980).

At low densities of hares on the Kenai Peninsula many of the remaining hare refugia or "pockets" were remote from trails, drainages or open areas of hard packed snow and therefore were energetically costly for coyotes to hunt. Conversely, many winter-killed moose died near roads or trails that coyotes often used. Coyotes also used trails and terrain used by wolves, which have foot-load values similar to coyotes (Murray and Boutin 1991, Formozov 1946), to search for wolf-kills.

When Kenai coyotes increased their consumption of hares in the warmer months they appeared to be responding functionally to increased availability of hares due to the availability of young hares and increased access to areas of suitable covers. Frequency of occurrence of hare remains (21.2%) in snow-free season coyote scats was, however, significantly lower than that observed (32.5%), $Z = 3.04$, $P < 0.01$ during the hare low in 1976-1980 (Thurber and Peterson 1992). This suggests that current densities of hares are lower than during the previous cyclic low, perhaps because of the deteriorated condition of browse in the 1947 burn area that has resulted in decreased densities of moose in that habitat (Schwartz and Franzmann 1989). Use of moose carrion by coyotes during the snow-free season remained high (23.4%) during this study compared with the summers of 1976-1980 (2.4%).

Use of salmon by coyotes was probably underestimated because scats consisting largely of salmon remains tended to be liquid in nature and therefore more difficult to see and collect. Moose meat is also very digestible, but coyote scats consisting primarily of moose remains were more easy to see than scats consisting mostly of fish remains.

The higher frequency of salmon remains in coyote scats from the snow season as compared with scats from the snow-free season is explained by a run of silver salmon that spawn in the Swanson River and its tributaries from late August through November. Salmon are probably much more important to coyotes residing south of the study area in the Sterling Corridor. The Kenai River has runs of 4 salmon species that are available from approximately July to November. The great size of these runs and that the Kenai River does not completely freeze over during most winters insure that salmon carcasses are available to coyotes during most snow seasons as well as during summer. I speculate that the availability of salmon on the Kenai Peninsula contributes to the maintenance of higher coyote numbers on the Peninsula than in more continental areas of Alaska.

5.5 Lynx Habitat Use

Lynx habitat use during my study was similar to that observed by Kesterson (1988) for 1984-1987 (Appendix N). Kesterson and I, however, determined proportionally quite different habitat availabilities for the rare habitat types (crushed/crushed, 1947 burn/crushed, mature/1947 burn) in the same 250 km^2 study area. These differences were probably due to recent logging of mature forest in crushed areas and differences in demarcation of boundaries between 1947 burn and remnant mature stands by Kesterson and myself. These boundaries were often indistinct and consisted of a gradually increasing density of mature trees. Results in the 250 km^2 area for the 1987-91 period (Appendix O and P) indicate that the E^* index is very sensitive to differences in availability, so a comparison using this index is not valid. Comparisons that assume that availabilities were equal in both study periods are appropriate in this situation. Use percentages during both periods suggest little difference in habitat use, and a Chi-square test indicated no significant difference ($X^2 = 6.26$, 5 *df*, $P = 0.28$) in lynx use of 6 habitat combinations.

Lynx appeared to prefer 1947 burn habitat during both study periods because it was the most productive area for snowshoe hares. The large number of hare trails in reburn areas with high overhead cover percentages suggests that densely vegetated areas in the 1947 burn are valuable habitat to hares and lynx. The 1947 burn also appeared to support higher densities of red-backed voles. Remnant stands of mature forest in the 1947 burn also provided lynx access to red squirrels and spruce grouse in close proximity to cover for hares.

The frequent sitting by lynx on ridges, steep hill slopes, dead fall and snow piles suggests that the animals used high terrain to visually search adjacent areas for potential prey. Lynx may use remnant mature stands because unburned areas are usually present on the highest available terrain of the 1947 burn. Observing large areas from high vantage points also increases the probabilities of finding moose carcasses. I sighted ravens (*Corvus corax*) and bald eagles (*Haliaetus leucocephalus*) roosting in trees over large carcasses at ranges of over 1 km during the snow season. The speed with which Kenai lynx found fresh carcasses and their frequent attraction to residences where birds were fed suggests that lynx often find carrion by sighting feeding birds.

Lynx may make heavy use of remnants of mature forest because the adjacent 1947 burn/1947 burn regrowth is superior hare habitat. Large white spruce not killed by the 1947 fire have seeded dense stands of white spruce saplings near the edge of these mature forest stands. White spruce regrowth provides both cover, and food for hares in the study area. Black spruce regrowth, which is abundant and more widespread in its distribution in the 1947 burn, provides similar escape cover and thermal protection, but is not used as food by hares (Cook and Robeson 1945, Pease et al. 1979). Bryant and Kuropat (1980) reported that plant tissues with high concentrations of ether extracted "crude resin" are low in palatability and digestibility. Ellison (1966, 1976) noted that white spruce needles contain less resin than black spruce needles and that Alaskan spruce grouse find white spruce considerably more palatable than black spruce. Feeding experiments indicated that snowshoe hares also prefer white spruce over black spruce (Bryant 1980, Klein 1977).

Stands of small white spruce near remnants of mature forest may be particularly important habitat to hares now that most deciduous browse in the 1947 burn has either been killed or grown out of reach.

Use of remnant mature stands in the 1947 burn and large areas of unburned forest during snow-free seasons allows access to vulnerable young squirrels near large white spruce during the summer months.

Higher use of burned portions of the 1947 burn during the snow seasons may have been due to the lower availability of nonhare prey and the resulting need of lynx to spend more time hunting optimal habitats for snowshoe hare.

Future fire management and logging activities should leave mature stands to provide habitat heterogeneity necessary to maintain snowshoe hare, grouse and red squirrel populations. Lynx almost always climb large trees when pursued by hounds so the maintenance of small stands of mature forest may provide lynx valuable escape terrain.

Lynx made little use of large contiguous stands of unburned forest that supported few hares. Pellet counts conducted by Bailey et al. (1986) indicated that over 10 times as many hares occupied 1947 burn areas (94.5 pellets/m^2) as occupied unburned mature forest (7.9 pellets/m^2). Track observations made while trapping, tracking lynx and walking random transects during lynx census efforts indicated that hares continued to be generally rare in unburned forest compared with 1947 burn regrowth during the study period.

Unburned forest, however, did contain small areas of hare habitat located in and adjacent to alder and dense black spruce stands. Hare sign was approximately one-half as plentiful in this select mature habitat used by lynx as it was in 1947 burn areas through which lynx were tracked. Lynx, however, appeared to be more often successful when pursuing hares in the more open mature forest. Conversely, high densities of spruce and birch saplings appear to obstruct lynx pursuit of hares. Hornocker (1970) and Schaller (1972) have documented varying vulnerability of prey to cougar (*Felis concolor*) and African lion (*Panthera leo*), respectively, in different habitat types. Increased vulnerability of hares in mature forest may compensate lynx energetically for lower hare densities in unburned areas.

Lynx avoided the 1969 burn where snowshoe hares were scarce, despite abundant deciduous browse that supports the highest moose densities on the peninsula. The lack of spruce overhead cover may be responsible for low numbers of hares in the 1969 burn. High densities of deciduous stems may not be sufficient to protect hares from detection by aerial predators, and probably provide less thermal protection to snowshoe hares than dense stands of small conifers. Aerial seeding of white spruce in hot burns like the 1969 burn where few mature nurse trees survive might be conducted in the future to provide more habitat heterogeneity and palatable cover for hares and grouse.

5.6 Coyote Habitat Use

Coyotes also displayed high preference for the 1947 burn probably because more small game were available in this habitat. Coyote preference for crushed areas was probably due to the open grassy ground cover between clumps of birch saplings, which may have made it easier for the cursorial coyote to pursue and capture hares and other small mammals.

Mature forest may have been avoided by coyotes because it contained low moose densities relative to the 1947 and 1969 burns (Schwartz and Franzmann 1989) and therefore provided little moose carrion. Further, travel may be more difficult for coyotes in mature stands for snow seemed to be softer and deeper and remained in unburned areas later in the spring because of shading by large trees. The avoidance of large expanses of unburned forest by coyotes also may be due to lower hare and vole numbers in mature forests.

Avoidance of the 1969 burn by coyotes appears to be partially due to low numbers of hares and small mammals in this habitat. The low number of coyote relocations in the 1969 burn is puzzling, because the 1969 burn contains the highest density of moose on the Kenai Peninsula (Schwartz and Franzmann 1989) and refuge staff have observed coyotes feeding on moose carcasses in that burn. Coyote use of the 1969 burn may have been limited by wolves. Relocation of collared Kenai wolves indicates that the 1969 burn has been used heavily by at least 1 wolf pack for the last several years (T. N. Bailey, pers. commun.). My daily observation of tracks on Swanson River Road, which approximately borders the east edge of the 1969 burn, confirms that wolves used the 1969 burn heavily. Two collared coyotes and one coyote restrained by a trap were killed by wolves along the eastern periphery of the 1969 burn during the study. Thurber and Peterson (1992) concluded that Kenai wolves excluded coyotes from some areas during their 1976-1980 research in my study area.

5.7 Comparison of Lynx and Coyote Diets and Habitat Use

Lawlor (1980) and Schoener (1982) have argued that high overlap in resource utilization does not indicate intense exploitation competition if a shared resource is super-abundant. Consumption of an abundant resource by one species could not markedly reduce the availability of the resource to a competitor. Schoener's (1982) review of field studies indicated that apparently co-evolved species overlapped the least in food and or habitat use during the lean season. Conversely high overlap during the "lean season" or during years of resource scarcity is likely to indicate high levels of competition. Because our examination of lynx and coyote diet and habitat use was conducted during a cyclic hare low, high resource use overlap between these species would suggest high levels of exploitation competition. I also believe that the probability of detecting aggressive interactions or interference competition occurring between these species would be highest during a period of food scarcity.

Investigators of bobcat-coyote interactions in northern areas reported high indices of prey-use overlap during the lean winter season but concluded that competition was minimal due to an abundance of resources (Witmer and deCalesta 1986) or because resources were partitioned due to spatial separation of bobcats and coyotes (Toweill 1986). Partitioning, however, may indicate that competition between two species limits the range and therefore the population of one or both species. Litvaitis and Harrison (1989) observed high overlap of bobcat-coyote resource use in Maine, and speculated that the coyote reduced the carrying capacity of their study area for bobcat because the coyote decreased the availability of deer to bobcat.

My results indicate 42% total lynx-coyote dietary overlap during 3 snow seasons and more similar diets during the snow-free season in agreement with Schoener's (1982) prediction that the period of least overlap between potential competitors coincides with the season when resources are least abundant.

I do not believe that significant exploitation competition for food occurred between lynx and coyotes during snow-free seasons because of the increased variety and abundance of small game during the warmer months.

Although Zaret and Rand (1971) and Toweill (1986) considered a dietary overlap value of 60% or higher indicative of similar diets, I believe that the 42% snow season overlap detected in this study with its constituent 15.9% overlap in snowshoe hare use had the potential to result in significant exploitation competition because hares were scarce and other foods not abundant during study period winters. Lynx relied heavily on hares during snow seasons, so any hare removed by a coyote would have represented a loss of food to sympatric lynx.

If coyotes were removed from the Kenai ecosystem and all other environmental variables could be kept constant, I believe it likely that the carrying capacity of the area for lynx would be increased. One of the assumptions of this hypothetical removal, however, is that hares or other prey not consumed by coyotes would be available to lynx. This assumption may not be a true if another predator with similar food habits would be available to take these prey.

Red fox (*Vulpes vulpes*) populations have been reduced or displaced by coyotes colonizing northern regions (Voigt and Earle 1931, Dekker 1983, Major 1983, Harrison 1986, Sovada et al. 1995). Coyotes coexist with red fox in Denali National Park (Murie 1944) and I have often observed both species in the Fairbanks area, but red fox disappeared from the Kenai lowlands when the Kenai Peninsula was colonized by coyotes (Walker 1923, Bangs et al. 1982). I speculate that coyotes exclude red fox from the study area by interference competition, because relatively high densities of coyotes exist on the Kenai Peninsula (Bangs et al. 1982) compared to other areas of Alaska. I also believe that the abundance of moose and salmon carrion available in this unique coastal ecosystem supports these high coyote densities. Despite the absence of red fox in the study area, red fox have persisted in some alpine areas (T. Bailey, pers. commun.). If coyotes were absent from the lowlands red fox may occupy or re-colonize some habitats.

Studies of fox food habits in Alaska (Murie 1944, Hobgood 1984) and on Isle Royal (Johnson 1970) indicate that winter diets of fox consist mainly of microtines, snowshoe hare and carrion and therefore are similar to coyote winter diets that we observed. More specifically, Hobgood (1984) reported that carrion was the most important winter food item in the Susitna Valley, Alaska where winter snows made access to microtines difficult and snowshoe hares were scarce. Wells and Bekoff (1982) also reported that coyote and fox were less successful when hunting voles and mice in deep snow (>10 cm). Thus, red fox eat the same foods as coyotes in sub-arctic ecosystems and also use these foods in similar proportions in response to changing environmental factors and prey availability.

There is the question of whether populations of foxes or coyotes at carrying capacity on the Kenai flats would actually consume the same amount of prey and provide equal exploitation competition pressure on lynx. This in turn depends upon whether approximately equivalent weights of foxes would replace coyotes and whether coyotes and fox would remove foods from the same habitats. Because the smaller red fox has lower energy demands, can live almost exclusively on small mammals where hares are scarce (Jones and Theberge 1983) and generally appears to be better adapted to deep snow due to foot loads 1/2 to 1/3 less than coyote foot loads (Murray unpubl. data), I speculate that the Kenai Flats would support a greater total mass of red fox than coyotes during most of the hare cycle. The work of Theberge and Wedles (1989) in southeast Yukon indicates that fox and coyotes use northern habitats similarly. The spatial distribution of food consumption by these canids could be expected to have approximately the same effect on lynx.

Red fox may, however, be more efficient hunters of hares than coyotes because of their lower foot loads and smaller size (shorter turning radius). In western Maine, where snow depths average 250 cm, percent occurrence of hares in coyote winter diets was 37% compared with 61% and 64% in red fox and bobcat diets, respectively (Major 1983). These data suggest that coyotes may not be as capable as fox of capturing hares in deep snow and heavy cover areas. I therefore speculate that the native red fox may compete more with the lynx through exploitation for hares than does the coyote during most of the hare cycle.

Lynx utilize the red fox as food and severely reduce populations of this small canid when hares are scarce (Stephenson 1986, O'Donoghue et al. 1995, C. Perham, pers. commun.). Lynx, however, have not been observed to kill coyotes or reduce the numbers of this medium-sized canid in any northern areas yet studied. Because the lynx can not eliminate the coyote as a competitor, lynx may experience more exploitation competition from coyotes than red fox during the few years of the hare cycle that hare numbers are very low.

I do not believe that coyotes deprived lynx of a significant amount of food by consuming large amounts of carrion during the study period. First, because the coyote has long jaws, robust teeth and an apparent resistance to bacterial contamination in meat, a large portion of carrion eaten by coyotes was spoiled and frozen meat, dead fish, and heavy moose bone and hide, items not usually utilized by lynx. Second lynx were not observed to feed on wolf kills while wolves were present, so meat that coyotes ate off carcasses while wolves are near was not really available to lynx. Third we observed adult lynx feeding on fresh moose and bear carcasses when coyotes were nearby. This suggests that Kenai coyotes seldom deny adult lynx use of palatable carrion through antagonistic interactions.

If red fox were filling the niche for small canids on the Kenai Peninsula, it is likely that they would find and consume fresh carrion that a lynx might use in approximately the same amounts as the coyote.

The red squirrel was a major alternate prey of the lynx during this study but coyotes seldom consumed this food item. O'Donoghue and Hofer

(1995) similarly noted that Yukon lynx subsisted largely on red squirrels during a hare low, while coyotes relied mainly on voles. I believe that the lynx is a superior red squirrel predator and therefore exploitation competition with coyotes for this important prey of lynx is low.

Habitat use overlap of lynx and coyotes during the study period was high (92% and 79% for the snow and snow-free seasons respectively). The substantial difference in lynx-coyote winter diets and my tracking observations, however, suggest that larger differences in habitat use at some level did occur during snow seasons. I believe that the morphological and behavioral differences between these species cause lynx and coyotes to use habitats quite differently, particularly during the winter season. I apparently did not use appropriate habitat categories to detect this difference.

Within each of the micro-habitat types that I used there are sub-habitat categories that may be used differentially by these two predators. Potential sub-habitats consist of forest stands of different species, different forest species composition and varying stem densities/overhead cover. Our detection of substantially higher coyote use of the open crushed habitat and study area roads suggests that coyotes may also use the open (0-25% overhead cover) parts of the 1947 burn more than the lynx, which would reduce competition for prey between these two predators. Theberge and Wedles (1989) similarly reported that coyotes in southwest Yukon preferred edge ecotones over more central ecotones and open communities over more heavily vegetated brushy, spruce and woody habitat types.

Conversely, I assert that lynx spent more time than coyotes in dense regrowth areas in the 1947 burn because hares were more abundant in these refugia <u>and</u> because the lynx is better adapted than the coyote to hunt and capture prey in heavy cover. Hik (1994) recently reported that hares used closed habitats at Kluane Lake, Yukon during a hare low. Litvaitis and Harrison (1989) contended that the bobcat is a more effective predator in dense understories than the coyote. Felid adaptations that may enable the lynx to detect and capture prey more efficiently than coyotes in dense understories include eyes that can see at lower light levels (Walls 1942 cited in Ewer 1973, Lehner 1978) and that are better adapted to detect horizontal movement (Koch and Ruben 1972, Hughes 1977, 1985) as well as the ability to accelerate to maximum speed faster than canids (Taylor 1989, Houston 1988), long rear legs that give the lynx superior springing ability (Mandal and Talukder 1975, Kleiman and Eisenberg 1973), a more flexible spine (Taylor 1989) and distal leg joints (Vaughan 1978) that allow the lynx to move quietly through dense cover and the dexterous front paws typical of felids that allow lynx to rapidly seize prey dodging around obstacles.

The extremely low foot loading of lynx (31.6 g/cm^2) compared with coyotes (136.8 g/cm^2) (Murray and Boutin 1991) may have helped Kenai lynx to be more effective predators of snowshoe hares during snow seasons and also contributed to separating lynx and coyotes spatially in the study area. While lynx were often tracked in soft deep snow, coyotes were seldom tracked in remote hare refugia hunted by lynx when deep snow was present. Murray and Boutin (1991) also observed that lynx used areas with deeper snow and pursued hares in deeper snow than did coyotes. They also reported that lynx pursued hares for more bounds than coyotes suggesting that lynx are better able to capture hares in deep snow once a chase is initiated. Murray and Boutin (1991) further reported that coyotes used animal trails and roads more than lynx and that coyotes apparently compensated for their lower ability to successfully pursue hares in deep snow by ambushing hares. Hare numbers, however, were high at the time of their study. During my study, hare numbers were too low for coyotes to use a stationary or ambush hunting strategy. Recently O'Donoghue and Hofer (1995) have confirmed my observations that lynx are more efficient hare predators than coyotes by reporting snowshoe hare daily kill rates of 0.3 hares/day for lynx compared to 0.1 hares/day for coyotes during a period of hare scarcity.

I believe that lynx and coyotes used the best habitat in the study area, the 1947 burn in the following way. Lynx made intense use of heavily vegetated hare refugia regardless of snow depth and distance from roads and trails. Coyotes searched more open areas, edges of hare refugia and areas adjacent to roads and trails for the occasional vulnerable hare that might have left heavy cover. Coyote diet during the study period, however, suggests that Kenai coyotes were not able to encounter and capture enough hares or other small game to either meet their dietary needs or maintain existing population densities. By moving through open areas and along roads and trails coyotes were able efficiently search large areas for wolf, road and winter-killed moose.

Investigators have reported instances of coyotes killing bobcats (Anderson 1986, Toweill 1986, Litvaitis and Harrison 1989) and suggested this might be proof of substantial interference competition between these species. Recently O'Donoghue et al. (1995) reported observing a coyote kill a young 7 kg lynx in Yukon, Canada, but coyote predation on lynx in Yukon, Canada appears to be rare compared with lynx mortality attributed to wolves, wolverine and lynx cannibalism.

We did not detect interference competition between coyotes and lynx that would reduce the carrying capacity of the Kenai Peninsula for lynx. No lynx were killed by coyotes during the 12 year Kenai lynx study (89 radio-collared lynx). Coyotes tracked and seen in the study area are usually alone or in pairs suggesting that the probability of coyotes cooperating to attack lynx in this ecosystem are small. Lynx behaviors that protect this wildcat from wolf predation should be equally effective at protecting lynx from the occasional aggressive coyote.

Although it is likely that Kenai coyotes occasionally kill a lynx kitten or a sub-adult lynx in poor health, I do not believe that this results in a significant mortality rate increase over pre-coyote conditions. Also our observations made while snow tracking and pursuing lynx with hounds indicate that unless lynx are surprised at close range they can almost always escape by tree climbing.

Habitat use by both coyotes and lynx appeared to be constrained by the possibility of wolf predation. Lynx avoidance of the 1969 burn, open crushed areas, open wetland and lakes was probably due partly to the absence of climbable trees and or escape cover as well as due to low hare densities in these areas. May (1981) noted similar avoidance of open areas by bobcats in Maine. Lynx avoidance of open areas that serves to reduce the likelihood of wolf predation should also reduce vulnerability of young lynx to attacks by coyotes to low levels. Areas adjacent to study area roads that are heavily used by coyotes due to avoidance by wolves (Thurber and Peterson 1992) may be more hazardous for young lynx to use. This risk appears to be minimized by the presence of climbable trees in most areas with enough stalking cover for lynx or enough over head cover to be good hare habitat. Our experience treeing lynx with hounds indicates that, although lynx prefer climbing large trees (Bailey 1991), relatively small spruce (≥5 m tall) are sufficient for lynx to escape canids. Heavy use of the 1969 burn by wolves apparently deterred coyotes from using this habitat despite the availability of moose carrion.

Development that increases the density of roads, trails and cleared areas in northern areas will cause the coyote to compete more with the lynx. During deep snow winters, these habitat alterations will allow coyotes access to more habitat and increase the hunting efficiency of coyotes reducing the competitive advantage of the snow-adapted lynx.

Because wolves seldom kill lynx but kill coyotes relatively frequently, the present near natural densities of wolves on the Kenai Peninsula may suppress or control coyote numbers, reducing the effects of coyotes on lynx and other wildlife. Also, wolves kill and consume many old and weak moose and therefore deprive coyotes of a significant amount of carrion that would be available in the absence of wolves. Finally, because harvest of coyotes continues on the Kenai Peninsula, trapper and hunter mortality inflicted on coyotes serves to decrease any competitive effect that coyotes have on lynx.

LITERATURE CITED

ALDAMA, J. J., and M. DELIBES. 1991. Observations of feeding groups in the Spanish lynx (*Felis padina*) in the Donana National Park, SW Spain. Mammalia. 55:143-147.

ALLDREDGE, J. R., and J. T. RATTI. 1986. Comparison of some statistical techniques for analysis of resource selection. J. Wildl. Manage. 50:157-165.

ALLDREDGE, J. R., and J. T. RATTI. 1992. Further comparison of some statistical techniques for analysis of resource selection. J. Wildl. Manage. 56:1-9.

ANDERSON, E. M. 1986. Bobcat behavioral ecology in relation to resource use in Southeastern Colorado. Ph.D. Dissertation, Colorado State Univ., Fort Collins. 107pp.

ANTHONY, R. G., and N. S. SMITH. 1977. Ecological relationships between mule deer and white-tailed deer in Southeastern Arizona. Ecol. Monogr. 47:255-277.

BAILEY, T. N. 1974. Social organization in a bobcat population. J. Wildl. Manage. 38:435-446.

---. 1991. Use of trained dogs to live-capture lynx on the Kenai Peninsula, Alaska. p. 36 (In) Proceedings of the Sixth Northern Furbearer Conference; April 10-11, 1991. Univ. Alaska, Fairbanks.

BAILEY, T. N., E. E. BANGS, M. F. PORTNER, J. C. MALLOY, and R. J. MCAVINCHEY. 1986. An apparent overexploited lynx population on the Kenai, Peninsula, Alaska. J. Wildl. Manage. 50:279-290.

BANGS, E. E. 1979. The effects of tree crushing on small mammal populations in South Central Alaska. M.S. Thesis, Univ. Nevada, Reno. 80pp.

BANGS, E. E., T. H. SPRAKER, T. N. BAILEY, and V. D. BERNS. 1982. Effects of increased human populations on wildlife resources on the Kenai, Peninsula, Alaska. p. 605-616 (In) Transactions of the 47th North American Wildlife and Natural Resources Conference 1982. Wildlife Management Institute, Washington, D. C.

BANGS, E. E., S. A. DUFF, and T. N. BAILEY. 1985. Habitat differences and use of two large burns on the Kenai, Peninsula, Alaska. Alces. 21:17-35.

BARASH, D. P. 1971. Cooperative hunting in lynx. J. Mamm. 52:480.

BEKOFF, M., and M. C. WELLS. 1981. Behavioral budgeting by wild coyotes: The influence of food resources and social organization. Anim. Behav. 29:794-801.

BERGERUD, A. T. 1983. Prey switching in a simple ecosystem. Sci. Am. December. 130-141.

BERRIE, P. M. 1974. Ecology and status of the lynx in interior Alaska. p. 4-41 {In} R. L. Eaton {Editor} The world's cats. Vol. 1. World Wildlife Safari, Winston, Oreg.

BOWYER, T. R., S. A. McKENNA and M. E. SHEA. Seasonal changes in coyote food habits as determined by fecal analysis. Am. Midlland Nat. 109:266-273.

BRAND, C. J., L. B. KEITH and C.A. FISCHER. 1976. Lynx responses to changing snowshoe hare densities in central Alberta. J. Wildl. Manage. 40:416-428.

BREITENMOSER, U., and H. HALLER. 1993. Patterns of predation by introduced European lynx in the Swiss Alps. J. Wildl. Manage. 57:135-144.

BROCKE, R. H. 1990. The return of the lynx. Wildl. Rehab. Today. fall:7-13.

BROTHERS, A. W. 1990. Lynx farming in the 80's. Canadian Fur Consultants & Associates, 116 David Street East, Elora, Ontario NOB 1SO. 52pp.

BRYANT, J.P. 1980. The regulation of snowshoe hare feeding behavior during winter by plant antiherbivory chemistry. p. {In} Proc. 1st Int. Lagomorph Conf., 1979. Guelph Univ., Canada.

BRYANT, J. P. and P. J. KUROPAT. 1980. Selection of winter forage by subarctic browsing vertebrates: The role of plant chemistry. Ann. Rev. Ecol. Syst. 11:261-285.

COOK, D. B., and S. B. ROBESON. 1945. Varying hare and forest succession. Ecology 26:406-410.

CONOVER, W. J. 1980. Practical nonparametric statistics. Second ed. John Wiley and Sons, New York, N.Y. 493pp.

CRAWFORD, J. S. 1976. The curious life of the coyote. Alaska. June:38-40.

DAVIS, J. L., and A. W. FRANZMANN. 1979. Fire-moose-caribou interrelationships. Proc. North Am. Moose Conf. Workshop. 15:80-118.

DEKKER, D. 1983. Denning and foraging habits of red foxes, *Vulpes vulpes,* and the interaction with coyotes, *Canis latrans,* in Central Alberta, 1972-1981. Can. Field-Nat. 97:303-306.

ELLISON, L. 1966. Seasonal food and chemical analysis of winter diet of Alaskan spruce grouse. J. Wildl. Manage. 30:729-735.

ELLISON, L. 1974. Population characteristics of Alaskan spruce grouse. J. Wildl. Manage. 38:383-395.

---, 1976. Winter food selection by Alaskan spruce grouse. J. Wildl. Manage. 46:205-213.

EWER, R. F. 1973. The carnivores. Cornell Univ. Press, Ithaca, N.Y. 494pp.

FORMOZOV, A. N. 1946. Snow cover as an integral factor of the environment and its importance in the ecology of mammals and birds. p. 1-152 {In} Translated by W. Prychodka and W.O. Pruitt 1963. Materials for fauna and flora of the USSR, New series zoology. Vol. 5. Univ. Alberta Boreal Inst. Occas. Publ. No. 1, Edmonton.

FREUND, J. E. 1984. Modern elementary statistics. Sixth Ed. Prentice-Hall, Inc. Englewood Cliffs, N.J. 561pp.

GEERTSEMA, A. A. 1985. Aspects of the ecology of the serval (*Leptailurus serval*) in the Ngorongora Crater, Tanzania. Neth. J. Zool. 35:527-610.

HAGLUND, B. 1966. Winter habits of lynx (*Lynx lynx L.*) and wolverine (*Gulo gulo L.*) as revealed by tracking in the snow. Viltrevy. 4:81-310.

HALFPENNY, J. C. 1986. A field guide to mammal tracks in North America. Second ed. Johnson Publ. Co., Boulder, Colo. 161pp.

HARRISON, D. J. 1986. Coyote dispersal, mortality, and spatial relationships with red foxes in Maine. Ph.D. Thesis, Univ. Maine, Orono. 109pp.

HAWBAKER, S. S. 1974. Trapping North American furbearers. Eleventh ed. Kurtz Brothers. Clearfield, PA. 352pp.

HIK, D. S. 1994. Predation risk and the 10-year snowshoe hare cycle. Ph.D. Thesis, Univ. British Columbia, Vancouver. 140pp.

HOBGOOD, T. W. 1984. Ecology of the red fox (*Vulpes vulpes*) in the Upper Susitna Basin, Alaska. M.S. Thesis, Univ. of Alaska, Fairbanks. 163pp.

HORNOCKER, M. G. 1970. An analysis of mountain lion predation upon mule deer and elk in the Idaho Primitive Area. Wildl. Monogr. 21. 39pp.

HOUSTON, D. C. 1988. Digestive efficiency and hunting behavior in cats, dogs and vultures. J. Zool. Lond. 216:603-605.

HUGHES, A. 1977. The topography of vision in mammals of contrasting lifestyle: Comparative optics and retinal organization. p. 613-756 {In} F. Crescitelli {Editor} The Visual System in Vertebrates, Handbook of Sensory Physiology. Vol. 7. Springer, Berlin.

---. 1985. New perspectives in retinal organization. Prog. Ret. Res. 4:243-314.

JAMISON, R. 1983. The trapper's handbook. DBI Books, Inc., Northfield, Ill. 224pp.

JOHNSON, D. H. 1980. The comparison of usage and availability measurements for evaluating resource preference. Ecol. 61:65-71.

JOHNSON, R. P. 1973. Scent marking in mammals. Anim. Behav. 21:521-535.

JOHNSON, W. J. 1970. Food habits of the red fox in Isle Royal National Park, Lake Superior. Amer. Midl. Nat. 84:568-572.

JONES, D. M. and J. B. THEBERGE. 1983. Variation in red fox, *Vulpes vulpes*, summer diets in northwest British Columbia and southeast Yukon. Can. Field-Nat. 97:311-314.

KEITH, L. B., and L. A. WINDBERG. 1978. A demographic analysis of the snowshoe hare cycle. Wildl. Monogr. 58. 70pp.

KEITH, L. B., A. W. TODD, C. J. BRAND, R. S. ADAMCIK, and D. H. RUSCH. 1977. An analysis of predation during a cyclic fluctuation of snowshoe hares. Proc. Int. Congr. Game Biol. 13:151-175.

KEITH, L. B., E. C. MESLOW and O. J. RONGSTAD. 1968. Techniques for hare population studies. J. Wildl. Manage. 32:801-812.

KESTERSON, M. B. 1988. Lynx home range and spatial organization in relation to population density and prey abundance. M.S. Thesis, Univ. Alaska, Fairbanks. 66pp.

KLEIMAN, D. G., and J. F. EISENBERG. 1973. Comparisons of canid and felid social systems from an evolutionary perspective. Anim. Behav. 21:637-659.

KLEIN, D. R. 1977. Winter food preferences in snowshoe hares (*Lepus americanus*) in Alaska. p. 266-275 {In} Proc. 13th Int. Congr. of Game Biol. Atlanta, GA.

KOCH, S. A., and L. F. RUBIN. 1972. Distribution of cones in the retina of the normal dog. Am. J. Vet. Res. 33:361-363.

KOEHLER, G. M. 1990. Population and habitat characteristics of lynx and snowshoe hares in North Central Washington. Can. J. Zool. 68:845-851.

KRUUK, H. 1986. Interactions between Felidae and their prey species: A review. p. 353-374 {In} S. D. Miller, and D. D. Everett {Editors} Cats of the World. Vol. Second International Symposium, 1982. Nat. Wildl. Fed., Washington, D.C.

KURTÉN, B., and E. ANDERSON. 1980. Pleistocene mammals of North America. Columbia Univ. Press, New York, N.Y. 442pp.

LAWLOR, L. R. 1980. Overlap, similarity and competition coefficients. Ecol. 61:245-251.

LECHOWICZ, M. J. 1982. The sampling characteristics of electivity indices. Oecologia. 52:22-30.

LEHNER, P. N. 1978. Coyote communication. p. 127-162 {In} M. Bekoff {Editor} Coyotes, behavior, biology, and management. Acad. Press, Inc., San Diago, Calif.

LITVAITIS, J. A. 1981. A comparison of coyote and bobcat food habits in the Wichita Mountains, Oklahoma. Proc. Okla. Acad. Sci. 61:81-82.

LITVAITIS, J. A., and D. J. HARRISON. 1989. Bobcat-coyote niche relationships during a period of coyote population increase. Can. J. Zool. 67:1180-1188.

LORANGER, A. 1991. Draft Technical Supplement. {In} Kenai National Wildlife Refuge moose management plan. U.S. Fish Wildl. Serv., Soldotna, Ak.

MAJOR, J. T. 1983. Ecology and interspecific relationships of coyotes, bobcats, and red foxes in western Maine. Ph.D. Thesis, Univ. Me., Orono. 64pp.

MANDAL, A. K., and S. K. TALUKDER. 1975. Skeletal differences in the appendicular skeleton on the lynx and caracal (Felidae: Carnivora) in relation to ecology. Anat. Anz. 137:447-453.

MARTIN, A. C. and W. D. BARKLEY. 1961. Seed identification manual. Univ. Calif. Press. Berkley and Los Angeles. 221pp.

MAY, D. W. 1981. Habitat utilization of bobcats in eastern Maine. M.S. Thesis, Univ. Maine., Orono. 36pp.

MECH, L. D. 1983. Handbook of animal radio-tracking. Univ. Minn. Press, Minneapolis, Minn. 107pp.

MECH, L. D. 1973. Canada lynx invasion of Minnesota. Biol. Conserv. 5:151-152.

MORRISON, M. L., B. G. MARCOT, and R. W. MANNAN. 1992. Wildlife-habitat relationships. First ed. Univ. of Wis. Press, Madison, Wis. 343pp.

MURIE, A. 1940. Ecology of the coyote in the Yellowstone. Fauna of the Parks of the U.S., Fauna Ser. 4. 206pp.

---. 1944. The wolves of Mount McKinley. Fauna of the Parks of the U.S., Fauna Ser. 5. 238pp.

---. 1962. Mammals of Mount McKinley National Park, Alaska. AK Nat. Hist. Assoc., National Park Service. 58pp.

MURRAY, D. L., and S. BOUTIN. 1991. The influence of snow on lynx and coyote movements: Does morphology affect behavior? Oecologia. 88:463-469.

NELLIS, C. H., and L. B. KEITH. 1968. Hunting activities and success of lynxes in Alberta. J. Wildl. Manage. 32:718-722.

NELLIS, C. H., S. P. WETMORE, and L. B. KEITH. 1972. Lynx-prey interactions in central Alberta. J. Wildl. Manage. 36:320-328.

NOWAK, R. M. 1978. Evolution and taxonomy of coyotes and related *Canis*. p. 3-16 {In} M. Bekoff {Editor} Coyotes: biology, behavior, and management. Acad. Press, New York, N.Y.

O'CONNOR, R. M. 1984. Population trends, age structure, and reproductive characteristics of female lynx in Alaska, 1961 through 1973. M.S. Thesis, Univ. Alaska, Fairbanks. 111pp.

O'DONOGHUE, M., E. HOFER, and F. I. DOYLE. 1995. Predator versus predator. Nat. Hist. 104(3):6-9.

O'DONOGHUE, M. and E. HOFER. 1995. Responses of coyotes and lynx to the snowshoe hare cycle. p. 15 {IN} Proceedings of the 8th Northern Furbearer Conference. Anchorage, AK.

OLDEMEYER, J. L., and W. L. REGELIN. 1984. Forest Succession, habitat management, and moose on the Kenai National Wildlife Refuge. Final Report. U.S. Fish and Wildl. Serv., Denver Wildlife Research Center. 390pp.

OLDEMEYER, J. L., A. W. FRANZMANN, A. L. BRUNDAGE, P. D. ARNESON, and A. FLYNN. 1977. Browse quality and the Kenai moose population. J. Wildl. Manage. 41:533-542.

OZOGA, J. J., and E. M. HARGER. 1966. Winter activities and feeding habits of northern Michigan coyotes. J. Wildl. Manage. 30:809-818.

PALMER, L. 1992. Loose dogs, road kills combine for parasite problems. Peninsula Clarion. Jan. 24:5.

PAQUET, P. C. 1992. Prey use strategies of sympatric wolves and coyotes in Riding Mountain National Park, Manitoba. J. Mammal. 73:337-343.

PARKER, G. R., J. W. MAXWELL, and L. D. MORTON. 1983. The ecology of lynx (*Lynx canadensis*) on Cape Breton Island. Can. J. Zool. 61:770-786.

PEASE, J. L., R. H. VOWLES, and L. B. Keith. 1979. Interaction of snowshoe hares and woody vegetation. J. Wildl. Manage. 43:43-60.

PERHAM, C. 1993. Pers. Commun. Dept. Biol. Wildl., Univ. Ak., Fairbanks.

PETERSON, R. O., J. D. WOOLINGTON, and T. N. BAILEY. 1984. Wolves of the Kenai Peninsula, Alaska. Wildl. Monogr. 88. 52pp.

ROY, L. D., and M. J. DORRANCE. 1985. Coyote movements, habitat use, and vulnerability in central Alberta. J. Wildl. Manage. 49:307-313.

SAUNDERS, J. K. 1963. Movements and activities of lynx in Newfoundland. J. Wildl. Manage. 27:390-400.

SCHALLER, G. B. 1972. The Serengeti lion: A study of predator-prey relations. Univ. Chicago Press, Chicago. 480pp.

SCHOENER, T. W. 1982. The controversy over interspecific competition. Am. Sci. 70:586-595.

SCHWARTZ, C. C., and A. W. FRANZMANN. 1989. Bears, wolves, and forest succession, some management considerations on the Kenai Peninsula, Alaska. Alces. 25:1-10.

---. 1991. Interrelationships of black bears to moose and forest succession in the northern coniferous forest. Wildl. Monogr. 113. 58pp.

---. 1992. Dispersal and survival of subadult black bears from the Kenai Peninsula, Alaska. J. Wildl. Manage. 56:426-431.

SCHWARTZ, C. C., E. F. BECKER, and K. J. HUNDERMARK. 1990. Development of population assessment techniques for lynx. Alaska Dept. Fish and Game, Fed. Aid Fish and Wildl. Restor. Final Rep., Proj. W-22-6, W-23-1, W-23-2, W-23-3, and W-23-4 Study 7.14., 11pp.

SEIDENSTICKER, J. C., M. G. HORNOCKER, W. V. WILES, and J. P. MESSICK. 1973. Mountain lion social organization in the Idaho Primitive Area. Wildl. Monogr. 35. 60pp.

SHERWOOD, M. B. 1981. Big game in Alaska: A history of wildlife and people. Yale Univ. Press, New Haven and London. 200pp.

SMALL, R. L. 1971. Inter-specific competition among three species of carnivora on the Spider Ranch, Yavapai Co., Arizona. M.S. Thesis, Univ. Arizona, Tucson. 78pp.

SMITH, M. C. 1967. Red squirrel (*Tamiasciurus hudsonicus*) Ecology during spruce cone crop failure in Alaska. M.S. Thesis, Univ. Alaska, Fairbanks. 67pp.

SPENCER, D. L. AND J. L. HAKALA. 1964. Moose and fire on the Kenai. Tall Timbers Fire Ecol. Conf. 3:11-33.

SOVADA, M. A., A. B. SARGEANT, and J. W. GRIER. 1995. Differential effects of coyotes and red foxes on duck nest success. J. Wildl. Manage. 59:1-9.

STEPHENSON, R. O. 1986. Development of lynx population estimation techniques. Alaska Dep. of Fish and Game Div. of Game Fed. Aid in Wildl. Restoration Research Final Report. Proj. W-22-2, W-22-3, W-22-4, and W-22-5 Job 7.12R, 84pp.

---. 1987. Keeping track of lynx in Alaska. Alaska Fish & Game. Nov-Dec:22-24.

STEPHENSON, R. O., D. V. GRANGAARD, and J. BURCH. 1991. Lynx, *Felis lynx*, predation on red foxes, *Vulpes vulpes*, caribou, *Rangifer tarandus* and Dall sheep, *Ovis dalli*, in Alaska. Can. Field-Nat. 105:255-262.

TAYLOR, M. E. 1989. Locomotor adaptions by carnivores. p. 620 (In) J. L. Gittleman (Editor) Carnivore behavior, ecology, and evolution. Cornell Univ., Ithaca.

THEBERGE, J. B., and C. H. R. WEDELES. 1989. Prey selection and habitat partitioning in sympatric coyote and red fox populations, southwest Yukon. Can. J. Zool. 67:1285-1290.

THURBER, J. M., and R. O. PETERSON. 1991. Body-size changes associated with range expansion in the coyote (*Canis latrans*). J. Mammal. 72:750-755.

---. 1992. Coyote coexistance with wolves on the Kenai Peninsula, Alaska. Can. J. Zool. 70:2494-2498.

TODD, A. W. 1985. The Canada lynx: Ecology and management. Can. Trapper.:15-20.

TODD, A. W., L. B. KEITH, and C. A. FISCHER. 1981. Population ecology of coyotes during a fluctuation of snowshoe hares. J. Wildl. Manage. 45:629-640.

TOWEILL, D. E. 1986. Resource partitioning by bobcats and coyotes in a coniferous forest. Ph. D. Thesis, Oregon State Univ., Corvallis. 154pp.

TRAPP, G. R. 1962. Snowshoe hares in Alaska II. Home range and ecology during an early population increase. M.S. Thesis, Univ. Alaska, Fairbanks. 137pp.

VANDERPLOEG, H. A., and D. SCALIA. 1979. Calculation and use of selectivity coefficients of feeding: zooplankton grazing. Ecol. Modeling. 7:135-149.

VAN ZYLL DE JONG, C. G. 1966. Food habits of the lynx in Alberta and the Mackenzie district, N.W.T. Can. Field-Nat. 80:18-23.

VAUGHAN, T. A. 1978. Mammalogy. Second ed. Saunders College Publ., Philadelphia. Pa. 522pp.

VIERECK, L. A., C. T. DRYNESS, A. R. BATTEN, and K. J. WENZLICK. 1992. The Alaska vegetation classification. Gen Technical Rep. PNW-GTR-286, July 1992. Forest Serv. U.S. Dep. Agric. Pacific Northwest Res. Station. Portland, Oreg. 278pp.

VOIGT, D. R., and B. D. EARLE. 1983. Avoidance of coyotes by red fox families. J. Wildl. Manage. 47:852-857.

WALKER, T. 1923. Kenai National Wildlife Refuge historical files. Soldotna, AK.

WALLS, G. L. 1942. The vertebrate eye and its adaptive radiation. Harper, New York 432pp.

WARD, R. M. P. and C. J. KREBS. 1985. Behavioral responses of lynx to declining snowshoe hare abundance. Can. J. Zool. 63:2817-2824.

WELLS, M. C., and M. BEKOFF. 1982. Predation by coyotes: Behavioral and ecological analysis. J. Mammal. 63:118-127.

WHITE, G. C., and R. A. GARROTT. 1990. Analysis of wildlife radio-tracking data. Academic Press, Inc., San Diego, Calif. 383pp.

WHITE, G. C., and R. A. GARROTT. 1986. Effects of biotelemetry error on detecting habitat selection. J. Wildl. Manage. 50:509-513.

WHITE, G. C., D.R. ANDERSON, K. P. BURNHAM and D.L. OTIS. 1982. Capture-recapture and removal methods for sampling closed populations. Los Alamos Natl. Lab. Rep. LA-8787-NERP. N.M. 235pp.

WIELGUS, R. B. and F. L. BUNNELL. 1994. Sexual segregation and female grizzly bear avoidance of males. J. Wildl. Manage. 58:405-413.

WILLIAMS, B. 1993. pers. commun. (Chair, Fur Institute of Canada) at 7th Northern Furbearer Conference, Whitehorse, Yukon, Canada April 22 and 23. Nelderdale Foxes, P.O. Box 381, Salisbury, N.B. 3OA.

WITMER, G. W., and D. S. DECALESTA. 1986. Resource use by unexploited sympatric bobcats and coyotes in Oregon. Can. J. Zool. 64:2333-2338.

WOLFF, J. O. 1980. The role of habitat patchiness in the population dynamics of snowshoe hare. Ecol. Monogr. 50:111-130.

YOUNG, S. P., and H. H. T. JACKSON. 1951. The clever coyote. Univ. Nebraska Press, Lincoln. 441pp.

ZARET, T. M., and A. S. RAND. 1971. Competition in tropical stream fishes: Support for the competitive exclusion principal. Ecol. 52:336-342.

APPENDICES

Appendix A

Capture summary of lynx monitored, areas used and fate of lynx on the Kenai National Wildlife Refuge, Alaska, September 1987-September 1991.

Lynx No. (File No.)	Initial Capture Date	Area & Winters Used**	Initial Age***	Date of last Observation	Fate as of 09/30/91
F29(1500)	02/17/85	S4-8	A	01/20/89	Starved
M30(1170)	03/24/85	S4-8, ES9	K	07/24/90	Radio Failed*
F41(1202)	02/25/87	S6-8,A9-0	K	12/21/90	Illegal Kill
M49(1145)	03/16/87	S6, F7-8	K	07/18/89	Illegal Kill
M55(1863)	08/16/87	M7-8	A	07/25/89	Radio Failed*
F56(1812)	08/28/87	M6-1	A	09/30/91	Transmitting
M57(1813)	03/16/88	S7-1	A	09/30/91	Transmitting
F58(1825)	03/24/88	S7-1	A	09/30/91	Transmitting
M59(1818)	03/24/88	S7-9	K	11/01/89	Radio Failed*
F60(1823)	03/24/88	S7-9,A(S)0-1	A	09/30/91	Transmitting
F61(1811)	04/03/88	S7-0	A	02/12/91	Starved
M62(1842)	04/08/88	S7-1	A	03/14/90	Radio Failed[1]
F63(na)	04/09/88	S7	A	04/11/88	Capture-related mortality
M64(1845)	05/03/88	S8-0	K	09/30/91	Transmitting
M65(1847)	05/19/88	S7-2	A	09/30/91	Transmitting
F66(1958)	06/01/88	S8	K	01/09/89	Starved
F67(1297)	06/29/88	M8-2	S	01/31/89	Radio Failed[2]
M68(1820)	04/26/89	S8	K	05/28/89	Starved
F69(1011)	05/23/89	S8	A	06/20/89	Capture-related mortality
F70(1832)	06/02/89	(R)9	S	11/02/89	Starved
M71(1012)	06/10/89	R8-9, F0	S	03/04/91	Illegal Kill
M72(1835)	06/14/89	R8	K	07/25/89	Starved
M73(1014)	07/19/89	(T)9, B9	K	01/23/90	Starved
F74(na)	08/25/88	(M)8	S		Capture-related mortality
M75(1420)	10/30/90	R0, F1	S	10/02/91	Transmitting
F82	Detected 1988-89,	R8-3	A		Captured 10/25/92
F83	Detected 1989-90,	S9-3	A		Captured 10/26/92

---

* Alive when radio failed, ** S=Study Area, R=Robinson Loop & Southern Boarder of Study Area, M=Mystery Creek Area, WS=West Skilak Loop, ES=East Skilak Loop, F=Funny River area, T=Soldotna Area, B=Benchlands, A=Atkins Road Area. Symbols in parentheses indicate areas used during snow-free seasons. (Adults, kittens of resident females and other individuals tracked before spring capture were assumed to reside in the area indicated during the previous snow season.) For winters used, number = year of Nov./Dec. of indicated winter (example, 9-0=winters 1989-90 and 1990-91) *** A=Adult, S=Sub-adult, K=Kitten.
[1]=recaptured 11/08/91, [2]=recaptured 10/21/92

Appendix B

Lynx response to human presence in Alaska.

Response of lynx to human presence during encounters at ranges of 50 m or less were obtained from refuge staff, reliable observers on the Kenai Peninsula and faculty of the University of Alaska Fairbanks. Only observations that indicated that lynx detected human presence were counted as lynx-human encounters. If lynx stopped and stared at observers, moved closer to investigate or resumed activities without apparent fear after detecting observers, the animal's response was considered a curious or indifferent response. If lynx ran or walked quickly away from observers this behavior was recorded as a flight response. Validity of observations was confirmed by tracks at the encounter site, photographs, our knowledge about study and non-study lynx using the encounter area and specific details of lynx behavior described by the observer.

A total of 106 close (<50 m) encounters with lynx on the Kenai Peninsula by refuge staff and the general public for which range and animal response could be determined were recorded between 1 January 1988 and 30 September 1991. During 79 (75%) of the encounters lynx responded to close approach of humans on foot or in vehicles with indifferent behavior (indicating awareness of human but continuing with original activity). During 13 (12%) encounters lynx responded with curious behaviors such as exaggerated staring for long periods, by moving closer or by moving to a different vantage point to better view the human observer(s). On 14 (13%) occasions lynx fled from human observers. In

9 instances when lynx fled they were startled on roadways by moving vehicles. On one occasion a lynx fled when encountered 100 m above treeline on a mountain east of the study area. In another encounter a young sub-adult lynx (M59) was surprised in his bed and climbed a tree. When I frightened 2 lynx from 2 fresh hare kills and 1 lynx from a large carcass the lynx circled me at close range and returned to feed as soon as I departed the immediate vicinity.

Accounts of a trapper and a hunter on the Kenai Peninsula shooting lynx females with kittens indicate that these lynx were not frightened by small caliber rifle shots. One trapper shot 2 females and their kittens (5 lynx) in the study area during the snow season of 1972-73 (D. Johnson, pers. commun.), and a hunter illegally shot an untagged female and her 2 kittens south of the study area during the snow season of 1988-89 (Soldotna Office, Alaska Department of Fish and Game, pers. commun.).

Lynx feeding on large carcasses or watching potential prey in both natural and depredation situations were very tolerant of human presence. Five tagged lynx and 1 untagged lynx continued to feed on a total of 7 different large carcasses as refuge staff or Swanson River Oil Field personnel approached to within 30 m or less. On one occasion M30 approached 2 hunters butchering a moose and began to feed at 1-2 m range before the hunters realized the lynx was present. The hunters then fed the lynx by throwing it pieces of meat for several minutes until it began to regurgitate meat for rechewing. Four study lynx and 2 non-study lynx sat within 30 m or less of Kenai residents watching domestic animals. Two study lynx and 2 non-study lynx attacked domestic animals and fowl in the presence of their owners. Residents attempted to frighten 3 depredating lynx away by firing 22 caliber rifles, but the lynx did not respond. Firing a 30 caliber rifle and a 12 gauge shotgun with "cracker" shells at 2 of these 3 lynx caused the animals to flee. Encouraging a large dog to pursue a lynx caused the lynx to flee and drop the domestic cat kitten that it had seized.

Lynx sunning themselves or resting during mid-day also were very tolerant of human presence. Female lynx F60 was photographed for over an hour at ranges of 4-5 m on 3 February 1989. Refuge staff conducting lynx research at the Tetlin National Wildlife Refuge also have observed sunning lynx at close range on 2 occasions (C. Perham, pers. commun.). Two male lynx (M65 and M57) were observed resting during the warmer months long enough for observers to take several photographs.

Fifteen additional close encounters made in other locations in Alaska between 1955 and 1993 were related to me by University of Fairbanks faculty and other reliable observers. In 12 of these observations lynx detected humans and continued their activities without response. In 3 of these encounters lynx displayed considerable curiosity about observers and watched observers for several minutes.

Murie(1962), Mech(1973), Berrie(1974), and Todd(1985) have reported observations that suggest that the North American lynx is tolerant of human activity. Our observations on the Kenai Peninsula and reports of encounters with lynx from other areas in Alaska confirm that lynx are behaviorally tolerant of human presence and activity if escape cover and or climbable trees are nearby.

Adult lynx appear to be almost invulnerable to natural predators except for rare instances when they are surprised away from climbable trees, injured, or in very poor condition. Experience gained from 3 seasons of pursuing lynx with trained hounds indicate that adult lynx can run extremely fast for short distances and climb trees faster than any potential enemy in Alaska. Lynx also can jump distances of 4 m or more from tree to tree and therefore are capable of escaping larger climbing predators like bears and wolverine. From 1984-1994 only 2 of over 90 radio-collared Kenai lynx have been killed by wolves. One of these lynx had a capture-related paw injury. I believe that the lynx's lack of vulnerability and perhaps the scarcity of potential lynx predators in northern ecosystems has selected for unwary behavior and a reluctance to flee from strange stimuli unless the animal is actually attacked at close range.

I do not believe that lynx tolerance of human presence and other novel stimuli is due to habituation or food related stress. It is possible that lynx with home ranges near human development become habituated to human presence, but individuals we observed for 2-5 years were also tolerant of human presence when first encountered in remote areas. Remote encounters by other reliable observers in Alaska also indicate that tolerant lynx behavior is not due solely to habituation. Although 2 of our depredating lynx were food stressed and in poor condition (M30 had a paw injury and M73 was an underdeveloped kitten), 3 other depredating individuals were in good physical condition. Also, a great many encounters in which lynx behaved indifferently or curious about human presence occurred during the snow-free season when prey was relatively available and adult lynx were observed to be in good condition.

The number of lynx/human encounters reported in the Kenai, Anchorage and Fairbanks areas have increased recently. I believe that the Kenai trapping closure has greatly reduced annual removal of lynx residing close to areas used by humans and increased the probability of lynx-human interactions. Similarly low fur prices and more conservative management of lynx in other areas of Alaska in recent years probably has allowed lynx numbers and the probabilities of lynx-human encounters to increase near Anchorage and Fairbanks.

Increased lynx sightings also appear to coincide with low hare numbers. An explanation for increased lynx sightings during hare lows might be that hunger associated with prey scarcity makes lynx generally less wary and therefore lynx do not attempt to avoid humans during these periods. I believe, however, that food related stress is not the reason for the lack of fear displayed by lynx in most encounters. Alternatively, I believe that more lynx are sighted during hare lows because the probability of human/lynx encounters during these periods is greater due to high daytime activity rates, larger home ranges (Ward and Krebs 1985) and the greater use of more open habitats as lynx seek non-hare prey.

The "confidence and complacency" of the Alaskan lynx described by Murie (1962), however, makes this species extremely vulnerable to human caused mortality due to shooting, trapping, vehicle collision and depredation conflicts. During hare lows when human/lynx encounters are more likely, lynx lack of fear may subject populations to dangerous levels of human related mortality despite trapping closures by game management agencies.

Because lynx virtually ignore humans when watching or pursuing small animals and fowl, they are particularly vulnerable to shooting during depredation incidents. Lynx are also reluctant to leave a palatable food item when approached by humans. Therefore, they are also particularly vulnerable when feeding on garbage, road kills and winter or hunter killed carcasses. This appears to be normal lynx behavior and is not necessarily an indication that an animal is rabid or a danger to humans. Most lynx will move off if humans approach to within a few meters, but lynx engaged in an attack may have to be separated from their prey with a broom or pole.

The alternately indifferent and curious response of lynx to human presence is much appreciated by tourists and residents on the Kenai Peninsula and suggests that this wildcat can become a valuable "viewable species" in northern areas when near natural densities of this carnivore occur in easily accessible areas.

Appendix C

Capture summary of coyotes monitored, areas used and fate of coyotes on the Kenai National Wildlife Refuge, Alaska, April 1988-September 1991.

Coyote # (File No.)	Capture Date	Areas & Winters Used**	Initial Age***	Date of Last Observation	Fate as of 09/30/91
M1	4/28/88	S7	A		Illegally Killed in Trap
M2(C848)	4/28/88	S7-8, T9	A	1/23/90	Hunter Killed
F3(C874)	4/30/88	S8-9	S	11/29/89	Radio Failed*
F4(C850)	4/30/88	S8-9	S	1/02/90	Radio Failed*
F5(C844)	5/03/88	S7-9	A	4/04/90	Wolf Killed
M6(C248)	5/23/88	S7-9	A	10/12/89	Radio Failed*
F7(C837)	6/03/88	S7-9	A	12/29/89	Radio Failed*
M8(C834)	6/17/88	NW7-8	A	9/21/89	Radio Failed*
F9(C831)	6/25/88	NW7-8	A	8/28/89	Wolf Killed
M10	6/29/88	(S)8	S		Not Collared
F11(C852)	7/02/88	M7-9	A	12/29/89	Radio Failed
F12(C832)	8/04/88	R7-9	A	1/23/90	Radio Failed
F13	7/12/88	(M)8	S		Not Collared
F14(C829)	7/09/88	M7-0	A	2/23/90	Road Killed
M15	8/15/88	(S)8	P		Wolf Killed in Trap
M16	7/15/88	(S)8	S		Not Collared
M17	8/22/88	(S)8	S		Not Collared
M18(C003)	4/16/89	S8-0	A	9/13/90 2/26/91	Radio Failed* Hunter Killed
F19(C846)	4/18/89	S8-9	A	2/11/90	Wolf Killed
F20(C005)	4/19/89	(S)9	S	10/05/89	Hunter Killed
F21(C007)	4/23/89	S9	S	7/16/90	Radio Failed*
M22	4/23/89	S8	A		Not Collared
M23	7/04/89	M8	A		Not Collared
F24	7/06/89	(M)9	S		Not Collared
M25	4/21/90	S9	A		Not Collared
M26	5/21/90	S9	A		Not Collared
F27	7/21/90	(S)0	S		Not Collared
M28	8/16/90	WS9	A		Not Collared
M29	8/16/90	(WS)0	P		Not Collared

* Alive when radio failed ** S=Study Area, T=Soldotna Area, R=Robinson Loop & Southern Border of Study Area, M=Mystery Creek Area, NW=North West Border of Study Area and Area to North, WS=West Skilak Loop, An area symbol in parentheses indicates that an area was used during the snow-free season. For winters used--number = year of Nov./Dec. of indicated winter (example-- 8-0=winters of 1988-89, 1989-90 and 1990-91) Spring/Summer captured adults are assumed to have resided in area during previous snow season. *** A=Adult, S=Sub-adult, P=pup

Appendix D

Percent occurrence of food items recovered from lynx scats by season on the Kenai National Wildlife Refuge, 1987-1990.

	Snow 1987-88, N=68		Snow free 1988, N=12		Snow 1988-89, N=68	
	%Freq. Total Scats	%Freq. Total Items	%Freq. Total Scats	%Freq. Total Items	%Freq. Total Scats	%Freq. Total Items
Hare	95.6	66.3	91.7	55.0	91.2	64.6
Grouse	14.7	10.2			4.4	3.1
Squirrel	11.8	8.2	16.7	10.0	8.8	6.3
Moose	1.5	1.0			8.8	6.3
Vole	13.2	9.2	41.7	25.0	16.2	11.5
Shrew						
Mallard						
Unid. Bird			8.3	5.0	2.9	2.1
Salmon	1.5	1.0				
Unid. Fish	1.5	1.0				
Grass	1.5	1.0			2.9	2.1
Porcupine					1.5	1.0
Ermine					1.5	1.0
Unid. Mammal	1.5	1.0	8.3	5.0	2.9	2.1

	Snow free 1989, N=19		Snow 1989-90, N=25		Snow free 1990, N=11	
	%Freq. Total Scats	%Freq. Total Items	%Freq. Total Scats	%Freq. Total Items	%Freq. Total Scats	%Freq. Total Items
Hare	73.7	41.2	80.0	51.3	27.3	14.3
Grouse	5.3	2.9	12.0	7.7	36.4	19.0
Squirrel	52.6	29.4	40.0	25.6	81.8	42.9
Moose			16.0	10.3		
Vole	26.3	14.7	4.0	2.5	9.1	4.8
Shrew	5.3	2.9				
Mallard					9.1	4.8
Unid. Bird	5.3	2.9			9.1	4.8
Salmon						
Unid. Fish						
Grass	5.3	2.9				
Porcupine						
Ermine						
Unid. Mammal					18.2	9.5

Appendix E

Carcass use by lynx on the Kenai Peninsula, Alaska, 1988-1990.

Lynx ID	Carcass Species	*Location	Cause of Death	Time in Vicinity Carcass Dates	Time in Vicinity Carcass Total Days
Unident.	moose	in	road-kill	3/3-11/88	9
F60	moose	in	serious injury, euthanized by MRC staff	11/15-30/89	16
M30	moose	in	winter-kill	3/6-27/89	18
M65	moose	in	winter-kill	1/2-9/90	8
M65	moose	in	unknown	1/18-22/90	5
M65	moose	in	winter-kill	2/8-11/90	3
M30	moose	out	road-kill	1/15/90	1
M30	moose	out	road-kill	2/15-27/90	13
F60	moose	in	winter-kill	2/23-25/90	3
M75	black bear	out	hunter-kill	11/22-12/14/90	22
F41	moose	in	winter-kill, wolverine bait	3/29/89	<1, fed little
F60	moose	in	winter-kill, wolverine bait	4/5/89	<1, fed little
M30	moose	out	hunter-kill, while hunters were butchering carcass, 1 m range	9/29/90	<1, fed on meat thrown by hunters

*Location- in = within 1987-1991 study area
out = outside boundaries of study area

Appendix F

Lynx hunting strategies used on the Kenai National Wildlife Refuge, 1988-1990.

Lynx used mobile (M) and stationary (S) hunting strategies (Geertsema 1985, Kruuk 1986), but also used an intermediate strategy resembling human "still hunting". The mobile strategy consists of pursuing prey detected while moving across the landscape; Nellis and Keith (1968) consider this to be the optimal lynx hunting strategy at low hare densities. The stationary strategy involves lying or crouching in one location for long periods of time waiting for prey to move to the predator. Only one hare kill was made using the stationary or ambush bed strategy. Kenai lynx used the mobile hunting strategy. They also used a hunting strategy that appears to be intermediate between the mobile and stationary strategies to kill 11 of 12 hares. This strategy closely resembles the "still hunting" strategy often practiced by human hunters which entails moving slowly through prime habitat and stopping frequently to look for game.

Snow tracking observations indicated that Kenai lynx moved through areas with little prey sign in a relatively straight line at a moderate pace (M strategy). Upon encountering hare tracks lynx zigzagged, looped, backtracked and frequently sat down. Often tracks indicated that the lynx shifted their orientation 90 degrees or more during a sitting episode. This slow movement and frequent stopping to scan the area for prey closely resembles still hunting practiced by human hunters. On one occasion Ian Martin (pers. commun.) observed a lynx in an alert sitting position on the side of a road for approximately 3 minutes before it pursued and killed a squirrel. On another occasion I watched a lynx sit on Swan Lake Road for 5 minutes watching the edge of an area containing relatively high hare densities before it and 2 other lynx entered the woodline.

Appendix G

Detailed observations of lynx food habits in the Sterling Corridor area Kenai Peninsula, Alaska 1987-1991.

Areas cleared for agriculture and residential construction often had abundant deciduous regrowth and more hare sign than the study area. Several residents stated that they had "hare pockets" on their property despite generally low hare densities on the peninsula. During the snow-free season Kenai River riparian areas were populated with large numbers of gulls (*Larus* spp.) supported by annual runs of Chinook (*Oncorhynchus tschawytscha*), sockeye (*O. nerka*), coho (*O. kisutch*) and pink (*O. gorbuscha*) salmon and their smolt. Large sections of the Kenai River did not freeze during the snow season and supported an over-wintering population of mallard ducks. Hay fields offered areas with high densities of voles.

Human activities directly supplied other potential food sources. Traffic on the Sterling Highway resulted in road-killed moose carrion during the snow season and road-killed birds and smaller mammals all year long. Unpenned "herds" of domestic rabbits, poorly caged domestic fowl, cats and small dogs in lightly developed residential areas provided potential prey for small carnivores. Meat and fat placed by residents for birds also provided a potential food source for predators.

Six study lynx moved south and used the corridor area during the study period. Three of these, lynx M49, F60, and M71' used domestic rabbits and fowl at 8 different residences (Appendix E). Five additional lynx, a year-old male kitten (M73), an unidentified female with kitten and 2 adult male lynx, that did not reside primarily in the study area were responsible for taking rabbits and fowl at 2 additional residences. At 6 of the 10 residences rabbits or fowl were running loose on the owner's property. At one residence a pen gate was left open, and at another location a 10 cm gap existed under a wire fence when losses occurred. At another 3 of the 10 depredation sites pen wire was less than 1 meter high and no overhead net or wire was present. At one residence, lynx F60 was able to lift loose wire tops of rabbit cages resting on the ground and remove rabbits. At one site a lynx killed a rabbit through the coarse wire bottom of a elevated wire hutch but could not remove the kill. None of the residents experiencing losses had large dogs or dogs that were kept outside of buildings in order to guard property.

All losses of small livestock to lynx could have been prevented by standard husbandry practices. Lynx were not able to kill or remove rabbits from elevated hutches with fine wire or double coarse wire bottoms. When revisiting 2 depredation sites, lynx were not able to take chickens or ducks from 2 m-high, gap free wire enclosures when entrance gates were tightly closed.

Study and non-study lynx were seen by residents at 7 of 10 depredation sites. Investigation determined that coyotes, feral dogs, cats and raptors were known to have killed small livestock at 3 sites but that these other predators were seldom seen by home owners. Resident #2 shot 3 feral dogs on his property while a kitten lynx (M73) was taking free-ranging rabbits. Detailed observations revealed that coyotes, dogs and the neighbor's cat were taking as many rabbits at residence #2 as was lynx M73. These observations indicated, that in situations where rabbits and fowl were allowed to run free on the Kenai Peninsula, depredations of other predators were attributed to the lynx.

Lynx were not observed to engage in surplus killing at depredation sites. Two owners commented that lynx tended to take one animal at a time while dogs often killed several fowl or rabbits in one incident. Two chickens were killed in one depredation event, but a female adult and a kitten were later seen pursuing fowl at the site suggesting that the female and the kitten killed one bird each.

Three lynx were observed feeding on road killed carcasses in the presence of heavy road traffic. In January and February of 1990 adult lynx M30 was detected feeding on 3 road-killed moose along the Sterling Highway in the Mystery Hills area. A lynx was seen feeding on a small mammal carcass on the side of the highway in Sterling in March of 1989. Two lynx were also observed feeding on a road-killed moose 50 m from the Oil field Pump Station in the Swanson River Oil field during March of 1988. For 7 days oil field workers parked their vehicles within several meters of the carcass and watched the lynx feed.

Lynx also used aquatic birds in the Kenai River riparian zone. Snow season use was detected when tracking revealed that adult male M30 jumped into a Kenai River slough and killed a mallard on 24 January 1990. On another occasion, in February of 1989 residents reported observing a lynx intently watching over wintering mallards in a small unfrozen section of the Kenai River. On 13 September 1988 a bear hunter observed adult female F60 kill and carry off a large gull in the vicinity of the Killey and Kenai River confluence. F60 returned to her study area home range in October of 1988 after spending over 2 months along the Kenai River. In the summer of 1989 F60 again left her home range but headed north and spent over a month along the Chickaloon River which has an annual salmon run and large numbers of associated gulls.

Our observations indicate that Kenai lynx made use of salmon during the study period. In September of 1988 F60 was observed clawing dead pink salmon on the banks of the Kenai River. She did not feed on this occasion, but her interest in the fish suggested that she might have fed if the salmon were fresher. In September of 1989 a moose hunter observed an unmarked lynx drag a silver salmon from a creek flowing into Tustumena Lake. While our captive lynx repeatedly refused thawed frozen salmon, 2 male lynx did consume fresh king salmon and rainbow trout (*Salmo gairdneri*). A Soldotna fur farmer informed me that although her lynx preferred red meat she routinely fed them a feed comprised largely of salmon byproducts from local fish processors (pers. commun. Mary Bahl 1989).

I documented that lynx hunted, pursued and killed snowshoe hares in 6 locations in the developed Kenai River corridor. Lynx male M71 pursued a hare in an area of abundant hare sign, 200 m from residence #8, approximately 2.5 km east of Soldotna. Owners of depredation residence #10 located 10 km east of Soldotna reported that lynx tracks were often present in a "hare pocket" on their property. Female F60 killed and consumed a wild hare less than 30 m from depredation residence #9 located 29 km east of Soldotna. Hare browse and amounts of hare sign equivalent to the best areas in the study area were present around residence #9. Male lynx M75 pursued a hare 31 km east of

Soldotna while he was scavenging a frozen bear carcass. Unlike other lynx observed using carrion, M75 spent a lot of time moving about in an area that contained hare sign in the vicinity of the carcass. In October of 1988 an unidentified lynx was seen carrying a hare across the Sterling Highway 32 km east of Soldotna.

Lynx were also observed scavenging food placed for birds by area residents. Non-study lynx were observed at 3 different locations feeding on holiday turkey carcasses during 1989. At one of these locations 2 lynx kittens returned to a house deck for three evenings to chew on a turkey carcass and other discarded meat items. At a fourth residence a lynx was observed on top of a smoke house eating suet intended for birds.

Three confirmed reports of lynx returning repeatedly to feed on food placed for them were recorded. At one residence a lynx kitten was fed for an entire winter and was noted to have increased greatly in size by spring. At another residence an adult lynx was fed 3 to 4 times a week and finally was observed to sit on the porch waiting to be fed. At a third site dead fowl and table scraps were left for a lynx in a "cubby" to the rear of a house. Tracks in the snow revealed that a lynx visited this cubby frequently during the winter of 1989-90. A fourth unconfirmed report from a person who wanted to remain anonymous stated that a female lynx denned close to a residence located on the southern boundary of the study area during 2 or more summers. Food was allegedly placed near the den site and consumed by the adult female. Our tracking, capture and depredation observations indicated that a female with kittens did reside to the south of the study area during the period in question.

Lynx were also observed to consume small birds and voles in developed areas. At one residence a non-study lynx was observed to kill and eat a songbird while feeding on a turkey carcass. Apparently the same lynx was observed pursuing and eating small birds along the road leading to this residence for three days. A female lynx and kittens were observed pouncing on voles in a freshly cut hay field in September of 1988. The observer reported that voles were very vulnerable in freshly cut fields and that he had also seen coyotes catching voles from such fields over the years.

Appendix H

Attempted use of domestic animals by lynx on the Kenai Peninsula, Alaska, 1988-1990.

Lynx ID	Month &Year	Residence # Location	Kill Success	Prey	Circumstances
Male*	01/88	#1, 17 Mi., Funny River Road	Yes	Rabbit	Loose on property
Male*	01/88	#1, 17 Mi., Funny River Road	Yes	Duck	Loose on property
M49	02/89	#2, Lake Side Road	Yes Yes	Chicken Duck	< 1 m high wire, gaps in overhead net
M49	02/89	#3, 2.3 Mi. Brown's Lake Road	Yes	Chicken	2 chickens loose, pen door open
M49	02/89	#3, 2.3 Mi. Brown's Lake Road	No	Chicken	Chickens in pen, 2 m high wire, pen door closed
M49	11/88	#4, 2 Mi. Brown's Lake Road	No	Rabbit	Killed with claws through coarse wire cage floor, could not remove kill
M49	03/89	#4, 2 Mi. Brown's Lake Road	No	Chicken	2 m high wire pen, top of wire bent inward
M73	07/89	#5, North Boundary Road	Yes	Rabbits	Loose on property
M71	10/89	#6, Panorama Drive, Sterling	Yes	Chicken	< 1 m high wire, no overhead net
			Yes Yes	Duck Turkey	
M71	10/89	#7, Scout Lake Road, Sterling	Yes	Duck	Loose on property
			No	Duck	Owner pulled duck out of lynx's mouth
M71	01/90	#5, North Boundary Road	Yes	Rabbits	Loose on property
M71	02/90	#8, 1.5 Mi. east of Soldotna	Yes	Duck	Loose on property
F60	11/90	#9, Atkins Road	Yes	Chicken	< 1 m high wire around open coup
			Yes	Rabbits	Cage on ground with loose wire top
Fem. & Kit	08/89	#10, Robinson Loop Road, Sterling	Yes	Chicken	20 cm gap under pen wire
			No	Duck	Chased away by owners
Unid.	10/89	#10, Robinson Loop Road, Sterling	Yes	Duck	Loose on property
Unid.	05/90	#5, North Boundary Road, Soldotna	Yes	Rabbits	Loose on property
Unid.	07/89	#11, Cohoe Loop, Kasilof	No	Cat, kitten	Dog pursued lynx & lynx dropped the cat

Appendix I

Percent occurrence of food items recovered from coyote scats by season on the Kenai National Wildlife Refuge, 1987-90.

	Snow 1987-88, N=28		Snow free 1988, N=109		Snow 1988-89, N=97	
	%Freq. Total Scats	%Freq. Total Items	%Freq. Total Scats	%Freq. Total Items	%Freq. Total Scats	%Freq. Total Items
Hare	35.7	25.0	48.6	22.3	29.9	12.2
Grouse	7.1	5.0	8.3	3.8	4.1	2.4
Grouse egg	0	0	2.7	1.3	0	0
Squirrel	0	0	4.6	2.1	4.1	2.4
Moose	64.3	45.0	40.4	18.5	64.9	37.5
Vole	28.6	20.0	85.3	39.1	39.2	22.6
Loon egg	0	0	.9	.4	0	0
Merganser egg	0	0	.9	.4	0	0
Unid. egg	0	0	.9	.4	0	0
Mallard	0	0	.9	.4	0	0
Great Horned Owl	0	0	0	0	2.1	1.2
Unid. bird	3.6	2.5	7.3	3.4	3.1	1.8
Salmon	0	0	7.3	3.4	18.6	10.7
Grass	0	0	5.5	2.5	3.1	1.8
Beaver	0	0	.9	.4	1.0	.6
Caribou	0	0	0	0	1.0	.6
Porcupine	0	0	2.8	1.3	2.1	1.2
Unid. Mammal	3.6	2.5	0	0	0	0
Blue berry	0	0	0	0	0	0
Low Bush cranberry	0	0	0	0	0	0
Prickly rose	0	0	0	0	0	0
High Bush cranberry	0	0	.9	.4	0	0

Appendix I (Continued)

Percent occurrence of food items recovered from coyote scats by season on the Kenai National Wildlife Refuge, 1989-90.

	Snow free 1989, N=67		Snow 1989-90, N=54		Snow free 1990, N=7	
	%Freq. Total Scats	%Freq. Total Items	%Freq. Total Scats	%Freq. Total Items	%Freq. Total Scats	%Freq. Total Items
Hare	47.8	20.0	13.0	8.8	28.6	22.2
Grouse	6.0	2.5	11.1	7.5	14.3	11.1
Grouse egg	0	0	0	0	0	0
Squirrel	3.0	1.3	1.9	1.3	0	0
Moose	71.6	30.0	83.3	56.3	57.1	44.4
Vole	49.3	20.6	7.4	5.0	0	0
Loon egg	0	0	0	0	0	0
Merganser egg	0	0	0	0	0	0
Unid. egg	0	0	0	0	0	0
Mallard	0	0	0	0	0	0
Great Horned Owl	1.5	.6	0	0	0	0
Unid. bird	19.4	8.1	0	0	0	0
Salmon	11.9	5.0	14.8	10.0	0	0
Grass	6.0	2.5	7.4	5.0	14.3	11.1
Beaver	1.5	.6	0	0	0	0
Caribou	0	0	0	0	0	0
Porcupine	7.5	3.1	9.3	6.3	14.3	11.1
Unid. Mammal	0	0	0	0	0	0
Blue berry	10.4	4.4	0	0	0	0
Low Bush cranberry	1.5	.6	0	0	0	0
Prickly rose	1.5	.6	0	0	0	0
High Bush cranberry	0	0	0	0	0	0

Appendix J

Coyote food habits in the Sterling Corridor area, Kenai Peninsula, Alaska 1987-1991.

Coyotes fed on road kills along the Sterling Highway and other roads but were not observed consuming carrion in the presence of heavy traffic. Coyote C829 was feeding on a moose carcass by the side of the Sterling Highway but was struck and killed by an automobile when she attempted to flee from a vehicle traveling in the opposite direction. Moose hit by vehicles that managed to move into cover before dying were utilized by coyotes without apparent reservation.

Coyotes were also observed hunting for voles and using salmon in the corridor area. Two residents reported observing coyotes "pouncing" after voles in hayfields on numerous occasions. On 6 occasions coyotes were observed along the Kenai River digging up old salmon carcasses, driving eagles off freshly killed salmon or standing in the river waiting for salmon.

Depredation of unprotected domestic animals by coyotes appeared to occur at a low but constant rate during the study period. Tracking sign and resident observations indicated that coyotes killed loose domestic rabbits at 2 residences. A coyote was also observed to kill and carry off an unpenned domestic duck at a third residence. In the Robinson Loop residential area south of the study area 2 small dogs, a cocker spaniel and a beagle, were killed and partially eaten by local coyotes. No observations or other evidence, however, indicated that coyotes entered any kind of an enclosure in pursuit of domestic animals or fowl.

Appendix K

Multiple comparison test ranks assigned to the difference between percent lynx habitat use and percent availability (aerial relocations, both seasons) by micro/macro habitat type on the Kenai National Wildlife Refuge, Alaska, November 1987-September 1991.

	Micro/Macro Habitat Type								
Study Lynx	1947 burn/ 1947 burn	1947 burn/ Crushed	Mature/ 1947 burn	Mature/ Crushed	Crushed/ Crushed	Mature/ Mature	Mature/ 1969 burn	1969 burn/ 1969 burn	Locations per lynx (N =495)
500	8	5.5	7	5.5	3	1	4	2	32
170	8	6	7	4	5	1	3	2	30
842	8	5.5	7	5.5	3	2	4	1	27
823	8	5.5	7	5.5	3	1	4	2	54
847	8	5.5	7	5.5	3	1	4	2	64
825	8	5	7	6	3	2	4	1	64
202	8	6	7	5	3	1	4	2	71
813	8	5.5	7	5.5	3	1	4	2	59
811	8	4.5	7	4.5	2	6	3	1	31
845	8	4.5	7	4.5	6	1	3	2	44
818	8	5.5	7	5.5	3	1	4	2	19
Rank Sums	88	59	77	57	37	18	41	23	
Multiple Comparison Rank Group	A	C	B	C	D	E	D	E	

Significant rank sum separation distance ($t_{.975}$) = 7.69 units

Appendix L

Lynx macro habitat selection (619 aerial locations) on the KNWR, Alaska, November 1987-September 1991.

Macro Habitat	Habitat Availability (%)p	Use (%)r	Forage Ratio r/p (*)	Multiple** Comparison Rank Group
1947 burn	43.5	86.6(536)	1.99(+0.46)	A
Crushed	3.8	2.3(14))	0.61(-0.09)	B
Mature	31.1	9.7(60)	0.31(-0.43)	C
1969 burn	21.6	1.4(9)	0.06(-0.85)	C

* equivalent Vanderploeg and Scavia Relativized Electivity Index(E*) value in parenthesis

** Habitats with same letter do not differ ($P > 0.05$)

Friedman's test result of $T = 66.64$, $P < 0.01$ indicates rejection of null hypothesis of equal use of 4 macro habitat types.

Lynx macro habitat selection in the 2,400 m road buffer (373 ground locations) on the Kenai National Wildlife Refuge, Alaska, November 1987-September 1991. Sample size in parentheses.

Macro Habitat	Habitat Availability (%)p	Use (%)r	Forage Ratio(*) r/p
1947 burn	33.9	72.4(270)	2.14(+0.44)
Crushed	5.3	2.7(10)	0.51(-0.25)
Mature	45.2	22.5(84)	0.50(-0.25)
1969 burn	15.6	2.4(9)	0.15(-0.66)

* equivalent Vanderploeg and Scavia Relativized Electivity Index(E*) value in parenthesis

The Wilcoxon sign rank test conducted on habitat use E* values of the whole study and road buffer areas resulted in a test statistic of $T = +0.73$, $P = 0.77$ indicating no significant difference between lynx habitat use in these two areas. At a minimum the ranked use of habitats for both areas is the same.

Appendix M

Multiple comparison test ranks assigned to the difference between percent lynx habitat use and percent availability (602 lynx aerial relocations, both seasons) by macro habitat type on the Kenai National Wildlife Refuge May 1988-April 1990.

	Macro Habitat Type				
Study Lynx	1947 burn	Crushed	Mature	1969 burn	Locations per Lynx
500	4	3	1	2	36
170	4	3	1	2	32
842	4	3	2	1	32
823	4	3	1	2	58
847	4	3	1	2	76
825	4	3	2	1	80
202	4	3	1	2	79
813	4	3	1	2	73
811	4	2	3	1	39
845	4	3	1	2	63
818	4	3	2	1	23
958	4	3	1	2	11
Rank Sums	40	29	15	16	
Multiple Comparison Rank Group	A	B	C	C	

Significant rank sum separation distance ($t_{0.975}$) = 5.06 units

Appendix N

Lynx habitat selection in smaller 250 km^2 study area (391 aerial locations)September 1984-May 1987, on the Kenai National Wildlife Refuge. Sample size in parentheses. (from Kesterson 1988).

Habitat		Avail-ability	Util-ization	Forage Ratioe	Multiple** Comparison
Micro	Macro	(%)	(%)	(*)	Rank Group
47 burn	47 burn	51.8	72.4(284)	1.40(-0.10)	A
47 burn	crushed	0.3	1.3(5)	4.33(+0.45)	AB
mature	47 burn	9.6	15.3(60)	1.59(-0.03)	B
mature	crushed	0.5	1.0(4)	2.00(+0.08)	B
crushed	crushed	3.5	0.3(1)	0.09(-0.89)	C
mature	mature	34.3	9.5(37)	0.28(-0.70)	C

* equivalent Vanderploeg and Scavia Relativized Electivity Index(E*)

** Habitat with same letter do not differ ($P > 0.05$)

Appendix O

Lynx habitat selection in the smaller 250 km^2 study area (323 aerial locations), November 1987-September 1991, on the Kenai National Wildlife Refuge, Alaska.

Habitat		Availability (%)	Utilization (%)	Forage Ratio (*)	Multiple** Comparison Rank Groups
Micro	Macro				
1947 burn	1947 burn	52.9	67.5(218)	1.28(-0.03)	AB*
1947 burn	crushed	0.8	1.2(4)	1.50(+0.06)	CD
mature	1947 burn	7.2	20.8(67)	2.89(+0.36)	A
mature	crushed	0.5	.9(3)	1.80(+0.15)	BC
crushed	crushed	4.8	1.2(4)	0.25(-0.70)	DE
mature	mature	33.8	8.4(27)	0.25(-0.70)	E

* equivalent Vanderploeg and Scavia Relativized Electivity Index(E*)

** Habitats with same letter do not differ ($P > 0.05$)

A Friedman test statistic of ($T2 = 20.35$, $P < 0.01$) indicated that lynx continued to be selective in their use of habitat in the smaller 250 km^2 study area from 1987-1991. Multiple comparison rank test groups indicate that preference differences between 1947 burn/1947 burn and mature/1947 burn and avoided mature/mature areas are significant.

As indicated in Appendix P a slightly higher t value ($t_{.950}$) results in a smaller separation distance and easy to see difference among habitat categories via nonoverlaping rank groups A, C, A, B and D. Combining 1969 burn and crushed habitat types in the analysis described in Appendix O also resulted in detection of distinct differences in habitat use via nonoverlaping rank groups A, A, B and B.

Appendix P

Multiple comparison test ranks assigned to the difference between percent lynx habitat use and percent availability (308 aerial relocations, both seasons) in the smaller 250 km^2 area by micro/macro habitat type, on the Kenai National Wildlife Refuge, Alaska, November 1987 to September 1991.

	Micro/Macro Habitat Type						
Study Lynx	1947 burn/ 1947 burn	1947 burn/ Crushed	Mature/ 1947 burn	Mature/ Crushed	Crushed/ Crushed	Mature/ Mature	Total Relocations
500	6	3	5	4	2	1	31
170	5	4	6	3	2	1	28
823	6	3	5	4	2	1	16
847	5	3	6	4	2	1	56
825	4	2	6	5	3	1	22
202	5	3	6	4	2	1	62
813	6	3	5	4	2	1	29
811	2	3	5	4	1	6	28
845	6	3	5	4	2	1	32
Rank Totals	45	27	49	36	18	14	
Multiple Comparison Rank Groups	AB	CD	A	BC	DE	E	
Significant rank sum separation distance (t $_{0.975}$) = 9.03 units							
Multiple Comparison Rank Groups	A	C	A	B	D	D	
Significant rank sum separation distance (t $_{0.950}$) = 7.53 units							

Appendix Q

Multiple comparison test ranks assigned to the difference between percent lynx habitat use and availability (304 aerial relocations, both seasons) in the small 250 km^2 study area by micro/macro habitat type, on the Kenai National Wildlife Refuge, Alaska, November 1987 to September 1991. All crushed habitat types were combined to simplify analysis and reduce sampling error associated with rare habitats.

	Micro/Macro Habitat Type				
Study Lynx	1947 burn/ 1947 burn	Mature/ 1947 burn	Mature/ Mature	All Crushed	Total Relocations
500	4	3	1	2	31
170	3	4	1	2	28
823	4	3	1	2	16
847	3	4	1	2	56
825	2	4	1	3	22
202	3	4	1	2	62
813	4	3	1	2	29
811	2	3	4	1	28
845	4	3	1	2	32
Rank Sums	29	31	12	18	
Multiple Comparison Rank Group	A	A	B	B	

Rank sum separation distance $t_{0.975}$ = 7.40 units

Friedman's test statistic T_2 = 12.20, $P < 0.01$ (null hypothesis of equal habitat use is rejected because 12.20 is greater than $\alpha = 0.05$ critical region of all values greater than 3.01.)

Appendix R

Lynx social behavior on the Kenai Peninsula, Alaska, 1987-1991.

Adult lynx were detected together on 4 occasions other than the early April breeding season. Two adult lynx fed on the same moose carcass in the Swanson River Oil Field 3-11 March 1988. On 12 December 1990 I detected both M75 and F41 within 5 m of a black bear carcass. Lynx F41, however, only remained in the vicinity of the carcass for 2 days while M75 used the carcass for 22 days. On 2 February 1988 I observed 2 adult lynx and one kitten traveling and apparently hunting together in the northeastern portion of the study area. On 11 February 1988 I found tracks indicating that 2 adult lynx in the northwestern portion of the study area traveled and interacted with each other for 550 m before separating.

We also observed 2 instances of adult females associating with sub-adult females. Adult lynx F29 was first seen with sub-adult F41 on 9 December 1987. These two lynx were relocated a total of 6 times between the initial sighting and 12 February 1988. During the next snow season adult lynx F56 was relocated with sub-adult F67 seven times between 11 November 1988 and 31 January 1989. Both young females were captured in areas used by the adult females with which they associated and both adult females were without kittens during the snow seasons in which they associated with their daughters so we assumed that the sub-adult lynx were the 1.5 year old daughters of the older animals.

I located 11 scent marking sites or latrines in the study area. Four of these were under robust white spruce growing on ridges. The snow shadow under 3 of these trees caused deposited scats to be exposed to view through the snow season despite heavy snow fall. Four latrine sites were located on the sides of narrow trails on grass tussocks or on mounds of moss. Three scent marking sites were located 3 to 5 m away from wide open trails, but scats were highly visible because they were deposited on the sides of steep embankments 2-3 m higher than trail surfaces.

I was able to capture 7 lynx at four of the latrines. Nine lynx captures were made during the study period with trap sets that used scats as attractors. Two of these trap sets were made intentionally for lynx, while 7 of the 9 lynx captures were made in scat sets intended for either wolves or coyotes. Canid scat sets that captured lynx used highly visible scat attractors placed on rocks by the sides of roads and trails.

Detailed descriptions of 54 lynx defecation sites (confirmed with tracks) indicate that 61% of these defecations occurred on elevated substrates like grass tussocks, mounds of moss, stumps and logs. Conversely, in 177 confirmed defecation events, coyotes never deposited scat on elevated objects. Kenai lynx defecation sites were similar to those observed by Saunders (1963), but I disagree with Saunder's contention that lynx did not select for site types. Kenai lynx latrines also resembled descriptions of prominent bobcat defecation sites reported by Bailey (1974).

Our observations suggest that North American lynx have a more flexible social structure than previously thought. Two Kenai females that hunted with their 18-month-old daughters may have gained the higher hunting efficiencies for groups of lynx reported by Parker et al. (1983) as well as increasing the probabilities that young with their genes survived. Both yearling female lynx survived their second winter and were recruited into the area population despite low hare numbers and starvation of many other kitten and yearling lynx during this period. Similarly Aldama and Delibes (1991) recently reported that an adult female Spanish lynx *(Felis pardina)* shared kills with her 21-month-old daughter and with her 18-month-old son during consecutive winters and suggested that this adult lynx increased her fitness through this behavior.

My sighting of 2 adults and 1 kitten apparently hunting together on 2 February 1988 and the observations of Haglund (1966) and Barash (1971) indicate that adult lynx occasionally cooperate while hunting. Haglund reported that 2 adult lynx shared a snowshoe hare after killing it in his study area in Sweden. Barash reported observing 2 adult lynx and a kitten traveling together in Glacier National Park, Montana. The two adults cooperated to kill a Columbian ground squirrel (*Spermophilus columbianus*) and all 3 lynx shared the squirrel.

Cooperative hunting has not been documented for other small solitary wildcats. I speculate that cooperative hunting and sharing of food by lynx may be an evolved behavioral response to frequent catastrophic food shortages in lynx habitats around the world. When female lynx without kittens cooperate with their yearling progeny they appear to be engaging in particularly evolutionarily stable behavior. I believe it is likely that "adults" that Barash, Haglund and I detected hunting together may also have been adult females and sub-adult progeny.

The extreme vulnerability of lynx to trap sets using scat attractors and the maintenance of scent marking sites in conspicuous locations suggest that marking with feces is very important to the maintenance of lynx social systems. The high percentage of lynx defecations that occurred on elevated objects and in established latrines during this study suggests that defecation location as well as tracks, morphology and smell can be used to differentiate lynx from coyote or wolf scats.

Appendix S

Multiple comparison test ranks assigned to the difference between percent coyote habitat use and availability (aerial relocations, both seasons) in the study area by micro/macro habitat type on the Kenai National Wildlife Refuge, Alaska, May 1988-April 1990.

	Micro/Macro Habitat Type								
Study Lynx	1947 burn/ 1947 burn	1947 burn/ Crushed	Mature/ 1947 burn	Mature/ Crushed	Crushed/ Crushed	Mature/ Mature	Mature/ 1969 burn	1969 burn/ 1969 burn	Total Locations
846	7.5	6.5	7.5	6.5	2	3	4	1	9
837	7	4.5	8	4.5	6	1	3	2	14
850	8	4	7	5	6	1	3	2	23
874	6	4.5	8	4.5	7	1	3	2	13
248	8	4	5	7	6	1	3	2	11
003	3	5	8	7	6	1	4	2	9
Rank Totals	39.5	28.5	43.5	34.5	33	8	20	11	
Multiple Comparison Rank Group	AB	CD	A	ABC	BC	F	DE	EF	
Significant rank sum separation distance ($t_{0.975}$) = 9.04 units									
Multiple Comparison Rank Group	AB	C	A	BC	BC	E	D	E	

Significant rank sum separation distance ($t_{0.950}$) = 7.50 units
(avoided habitat types mature/mature and 1969 burn are in separate letter groups from preferred 1947 burn and crushed habitat types at $t_{0.950}$.

Appendix T

Multiple comparison test ranks assigned to the difference between percent coyote habitat use and availability (aerial relocations, both seasons) in the study area by macro habitat type, on the Kenai National Wildlife Refuge, Alaska, May 1988-April 1990.

	Macro Habitat Type				
Study Coyote	1947 burn	Crushed	Mature	1969 burn	Total Relocations
846	4	2	3	1	11
837	4	3	1	2	16
850	4	3	1	2	25
874	4	3	1	2	13
248	4	3	1	2	11
003	4	3	1	2	11
Rank Totals	24	17	8	11	
Multiple Comparison Rank Group	A	B	C	C	

Significant rank sum separation distance ($t_{0.975}$) = 4.26 units

Appendix U

Number of occurrences and percent biomass of prey species in the diet of Kenai lynx as determined from analysis of 41 snow free season scats.

Prey Species	Occurrences	Biomass Value *	% Diet Biomass
Snowshoe hare	28	1400	81.5
Vole	11	25	0.6
Red squirrel	21	200	8.7
Spruce grouse	5	550	5.7
Miscellaneous	8	1660 **	3.5

* Biomass values used by Brand (1976)

** Phase III miscellaneous category includes 1 shrew, 1 mallard, 3 unidentified mammals and 3 unidentified birds compared to miscellaneous summer category of Brand (1976) which contained 2 shrews, 1 porcupine, 3 unidentified mammals and 10 unidentified birds.