BOBCAT HABITAT USE RELATIVE TO HUMAN DWELLINGS IN SOUTHERN ILLINOIS

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Abstract: Wildlife and humans are in increasing contact as human populations expand in rural areas. Although certain species are faring well given these conditions, it is unclear whether more sensitive species will respond favorably to increased human prevalence. Bobcats (*Lynx rufus*) are secretive predators that are generally thought to avoid humans; however, because most bobcat studies have been conducted in areas of low human population density, the influence of human activities other than harvest on bobcats remains unknown. We addressed this paucity in the literature by assessing habitat use by 19 adult bobcats (7 M, 12 F) relative to human dwellings in southern Illinois, a region dominated by rural landscapes and high human population density (17.8 persons/km²) relative to most bobcat studies. Because forest cover types were most prevalent and preferred by bobcats on the study area ($P < 0.0200$), we constrained location-based analyses to dwellings within forest cover types only ($n = 198$). We established zones of potential human influence (i.e., circular buffers of diameter 384 m) around dwellings based on the mean distance from the nearest bobcat location ($n = 1{,}648$) to each dwelling and created buffers of the same size for 198 random locations. More bobcat locations ($P < 0.0001$) were found in random areas than in zones of influence surrounding dwellings. Further, proportionately more ($t_{18} = -2.15$, $P = 0.0425$) structures were found within home ranges ($\bar{x}$ ratio of dwellings to home range size = 2.8, SD = 1.9) than core areas ($\bar{x}$ ratio of dwellings to core area size = 1.9, SD = 1.8). Although bobcats appear to avoid human presence and are subjected to relatively high rates of human-caused mortality, bobcat populations are growing in southern Illinois. However, if humans continue to populate non-metropolitan areas at increasing rates, bobcat populations may be adversely affected. Regardless, managers can take a conservative approach by focusing on areas of rugged terrain or public land ownership for bobcat conservation because these places will likely remain refugia for bobcats.

Key words: bobcat, habitat use, human dwellings, human-wildlife interactions, *Lynx rufus*.

Wildlife and humans are in increasing contact as human populations expand (Adams and Leedy 1991). Population growth in the United States was about 16% between 1980 and 1995 (Frey and Johnson 1998:95). Further, population growth in non-metropolitan areas during the 1990s (5.1%) almost doubled that of the 1980s (2.7%). Although certain species have fared relatively well given these conditions (e.g., white-tailed deer [*Odocoileus virginianus*], Halls 1984), it is unclear how more sensitive species will respond to increased human presence.

Bobcats (*Lynx rufus*) are secretive carnivores that thrive in a variety of habitats and are generally thought to avoid humans (Anderson 1987). However, bobcats have not been studied in areas of relatively high human densities; instead, they usually were studied in relatively undeveloped publicly-owned or protected settings (e.g., Bailey 1974, Berg 1979, Hamilton 1982). Although the numerical (e.g., removal of individuals; Heisey and Fuller 1985, Rolley 1985) and functional effects (e.g., changes in social organization; Litvaitis et al. 1987, Lovallo and Anderson 1995) of harvest on bobcat populations have been described, the influence of human activity other than harvest on bobcats remains essentially unknown.

During 1995–99, we studied ecology of unexploited bobcats in southern Illinois, a region characterized by rural landscapes and relatively high human population densities (Woolf and Nielsen 1999) that provided an excellent opportunity to gain insight into the influence of human presence on bobcats. Specifically, we assessed habitat use by adult bobcats relative to human dwellings (i.e., representative areas of human activity) and determined whether bobcats avoided dwellings in areas of preferred habitat.

STUDY AREA

We studied bobcats within a portion of a 1,000-km² study area in Jackson and Union counties, southern Illinois (Woolf and Nielsen 1999:8). Land use/land cover (Luman et al. 1996) consisted primarily of closed-canopy mixed hardwood forests (66%), dominated by white oak (*Quercus alba*), black oak (*Q. rubra*), and hickory spp. (*Carya* spp.); rural grasslands (16%); and cropland (8%) characterized by corn and soybeans. Streams were abundant on the landscape (stream density = 1.1 km/km²). Elevation ranged from 92–316 m, with an average slope of 1.4°. The study area also was characterized by a relatively high level of human influence, resulting in a patchy landscape with a high interspersion of land cover types. Human population density was 17.8 persons/km² and road densities were 1.4 km/km². Bobcats were a state-threatened species in Illinois until 1999 and have been protected from harvest statewide since 1971.

METHODS

Capture and Radiotelemetry

Bobcats were captured primarily on privately-owned lands during November–March 1995–99 with either cage-type traps constructed of galvanized wire mesh (38 x 38 cm x 90 cm) or padded number 3 Soft-catch®

(Woodstream Co., Lititz, Pennsylvania, USA) foot-hold traps. Traps were baited with meat from a variety of wild birds and mammals; commercial bobcat lures and visual attractants were frequently used in combination.

Captured bobcats were chemically immobilized for handling with a combination of ketamine hydrochloride (HCl) and xylazine HCl (both in 100 mg/mL concentration solution). The drugs were premixed in a solution of 90 mg ketamine and 10 mg xylazine/mL and administered intramuscularly at a target dose of about 13 mg ketamine/kg estimated body mass. We used a pole-syringe to inject the drug mixture into the hip or thigh muscle of bobcats in foot-hold traps. Most bobcats in cage traps were constrained in 1 end with a device constructed of reinforcing rods and injected with a hand-syringe.

Bobcats were sexed, weighed, measured, and classified as adults ($\geq$2 yr) or juveniles based on size, mass (bobcats <5 kg were considered juveniles), and condition of dentition. We also examined bobcats for injuries, ectoparasites, and overall physical condition. Capture and handling procedures were conducted in accordance with a protocol approved by the Southern Illinois University at Carbondale Institutional Animal Care and Use Committee (Southern Illinois University at Carbondale Animal Assurance #A-3078-01) and under provisions of Illinois Endangered Species Permit #95-14S issued to the second author.

We fitted bobcats with Telonics (Mesa, Arizona, USA) model 315-S6A and Wildlife Materials (Carbondale, Illinois, USA) model HLPM-2140M radiocollars equipped with mortality sensors. Collars weighed 120–130 g; expected transmitter life was 17 and 20 months for Telonics and Wildlife Materials units, respectively. We used standard ground and aerial radio-telemetry techniques to track bobcats (White and Garrott 1990). One vehicle, a TS-1 scanner (Telonics, Mesa, Arizona, USA), hand-held 2- or 3-element yagi antennas, and a compass were used for ground tracking. Two-element yagi antennas mounted on the wing struts of a Cessna 172 aircraft or on the skid of a Bell Long Ranger II helicopter were used for aerial telemetry.

We determined point locations (Universe Transverse Mercator coordinate system) of bobcats from radio-telemetry, capture, and visual locations. Most (91%) locations were obtained by taking $\geq$2 bearings from bearing stations <2 km from bobcats. Less than 20 min elapsed between first and last bearings for 94% of all locations. We used the program LOCATEII (Nams 1990) to estimate locations according to the maximum likelihood estimator (Lenth 1981) and to calculate bearing error (n = 200, $\bar{x}$ = 4.16°, SD = 3.00) and error polygons (n = 200, $\bar{x}$ = 1.59 ha, SD = 1.82; Springer 1979).

Bobcat Habitat Use Relative to Human Dwellings

We used locations (n = 1,648), home ranges, and core areas of 19 adult bobcats (7 M, 12 F) with >30 locations for habitat use analysis. The number of locations per bobcat averaged 89.6 (SD = 47.9). Program RANGES V (Kenward and Hodder 1996) was used to estimate 100% home ranges and 50% core areas (km^2) using the minimum convex polygon estimator (Mohr 1947). We analyzed habitat use by bobcats relative to 954 human dwellings within bobcat home ranges. Dwellings were obtained from county 911 data (S. Sylvester, Jackson County Illinois, personal communication) or were manually digitized from United States Geological Survey Digital Orthophoto Quadrangles. We derived land cover information from Landsat TM imagery at 28.5 m^2 pixel resolution (Luman et al. 1996) reclassified from the original 23 cover classes into the following 8 aggregations: urban, transportation (i.e., roads and railroads), agriculture, grass, woods, open water, streams, and marsh. All digital data were stored and analyzed in a geographic information system (ArcView 3.2; Environmental Systems Research Institute Corporation, Redlands, California).

We determined cover types associated with the study area and bobcat locations, and used chi-square (Neu et al. 1974) to test the null hypothesis of no differences (α = 0.05) in cover-type affiliations between bobcat locations and the study area. Other studies have indicated that bobcats prefer forest cover types (Anderson 1987). Therefore, to control for potential habitat preferences, we concentrated further analyses on dwellings and random areas within the most prevalent and preferred cover type (i.e., forest) only. We established circular zones of potential human influence around dwellings and random points and determined proportional land cover within each zone. The 1.2-km^2 circular zones were based on the mean distance from the nearest bobcat location to each dwelling ($\bar{x}$ diameter = 384 m, SD = 298); we reasoned this buffer size encompassed a liberal range of human influence. We retained zones of human influence (n = 198) with $\geq$70% forest cover (i.e., matching the proportional habitat use by bobcats) and selected an equal number of random zones containing $\geq$70% forest cover and no dwellings. The number of bobcat locations within zones of influence and random areas was then calculated; chi-square tests were used to test the null hypothesis of no difference in number of locations between the 2 areas.

We also examined the number of human dwellings within bobcat home ranges versus core areas. Because different use-area sizes among individuals would bias results, we calculated ratios of number of dwellings to use-area size for each individual. T-tests were then used to test the null hypothesis of no difference in mean ratios of number of dwellings to use-area size between home ranges and core areas.

RESULTS

Cover types used by bobcats differed from cover types available on the study area (χ_1^2 = 6.17, P < 0.0200). Bobcats used less grass and transportation cover, but more agriculture and forest cover, than available on the study area (Table 1). Random areas contained more bobcat

Table 1. Mean proportional cover types associated with the study area and bobcat locations in southern Illinois, 1995–99.

	Cover type proportions	
Cover type	Study area	Locations
Urban	—	—
Transportation	0.05	0.03
Agriculture	0.08	0.11
Grass	0.15	0.12
Forest	0.65	0.70
Water	0.03	—
Streams	0.03	0.03
Marsh	0.01	0.01

locations ($n = 656$, $\chi_1^2 = 80.36$, $P < 0.0001$) than zones of influence surrounding dwellings (n locations = 369).

Home range and core area sizes ranged from 4.8–80.3 and 0.4–11.2 km², respectively (Table 2). Number of dwellings per use-area ranged from 4–559 and 0–29 for home ranges and core areas, respectively (Table 2). Proportionately more dwellings ($t_{18} = -2.15$, $P = 0.0425$) were within bobcat home ranges ($\bar{x}$ ratio of dwellings to home range size = 2.8, SD = 1.9) than core areas ($\bar{x}$ ratio of dwellings to core area size = 1.9, SD = 1.8).

DISCUSSION

Human dwellings provided a surrogate for human activities that may cause bobcats to avoid areas inhabited by humans. We found more bobcat locations in random areas than zones of influence surrounding dwellings, which implies bobcats may avoid human activities. For this analysis, we controlled for the confounding effect of habitat preference by focusing on dwellings within forest, the most prevalent and preferred cover type on the study area.

Bobcat core areas contained proportionately fewer dwellings than were present within home ranges. We previously found habitat use did not differ between home ranges and core areas for either males or females (C. Nielsen, unpublished data); hence, core area placement was probably more influenced by social interactions than habitat use (Nielsen and Woolf, in review). Clearly, myriad factors influence spatial use in bobcats (Anderson 1987); however, our results imply bobcats may select core areas to provide retreat from human activity.

Potential negative influences of human activities on bobcats are manifold. First, landscape manipulation to less favorable cover types may occur with increased human density. As humans develop rural areas, highly-suitable forest cover will likely be removed and replaced with lawns, golf courses, and pavement; thereby reducing prey densities and suitable denning areas. Second, human

Table 2. Size (km²) of and number of human dwellings within minimum convex polygon home ranges and core areas of bobcats in southern Illinois, 1995–99.

	Home range			Core area		
Bobcat	No. dwellings	Size	Ratio	No. dwellings	Size	Ratio
1	46	24.1	1.9	2	3.6	0.6
5	67	14.5	4.6	9	2.9	3.1
8	29	12.9	2.2	0	1.8	0.0
9	90	45.2	2.0	12	11.2	1.1
13	109	34.2	3.2	29	4.4	6.6
14	73	48.8	1.5	10	6.3	1.6
15	43	26.3	1.6	2	8.9	0.2
17	559	80.3	7.0	19	9.5	2.0
32	42	16.9	2.5	5	4.2	1.2
33	60	19.1	3.1	4	2.5	1.6
36	19	38.0	0.5	3	5.9	0.5
47	135	41.8	3.2	16	3.3	4.9
48	36	9.5	3.8	4	1.6	2.5
49	9	8.1	1.1	1	2.0	0.5
57	4	4.9	0.5	0	0.4	—
58	71	9.3	7.6	5	1.3	3.8
60	7	7.1	1.0	1	2.1	0.5
68	15	4.8	3.1	3	1.5	2.0
72	11	5.1	2.1	2	0.6	3.4

activities near dwellings (e.g., all-terrain vehicle operation or mowing) may disrupt bobcat behavior. Third, road densities will likely increase as human densities grow. These changes will certainly have a negative influence on bobcats; indeed, vehicles caused 11 of 18 bobcat mortalities in our study (A. Woolf, unpublished data). Finally, increasing human densities may result in more accidental mortalities via hunting or trapping (e.g., Lovallo and Anderson 1996). We confirmed 2 instances of bobcats killed accidentally by trappers (Woolf and Nielsen 1999) and 1 bobcat killed by a car had been previously shot. Further, the unexplained disappearance of 3 bobcats from the study area may have been caused by humans and concealed via radiocollar destruction.

Although bobcats may avoid human activities and despite the fact that humans are the primary cause of mortality, the bobcat population in southern Illinois has increased in abundance and distribution (Woolf and Nielsen 1999). Almost 30 years of harvest restriction have allowed bobcat populations to increase from levels warranting their status as State Threatened (Woolf et al. 2000) to relatively high densities (0.27/km^2; A. Woolf, unpublished data). Bobcat survival rates of >80% are among the highest recorded (Woolf and Nielsen 1999). Critical life-history requisites are not limiting, as evidenced by only 1 confirmed natural mortality; cachexia due to stomach obstruction from a large hairball. Further, a separate database of bobcat necropsies (A. Woolf, unpublished data) confirmed that debility from either infectious disease or malnutrition was highly uncommon (Woolf and Nielsen 1999).

Several instances were confirmed of bobcats using human structures, indicating that human activities may occasionally be beneficial to bobcats. For example, we documented one instance of a female bobcat having a litter in a barn. Further, we received several complaints of bobcat depredation of pen-raised birds, and captured 2 bobcats in bird-raising facilities. We also captured several bobcats within 100 m of human structures.

MANAGEMENT IMPLICATIONS

Although bobcats appear to avoid human presence and are subjected to relatively high rates of human-caused mortality, bobcat populations are growing in southern Illinois. Our study area contained relatively high bobcat and human densities; however, we may not have yet reached the critical point at which human influence is a more severe limiting factor to bobcat populations. Conjecture about future trends in non-metropolitan development is questionable given the unpredictability of human migration and its manifold influences (Frey and Johnson 1998). However, if humans continue to populate non-metropolitan areas at increasing rates, bobcat populations may be adversely affected. Regardless, managers should take a conservative approach by focusing on areas of rugged terrain or public land ownership for bobcat conservation. Because human influence may continue to be limited in these areas, they will likely remain refugia for bobcats over the long term.

Finally, we propose that researchers consider human influence during studies of bobcat ecology. Our analysis represents a simple approach that provides a first look at bobcat-human interactions. A more complex analysis involving direct comparisons of survival and habitat use of bobcats in areas of high versus low human influence within the same region would likely provide more convincing evidence regarding human influence on bobcats.

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SPATIO-TEMPORAL RELATIONSHIPS AMONG ADULT BOBCATS IN CENTRAL MISSISSIPPI

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Abstract: Bobcats (*Lynx rufus*) are considered territorial and previous studies have indicated that intersexual overlap in space use occurs, but intrasexual overlap of females is rare. Most researchers have reported a lack of social interactions among bobcats except during mating, suggesting that bobcats are solitary. However, inferences regarding spatial and temporal relationships have been based on small sample sizes and studies of short duration. We radiomonitored 58 (20 M, 38 F) adult bobcats from 1989–97, documenting 33, 117, and 158 instances of home range overlap for males, females, and male-female combinations, respectively. Neighboring males exhibited greatest overlap during winter, whereas overlap among females was similar seasonally. Males and females exhibited greatest overlap during breeding periods. Intrasexual core area overlap was negligible during all seasons. Neighboring males were located rarely within <100 m of each other and frequently exhibited negative interactions, whereas females with overlapping home ranges and core areas were frequently located closer together than expected. Overlap averaged 20% seasonally for neighboring males and females, suggesting little territoriality at the home range level, but most core areas were maintained exclusively. Our findings suggest neighboring males and females likely use areas outside of core areas close to one another, but that movement of 1 individual into the core area of another is rare. Notably, several females shared home ranges, exhibiting nearly complete overlap of the home range and core area, a finding not reported previously. Because relation could influence spatial relationships, we suggest future research to quantify degree of relation among individuals before examining spatial distribution of bobcats.

Key words: bobcat, core use area, DYNAMIC, home range, interaction, *Lynx rufus*, overlap.

Intersexual differences in social behavior and spacing patterns in mammals reflect differences in selection pressures and life history characteristics (Crook et al. 1976, Eisenberg 1981). Male reproductive success is closely related to finding mates, whereas female reproductive success is related to locating and effectively exploiting resources (Clutton-Brock 1989). Therefore, distribution of males across landscapes should reflect female distribution, but female distribution should be more attuned to availability of quality resources (MacDonald 1983, Sandell 1989).

Reliable estimates of home range are essential to understand a species behavioral ecology (Bekoff and Mech 1984), and areas of concentrated use within home ranges are often denoted as core areas, implying that these selected areas are of greater importance to the animal (Leuthold 1977). Previous studies have used home range overlap as a method to examine social organization within bobcat populations (Bailey 1974, Zezulak and Schwab 1980, Berg 1981). Generally, research has indicated that considerable intersexual overlap occurs with adult females frequently maintaining exclusive home ranges, and male ranges frequently overlapping other males and several females (Marshall and Jenkins 1966, Lembeck and Gould 1979, Hamilton 1982). Conversely, Zezulak and Schwab (1980) reported that female home ranges frequently overlapped, but that male home ranges were nearly exclusive in California. They suggested that strict territoriality may occur only when bobcat density is low. This contention is not supported by other literature, as exclusive intrasexual home ranges were maintained at the greatest densities reported (Lembeck and Gould 1979, Miller and Speake 1979).

Bobcats are polygynous and considered solitary carnivores, with direct social interactions between adults rare, except for males and females during breeding periods (Anderson 1987). However, no research has attempted to quantify temporal interactions among bobcats, particularly simultaneous movements of multiple individuals within shared or overlapping regions of home ranges. Therefore, our objectives were to examine season- and sex-specific home range and core area overlap, and assess temporal interactions across seasons for a population of adult bobcats in central Mississippi from 1989–97. Based on previous literature regarding spatial relationships among bobcats and bobcat ecology, we predicted that male home ranges and core areas would overlap those of females, but that adult females would maintain exclusive home ranges and core areas. Furthermore, we predicted that adult males and females would not exhibit intersexual interactions outside of breeding periods. Lastly, we predicted that access to and interactions with females were important factors influencing male spatial distributions.

METHODS

Study Area

This research was conducted on the 14,410-ha Tallahala Wildlife Management Area (TWMA), a 4,900 ha area owned by Georgia Pacific Corporation (GP), and surrounding private lands in sections of Jasper, Newton, Scott, and Smith counties, Mississippi. The TWMA contained 30% mature (>30 yr old) bottomland hardwood forests, 37% mature pine (loblolly, *Pinus taeda;* shortleaf, *P. echinata*) forests, 17% mixed pine-hardwood forests, and 11% in 1–15-year-old loblolly pine plantations. A tornado bisected TWMA in 1992, altering approximately 1,000 ha of mature pine and hardwood forests; most (90%) of the damaged area was replanted to loblolly pine. The GP area, located adjacent to TWMA, was managed primarily for wood fiber production with 90% of the area composed of 1–35-year-old loblolly pine plantations, and the remaining 10% in Streamside Management Zones along creek drainages. Private lands were comprised mostly of mixed pine-hardwood and short-rotation pine forests. Topography was gently to moderately rolling, with 0–20% slope. Climate was mild, with a mean annual temperature of 20°C and mean annual precipitation of 152 cm. Hereafter, the TWMA refers to both study areas and the surrounding private lands.

Capture and Telemetry

We captured bobcats with Number 3 and 1.5 Victor soft-catch foot-hold traps (Woodstream, Lititz, Pennsylvania, USA) from 10 January to 15 August 1989, and from 4 January to 5 March annually from 1990–1997. Captured bobcats were netted and anesthetized with Ketamine hydrochloride (Ketaset Veterinary Products, Fort Dodge Laboratories Inc., Fort Dodge, Iowa, USA) at 15 mg/kg of estimated body mass. Each bobcat was weighed, standard body measurements were taken, and each was given a unique tattoo. We separated bobcats into 3 age classes (kitten, subadult, adult) based on tooth eruption, teat condition of females, and scrotum size on males (Crowe 1975). We fitted each adult bobcat with a 175–225-g mortality-sensitive radiotransmitter (Advanced Telemetry Systems, Isanti, Minnesota, USA). Subadult bobcats were not fitted with radiotransmitters because of concerns with indeterminate growth of bobcats and auspices of the Mississippi State University Institutional Animal Care and Use Committee. Drugged bobcats were placed in portable pet kennels and monitored until recovery, then released at the capture site the following morning. We conducted research under Mississippi State University Institutional Animal Care and Use Committee Protocol 93-032.

Bobcats were located by triangulation (White and Garrott 1990) using a hand-held, 3-element Yagi antenna (Wildlife Materials, Carbondale, Illinois, USA) from fixed telemetry stations ($n = 480$) ≥2 times/week. In most (92%) instances, distance from observer to bobcat was ≤1.0 km. We used 2 telemetry techniques to monitor bobcats: systematic point and sequential locations. We obtained systematic point locations by recording 2 locations weekly for each bobcat. We conducted sequential telemetry (focal runs) on a 3–6-hr basis with a location recorded on each bobcat every hour for the entire 3–6-hr period. Azimuths for a single radio location were recorded within a 15-min interval to reduce error due to bobcat movement; however, most (88%) consecutive azimuths were recorded within 6 min (4.1 ± 0.02). Triangulation angles were maintained between 45° and 135° to reduce error (Kitchings and Story 1979). Telemetry accuracy tests indicated that standard deviation from true bearing was 5.9°.

Home Range and Core Area Overlap

Bobcat locations were converted to a coordinate system using program TELEBASE (Wynn et al. 1990). We divided each year into breeding (1 Feb–31 May), kitten-rearing (1 Jun–30 Sep), and winter (1 Oct–31 Jan) seasons. Seasonal home range (95%) and core area (50%) contour intervals were estimated using an adaptive kernel estimator in program CALHOME (Kie et al. 1994). Area-observation curves conducted on 5 randomly chosen bobcats indicated that 30–35 locations/season were needed to estimate sizes of home ranges and core areas. Therefore, we estimated sizes of home ranges and core areas for bobcats sampled with ≥30 locations/season and monitored for ≥75% of a given season.

We used all locations (sequential and point) taken on each bobcat to estimate sizes of the home ranges and core areas. We seasonally estimated overlap of home ranges by intersecting home ranges of neighboring bobcats and determining the area of the overlap region in ARCVIEW (Environmental Systems Research Institute, Redlands, California, USA). We then superimposed point locations of each bobcat on the overlap region and counted the number of locations by bobcat within the overlap region to derive a proportion of each individual's locations within the overlap region. We assessed overlap of bobcats that shared portions of home ranges across 3 dyads (male-male, female-female, male-female combinations).

We described the spatial distribution of adult bobcat home ranges using home range overlap indices. During each season, we calculated a home range overlap index for 2 neighboring bobcats by modifying the simple ratio of Ginsberg and Young (1992) to quantify association:

$$n_1 + n_2 / N_1 + N_2 \text{ x } 100$$

Where n_1 and n_2 refer to number of locations for each bobcat within the overlap region, and N_1 and N_2 refer to the total number of locations recorded for each bobcat. We used a 2-way analysis of variance to test differences in mean home range and core area overlap indices among dyads and seasons.

Temporal Interactions

We used program DYNAMIC (Doncaster 1990) to assess temporal interactions among adult bobcats with overlapping or shared home ranges. Program DYNAMIC is a non-parametric procedure that probabilistically expresses the simultaneous movements of 2 individuals. The dynamic interaction test determines if 2 animals monitored simultaneously during a time interval were located within a critical distance more or less often expected if the 2 animals were moving independently (Doncaster 1990). The presence of dynamic interaction does not necessarily imply mutual awareness from the respective animals. Rather, DYNAMIC addresses whether animals are more likely to maintain a certain separation (positive interaction) or less likely (negative interaction) than expected from the configuration and use of areas within their known home ranges (Doncaster 1990). Observed separation distances between bobcats were calculated from paired x-y coordinates within a 10-min time interval. Expected differences were estimated in DYNAMIC from all possible combinations of unpaired coordinates. Observed and expected separation intervals were then estimated at 50-m intervals from 0 to 500 m. We assumed that bobcats were not likely to detect each other beyond 500 m in the forested environment of TWMA. A positive interaction occurred if observed interactions (paired) were greater than expected (unpaired) interactions. A negative interaction occurred if expected interactions (unpaired) were greater than observed (paired) interactions. Chi-square procedures were used to test significance of positive and negative dynamic interactions. All tests were performed at $\alpha = 0.05$.

RESULTS

Male home range sizes averaged 1,769 ± 182, 1,528 ± 188, and 1,877 ± 265 ha during breeding, kitten-rearing, and winter, respectively. Male core area sizes averaged 308 ± 40, 295 ± 41, and 295 ± 40 ha during those same seasons. Female home range sizes averaged 863 ± 68, 870 ± 80, and 855 ± 136 ha during breeding, kitten-rearing, and winter, respectively. Female core areas averaged 148 ± 13, 146 ± 16, and 136 ± 14 ha during those same seasons.

Home Range and Core Area Overlap

Interactions between dyad and season did not influence home range ($F_{4,291} = 0.61$, $P = 0.659$) or core area ($F_{4,291} = 0.46$, $P = 0.208$) overlap. Further, home range and core area overlap did not differ among seasons ($0.05 \leq F_{2,291} \leq 0.20$, $0.819 \leq P \leq 0.955$). Conversely, home range and core area overlap differed among dyads ($5.22 \leq F_{2,291} \leq 6.20$, $0.006 \leq P \leq 0.002$). Neighboring males and females exhibited greater home range overlap ($\bar{x} = 29\%$, SE = 3) than neighboring males ($\bar{x} = 18\%$, SE = 2) or females ($\bar{x} = 21\%$, SE = 4). Similarly, neighboring males and females exhibited greater core area overlap ($\bar{x} = 8\%$, SE = 1) than neighboring males ($\bar{x} = 3\%$, SE = 1) or females ($\bar{x} = 4\%$, SE = 1).

We documented 33 instances of seasonal home range overlap for neighboring males. Area of overlap averaged 431 (SE = 109), 364 (SE = 154), and 652 ha (SE = 322) during breeding, kitten-rearing, and winter, respectively. Greatest home range overlap among neighboring males occurred during breeding, but core area overlap was minimal during all seasons (Table 1).

We documented 117 instances of seasonal home range overlap among neighboring females. Area of overlap averaged 270 (SE = 47), 244 (SE = 42), and 170 ha (SE = 33) during breeding, kitten-rearing, and winter, respectively. Home range and core area overlap among neighboring females were similar during all seasons (Table 1). Additionally, several females exhibited substantial home range overlap and sharing of core areas (Fig. 1).

We documented 158 instances of intersexual home range overlap; area of overlap averaged 464 (SE = 47), 338 (SE = 44), and 384 ha (SE = 55) during breeding, kittenrearing, and winter, respectively. Home range and core area overlap were greatest during breeding periods (Table 1) and male core areas were frequently located in proximity to female core areas (Fig. 2).

Temporal Interactions

During the breeding season, comparisons between males ($n = 3$ pairs) within 50 m were either negative or no interaction occurred, indicating that males monitored simultaneously were not located within 50 m of one another. However, most comparisons between 100 and 500 m indicated positive interactions, suggesting that males were more likely to be located within 100–500 m

Table 1. Mean (± SE) percent home range and core area overlap for adult bobcats on the Tallahala Wildlife Management Area, Georgia Pacific Corporation, and surrounding private lands, Mississippi, 1989–97.

			Home range		Core area	
Dyad combination	Season[a]	n	% overlap	SE	% overlap	SE
Male	Breeding	16	17	4	2	1
	Kitten-rearing	10	15	5	3	1
	Winter	7	23	9	4	2
Female	Breeding	49	21	3	4	1
	Kitten-rearing	48	23	3	4	1
	Winter	20	19	4	3	1
Male-female	Breeding	68	33	3	9	1
	Kitten-rearing	55	27	3	6	1
	Winter	35	27	4	6	1

[a]Breeding = 1 Feb–31 May, kitten-rearing = 1 Jun–30 Sep, winter = 1 Oct–31 Jan.

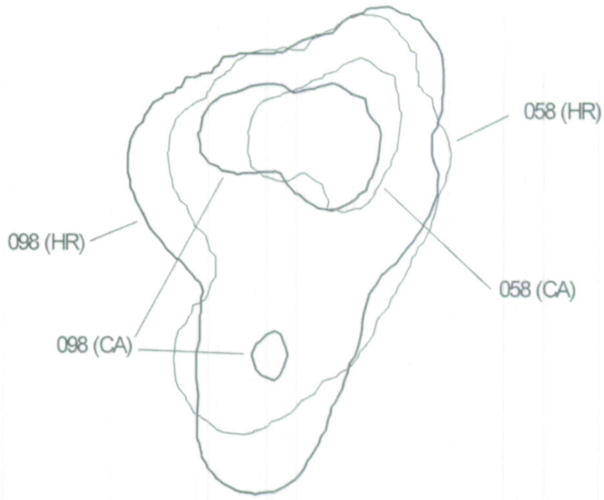

Fig. 1. Adaptive kernel 95% home range and 50% core area isopleths for 2 adult female bobcats (bobcats 058 and 098) demonstrating sharing of home ranges and core areas during the kitten-rearing season (1 Jun–30 Sep) on the Tallahala Wildlife Management Area, Georgia-Pacific Corporation, and surrounding private lands, Mississippi, 1997.

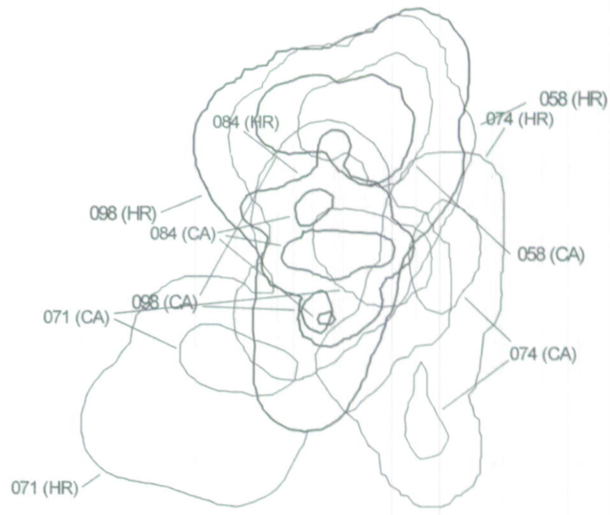

Fig. 2. Adaptive kernel 95% home range and 50% core area isopleths for 2 adult females (bobcats 074 and 084) and 1 adult male bobcat (bobcat 071) illustrating extensive home range overlap by male of female home ranges and core areas during the breeding season (1 Feb–31 May) on the Tallahala Wildlife Management Area, Georgia-Pacific Corporation, and surrounding private lands, Mississippi, 1996.

than expected. For females ($n = 16$ pairs), comparisons within 50 m indicated no interactions, but most comparisons beyond 100 m were positive, suggesting that females with overlapping home ranges and core areas were frequently located closer together than expected. For males and females ($n = 25$ pairs), several instances of presumed direct contact (separation distances <10 m) were documented and most comparisons were positive, indicating that males and females were located closer together than expected by chance.

During kitten-rearing, we noted only 1 instance of positive interactions between males ($n = 2$ pairs), whereas most interactions were negative, suggesting an avoidance among males. With 1 exception, no 2 females ($n = 15$ pairs) were located within 50 m of each other, but most comparisons from 100–500 m were positive, indicating that females were frequently located closer together than expected at these distances. Between males and females ($n = 29$ pairs), most comparisons, particularly those >100 m, indicated positive interactions. This suggests that males and females monitored simultaneously were frequently located closer than expected.

During winter, most comparisons indicated no interaction or negative interactions, suggesting that males ($n = 3$ pairs) were usually located farther apart than expected. For females ($n = 12$ pairs), most comparisons >200 m were positive; however, several females consistently exhibited negative interactions with other females, especially for those that maintained exclusive core areas. Notably, 2 females were frequently located <50 m of each other, exhibited significant positive interactions in all distance classes, and were located together on several occasions <100 m from researchers. These 2 females also shared home ranges and core areas during all seasons (Fig. 1). For males and females ($n = 20$ pairs), most comparisons >100 m were positive; however, all comparisons <100 m indicated no interaction or were negative, suggesting that males and females were more likely to be located >100 m apart.

DISCUSSION

Most previous studies have reported that adult female bobcats frequently maintain exclusive home ranges, suggesting territoriality among females. These same studies have indicated that males frequently overlap other males and several females (Marshall and Jenkins 1966, Lembeck and Gould 1979, Hamilton 1982, Anderson 1988). Our findings do not support these studies as females on TWMA maintained overlapping home ranges in all seasons, as did neighboring males. Our finding that male-male and female-female dyads exhibited home range overlap indices around 20% during all seasons suggests a lack of pronounced intrasexual territoriality. Additionally, the near sharing of home ranges by adult females is a finding not reported in previous bobcat literature. Differences between this study and others may have resulted from larger sample size and longer duration of this study, and methods previous studies used to assess overlap (i.e., use of area of overlap only). Further, the trapping protocol used during this project may have increased the probability of capturing all bobcats within the core of the study area. During each trapping season, researchers attempted to catch all bobcats on TWMA, basing potential capture sites on the spatial distribution of home ranges for bobcats being monitored. Voids, or areas without a radiomarked female, were targeted as well as females needing collars replaced. On several occasions, females were captured in areas where researchers were attempting to recapture individuals, rather than to capture new bobcats. Therefore, we believed that most adult females within the core of TWMA were being monitored.

Females on TWMA did not exhibit pronounced territoriality at the home range level, even during kitten-rearing when females may displace conspecifics to promote kitten survival (McCord and Cardoza 1982). On average, 15% of each neighboring female's locations were within the overlap regions of adjacent females and the area of overlap was 50% as large as the average female home range during all seasons. This, coupled with the observed maintenance of nearly exclusive core areas, suggests that although females frequently tolerated overlap of used areas at outlying portions of the home range, territoriality was most prevalent at the core area level. Notably, females were often located closer together than expected, supporting contentions that females likely use areas outside the core area close to each other, but that movement of 1 female into the core area of another is rare.

Zezulak and Schwab (1980) suggested that territoriality may only occur when bobcat densities are low. Presumably, as density increased, bobcats would be less able to defend territories and would yield to neighboring adults using outlying portions of their home range. However, this contention has not been supported in other studies, as greatest bobcat densities reported (Lembeck and Gould 1979, Miller and Speake 1979) witnessed exclusive intrasexual home ranges (presumed territoriality). Densities on TWMA reported by Conner et al. (1992) were within the range of estimates reported throughout the southeastern United States and bobcat density likely increased during our study (Chamberlain 1999). Therefore, our findings suggest that territoriality at the home range level is not prevalent, but that intrasexual territoriality at the core area level is common, regardless of density.

Conner et al. (1999) reported that experience influences home range characteristics of female bobcats. Presumably, as a female gains hunting experience, she becomes more efficient and needs to hunt less. Increased hunting experience should then lead to increased success, less time spent searching for prey and wandering, and a decrease in home range size (Conner et al. 1999). Because many females were monitored for several years in our study, experience also may have influenced spatial characteristics and observed overlap among females. Females with greater experience, who are assumed to be more efficient hunters, may tolerate greater overlap from neighboring females. Experienced females with increased hunting skill and greater hunting efficiency can likely meet energetic requirements even when sharing portions of home ranges with adjacent females. Alternatively, older, experienced females likely have greater fitness relative to younger females. Experienced females may produce kittens that eventually reside adjacent to their mother, either through filling a vacancy resulting from death of another female, or potentially sharing a portion of the mothers home range. Older, experienced females may allow greater overlap of their home range if adjacent females are siblings or daughters; however, the relationship between relation and spatial overlap is unclear. Future research should examine the influence of relation among adult females on spatial characteristics across various landscapes.

Because bobcats are polygynous breeders, it is not surprising that males overlapped large portions of female home ranges and were often located closer than expected to females, particularly during breeding periods. Furthermore, our findings suggest that male core areas frequently overlap large portions of females core areas, even those core areas maintained by multiple females. This suggests that distribution of male core areas across landscapes is perhaps a function of location of female core areas and potentially, males locate and maintain core areas during breeding to optimize breeding opportunities. Because male fitness increases with increasing mating opportunities, males maintaining core areas that overlap multiple females likely increase their fitness. Additionally, males and females selected core areas dominated by 0–8-year-old pine stands, presumably because of increased prey availability and overall habitat quality (Chamberlain 1999). Therefore, males locating core areas around female core areas is likely a result of both breeding behavior and habitat requirements.

Zezulak and Schwab (1980) reported that male home ranges were nearly exclusive in California, whereas most other studies have indicated that males exhibit little territoriality at the home range level, frequently overlapping portions of other male home ranges (Marshall and Jenkins 1966, Berg 1981). Our findings indicate that males maintain overlapping home ranges, but nearly exclusive core areas, suggesting territoriality at the core area level. Besides providing quality foraging habitats, core areas also may provide sites important to bobcats, such as den sites or escape cover (Ewer 1973, McCord and Cardoza 1982). If males establish core areas to overlap multiple female core areas, males should exhibit territoriality at the core area level, particularly during breeding periods, to increase fitness. The observed lack of interactions between neighboring males during all seasons is likely a function of maintaining exclusive core areas.

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MULTIVARIATE HABITAT MODELS FOR BOBCATS IN SOUTHERN FORESTED LANDSCAPES

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Abstract: Habitat models can be useful for understanding habitat needs of a species and may serve as a tool for habitat management. Few habitat models have been developed for bobcats (*Lynx rufus*); thus we developed sex-specific habitat models for bobcats within southern managed forests using a biometric approach and geographical information system (GIS) technology. One model described female bobcat habitat as near roads, on relatively steep slopes, far from creeks, and in forested stands with small trees (i.e., early successional habitat). Jackknife and cross-validation indicated this model performed well (76 and 78.5% correct classification, respectively). Another model described male bobcat habitat as near maintenance roads and in stands with small trees. Jackknife and cross-validation indicated this model also performed well (72 and 77.5% correct classification, respectively). Prey abundance can explain importance of variables in both models. The increased number of variables retained by the female habitat model provides evidence that females are more selective than males regarding habitat use. Model validation using independent data is needed before our models are implemented.

Key words: bobcat, forest ecosystem, geographic information system, habitat model, *Lynx rufus*, Mississippi.

Because apex predators may regulate mesomammals (Rogers and Caro 1998, Crooks and Soule 1999, Courchamp et al. 1999) and may play a role in predator mediated coexistence of other species (Henke and Bryant 1999), management of top carnivore populations is important. Bobcats (*Lynx rufus*) represent an apex carnivore in many forested ecosystems. Published bobcat habitat models are rare (Boyle and Fendley 1987, Conner and Leopold 1998), and these models are either based on expert opinion (Boyle and Fendley 1987) or only applicable to a narrow range of habitat conditions (Conner and Leopold 1998). Previously, Conner and Leopold (1998) developed a bobcat habitat model of a national forest in central Mississippi. Although this model performed well on the national forest, it performed poorly on an adjacent industrial forest.

Habitat modeling is perhaps best viewed as an iterative process in which models are developed, tested, and refined based on test results and revised needs (Conner and Leopold 1998). Because our initial model did not perform well on an industrial forest (Conner and Leopold 1998), we do not think that models developed on an industrial forest will perform well on a national forest. However, models developed using animals from both industrial and national forests may provide a more generalized description of bobcat habitat in forested ecosystems. Therefore, we developed sex-specific bobcat habitat models using data collected on bobcats residing in a national forest (i.e., a multiple use forest management philosophy) and data collected in an intensively managed industrial forest (i.e., a timber production management philosophy) to better describe bobcat habitat within managed southern forests.

METHODS

Description of Study Areas

We used 2 study areas: Tallahala Wildlife Management Area (WMA, multiple use management philosophy) and forests owned and managed by Georgia Pacific (GP, timber production management philosophy) in Newton and Jasper counties in central Mississippi.

The 142-km^2 Tallahala WMA is located in the Bienville National Forest. Mean annual temperature was 18°C and annual precipitation averaged 152 cm. Pine (*Pinus* spp.) stands ($\geq$ 70% pine dominated with mean dbh >5.0 cm) comprised 46% of the study area. Loblolly pine (*P. taeda*) was the dominant species, whereas shortleaf pine (*P. echinata*) and longleaf pine (*P. palustris*) occurred in scattered patches. Approximately 29% of the area was in sapling stands (forested with mean dbh $\leq$5 cm). Sapling stands averaged 13 ha in size and rarely exceeded 20 ha. Bottomland hardwoods accounted for 21% of the area and were located primarily in riparian zones along major drainages. Approximately 4% of the area was in agriculture. Pines were regenerated by clear-cutting followed by site preparation and planting. Hardwood stands were regenerated using the shelterwood method or coppice management. Hardwood clear-cutting was prohibited.

The 80-km^2 GP study area was located adjacent to Tallahala WMA, thus weather patterns between the 2 study areas were similar. Pine stands covered 60% of the area, but 88% of pine stands on GP consisted of trees that were <33 cm dbh (as opposed to 18% on Tallahala WMA). Sapling (20%), hardwood (12%), and agriculture (8%) comprised the remainder of the study area. The land was managed primarily for timber production, and stands were regenerated by clear-cutting and planting. Sapling stands >100 ha were common. Larger clear-cuts, intensive pine management, absence of mature timber, and lack of hardwood stands on GP (relative to Tallahala WMA) permitted study of bobcat ecology under 2 different, yet common, forest management regimes.

Geographical Information System Development

We constructed a geographical information system (GIS) for each study area. We transferred stand boundaries from color infrared photographs to 1:24000 United States Geological Survey (USGS) quadrangles. We classified habitat into 1 of 3 types: non-forested (e.g., agriculture), pine forest, and hardwood forest. Additionally, we categorized each stand into 1 of 5 condition classes; non-forested, sapling (dbh < 5.0 cm), pole (5.1 cm < dbh < 12.7 cm), pulpwood (12.8 cm < dbh < 38.1 cm), and sawtimber (dbh > 38.2 cm). We digitized data of stands using ARC/INFO (Environmental Systems Research Institute 1992).

We also constructed coverages for roads, creeks, and elevation. We classified roads as paved, gravel, or maintenance (i.e., roads closed to the general public) and creeks as either ephemeral or permanent. We digitized road and creek coverages directly from USGS quadrangles. We obtained digital elevation models from the USGS to create elevation and slope layers. We developed 8 slope classes ranging from class 1 representing a midpoint of approximately 5.5% slope, to class 8, representing a midpoint of approximately 84.5% slope. The range of each slope class was approximately 11% (Environmental Systems Research Institute 1992). In all, our GIS contained 15 habitat variables (Table 1).

Bobcat Capture and Monitoring

We captured bobcats using Victor Soft-catch traps (Woodstream Corp., Lititz, Pennsylvania, USA.). Following capture, we netted and drugged bobcats with Ketamine hydrochloride (15 mg/kg body mass). We separated bobcats into 3 age classes (kitten <1.0 year; sub-adult 1–2 years; adult >2 years) based on tooth eruption, staining and wear, body size, pelage characteristics, teat condition of females, and scrotum size of males (Crowe 1975). We fitted all adult females and select adult males (i.e., males captured in interior portions of study areas) with a radiocollar (ATS, Isanti, Minnesota, USA and Wildlife Materials Incorporated, Carbondale, Illinois, USA). We monitored bobcats overnight to assess recovery prior to release at the capture site and allowed bobcats 1 week to recover from capture before we initiated radiotracking. We trapped bobcats during winters (7 Jan–15 Mar) of 1989–92. Bobcat capture and data collection followed Animal Care and Use Protocol 93-032 of Mississippi State University.

We monitored bobcats throughout the diel period using a TRX-1000S receiver and a hand-held 3-element Yagi antenna (Wildlife Materials Incorporated, Carbondale Illinois, USA). We estimated locations by triangulation from fixed points within the study areas (Cochran 1980, Kenward 1987, White and Garrott 1990). We frequently obtained ≥3 azimuths to minimize erroneous locations. To decrease error associated with bobcat movement, we allowed a maximum of 15 min between azimuths. We converted azimuths to coordinates using the program TELEBASE (Wynn et al. 1990).

Telemetry accuracy tests indicated the standard deviation from true bearings was 6° ($n = 42$). Approximately 90% of all telemetry bearings were taken <1 km from an animal. Based on our accuracy tests, a circle circumscribing the estimated location of the bobcat located 1 km from each telemetry station would cover approximately 3.5 ha.

Model Development and Validation

Identification of unused habitats is beneficial when developing habitat models, but it is impossible to identify unused habitats with certainty (e.g., if the site was used when the animal was not monitored; Clark et al. 1993). We attempted to reduce probability that a random point occurred at a site that was actually used by a bobcat by generating random points which did not occur within 200 m of a used location. We overlaid bobcat telemetry locations and random points onto GIS layers and determined habitat characteristics at each point.

Selection of variables for habitat modeling without prior indication of their ecological importance should be avoided (Johnson 1981; Rexstad et al. 1988, 1990; Taylor 1990). Therefore, we passed habitat variables through 3 filters before entering them into a model. The first filter eliminated non-significant ($P < 0.01$) variables using univariate hypotheses tests (i.e., t-test or χ^2 test). A conservative alpha level ($P < 0.01$) was chosen because we feared that our large sample sizes would have sufficient power to detect statistical differences when biological differences likely did not exist.

To further reduce the variable set, we subjected remaining continuous variates to a second filter to remove correlated variables. If variables were correlated ($P < 0.05$; $|r| > 0.4$) we omitted the least significant variable from further model building efforts (Brennan et al. 1986).

We used stepwise logistic regression (LR) as the final filter and statistical tool to develop the habitat model. Type of location, bobcat or random, served as the binary response variable in modeling attempts. We calculated

Table 1. Variables used to develop bobcat habitat model on Georgia Pacific landholdings and Tallahala Wildlife Management Area in central Mississippi, 1989–92.

Variable name	Description
TYPE	Forest type index (non-forested, pine, or hardwood)
COND	Stand condition (non-forested, sapling, pole, pulpwood and sawtimber)
EDGE	Distance[a] to edge
SAP	Distance to nearest sapling stand
PINE	Distance to nearest non-sapling pine stand
HWD	Distance to nearest non-sapling hardwood stand
RD	Distance to nearest road
RD1	Distance to nearest paved road
RD2	Distance to nearest gravel road
RD3	Distance to nearest maintenance road
CRK	Distance to nearest creek
CRK1	Distance to nearest primary creek
CRK2	Distance to nearest ephemeral creek
ELEV	Elevation (class)
SLOPE	Slope (8 equal classes 0–90°)

[a]All distances measured in km.

posterior probabilities (i.e., probability of bobcat use) from the final logistic regression model as a habitat suitability index (HSI, Brennan et al. 1986) for bobcats.

We subjected models to 2 levels of validation. We used jackknife validation to evaluate model predictions with data used in model construction. We also withheld approximately 20% of all locations from model building efforts. We used these locations to cross-validate model predictions as a second evaluation of the models (Capen et al. 1986, Verbyla and Litvaitis 1989).

We considered a location suitable for bobcats if the posterior probability was ≥0.5. We calculated sensitivity (i.e., bobcat location predicted correctly as a bobcat location), specificity (i.e., random location predicted correctly as a random location), and total correct classification for all validation trials. We used SAS (SAS Institute 1992) to construct and test models.

RESULTS

We used 1,084 locations from 21 female bobcats and an equal number of random locations to develop our female bobcat HSI. Significant ($P < 0.01$) non-correlated ($P \geq 0.05$, $|r| < 0.4$) variates subjected to LR were SLOPE, RD1, RD3, CRK1, CRK2, and COND. All variables except CRK2 were retained by the stepwise procedure. The female bobcat HSI model indicated relatively steep slopes to be preferred. There was an inverse relationship between HSI and distance to primary and maintenance roads. There also was an inverse relationship between stand condition and HSI. Lastly, distance to primary creeks was related positively to HSI (Table 2). Jackknife validation indicated 76% (sensitivity = 0.82, specificity = 0.67) correct classification. The model correctly predicted 78.5% (sensitivity = 0.91, specificity = 0.66) of locations when tested using cross-validation (Fig. 1).

We used 209 locations from 9 male bobcats and an equal number of random locations to develop our male bobcat HSI. Significant ($P < 0.01$) non-correlated ($P \geq 0.05$, $|r| < 0.4$) variates subjected to LR were RD3, CRK, COND, and CLASS. Only RD3 and COND were retained by the stepwise procedure. There was an inverse relationship between HSI and distance to maintenance roads and stand condition (Table 3). Jackknife validation indicated 72% (sensitivity = 0.81, specificity = 0.63) correct classification. The model correctly predicted 77.5% (sensitivity = 0.88, specificity = 0.67) of locations when tested using cross-validation (Fig. 2).

Table 2. Logistic regression coefficients of the female bobcat habitat suitability index (HSI) model developed on Georgia Pacific landholdings and the Tallahala Wildlife Management Area in central Mississippi, 1989–92.

Variable[a]	Coefficient	$P = 0$[b]
SLOPE	0.53	<0.001
RD1	-0.22	<0.001
RD3	-1.33	<0.001
CRK1	0.30	0.001
COND	-0.35	0.001
Constant	1.05	<0.001

[a]SLOPE = slope class, RD1 = distance to paved road, RD3 = distance to maintenance road, CRK1 = distance to primary creek, COND = stand condition class.
[b]Probability that coefficient = 0 using a χ^2 test statistic.

DISCUSSION

Johnson (1981) stated 20 observations plus 5 observations for each independent variable should be used as a rule of thumb in establishing minimum sample sizes for multivariate analyses. Using this recommendation, sample sizes associated with our models should have been

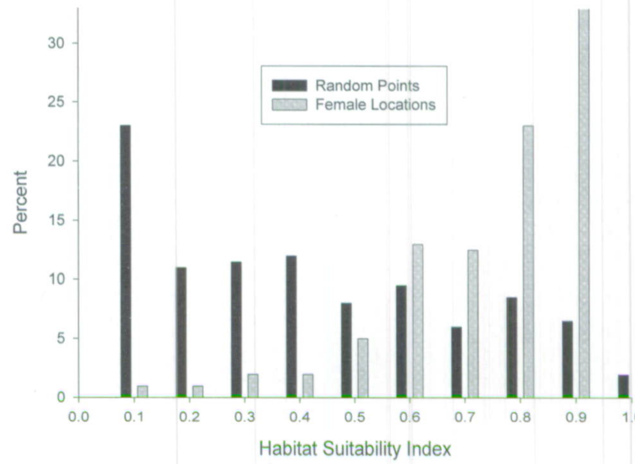

Fig. 1. Results of a cross-validation test of a female bobcat habitat suitability index (HSI) model developed on Georgia Pacific landholdings and the Tallahala Wildlife Management Area in central Mississippi, 1989–92. Shown is percentage of bobcat and random locations relative to habitat suitability index.

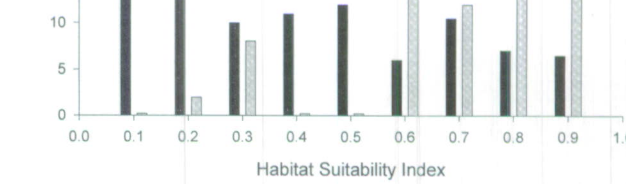

Fig. 2. Results of a cross-validation test of a male bobcat habitat suitability index (HSI) model developed on Georgia Pacific landholdings and the Tallahala Wildlife Management Area in central Mississippi, 1989–92. Shown is percentage of bobcat and random locations relative to habitat suitability index.

Table 3. Logistic regression coefficients of the male bobcat habitat suitability index (HSI) model developed on Georgia Pacific landholdings and the Tallahala Wildlife Management Area in central Mississippi, 1989–92.

Variable[a]	Coefficient	$P = 0$[b]
RD3	-1.16	<0.001
COND	-0.30	0.001
Constant	2.24	<0.001

[a]RD3 = distance to maintenance road, COND = stand condition class.

[b]Probability that coefficient = 0 using a χ^2 test statistic.

adequate because the least observation:variable ratio was approximately 100:1.

In general, random locations were predicted with less accuracy than were used locations. Habitat models that are based on used and random locations are expected to misclassify some random locations as suitable locations because some random locations used in model development were likely suitable habitat (Clark et al. 1993).

Bobcats are predators of small- to medium-sized mammals, reptiles, and birds (Fritts and Sealander 1978, Anderson 1987). Similarly, small mammals and rabbits occurred most frequently in bobcat diets on TWMA and GP (Chamberlain and Leopold 1999). On our study areas, these prey were most abundant in early successional habitats (Conner 1991); thus bobcat use of areas near and within sapling stands was likely because of prey abundance in these areas (Conner et al. 1992, Conner and Leopold 1993). Bobcats use seldom-traveled roads as travel corridors and for hunting (McCord 1974, Hall and Newsome 1976). This can explain distance to roads as a discriminator in both male and female habitat models. Notably, RDS1 was not a predictor in the male habitat model. Primary roads were located on study area peripheries, and we only monitored male bobcats that were captured at study area interiors. Therefore, lack of importance of RDS1 in the male model was likely a result of our monitoring protocol rather than a result of bobcat behavior.

Most pine stands in central Mississippi are located in upland sites and are harvested on a relatively short rotation. Thus, importance of slope to female bobcats may be an artifact of the presence of early successional habitats and the prey associated with these habitats in upland sites. However, bobcats may select more rugged terrain independent of forest type and condition (Zezulak and Schwab 1979, Hamilton 1982).

The female bobcat habitat model indicated that distance to creeks was related positively to HSI. However, there is no ecological reason for female bobcats to avoid creeks. Indeed, Yoakum (1964) observed bobcats fishing in a shallow portion of a river. We believe that the apparent avoidance of creeks by female bobcats resulted from a lack of early successional habitat near creeks, with this lack of early successional habitat being a result of forest management guidelines.

Male bobcats are habitat generalists relative to females (Bailey 1981, Sandell 1989, Conner et al. 1992). We retained 4 predictive variables in our female bobcat habitat model and only 2 variables in our male bobcat habitat model. Although sample sizes used in developing models differed between the sexes, we believe that the increased number of variables retained in the female model is, at least partially, the result of more specific habitat preferences of female bobcats.

Cross-validation and jackknife procedures yielded similar results and indicated models performed better than random. Because no independent data were available for testing the models, the applicability of these models to other forested areas within the Southeast is uncertain. Intuitively, these models should perform better than within-area models because they were developed using a much more diverse data set. Further testing is necessary on independent data sets before extrapolation of the models to other areas.

MANAGEMENT IMPLICATIONS AND FUTURE RESEARCH

Bobcats are important as an apex carnivore, but it is doubtful that wildlife managers will ever establish a habitat management plan with the goal of improving bobcat habitat. Fortunately, our models indicate that bobcats are associated with habitat traits that are promoted and maintained as a by-product of current forest management practices.

Bobcat habitat is perhaps best defined by prey abundance (Anderson 1987). Within southern ecosystems, prey abundance is often greatest within early successional habitats. Therefore, forest management practices that maintain early successional habitat should benefit bobcats.

Early successional habitat can be created and maintained using even- or uneven-aged forest management. However, our models of bobcat habitat were developed on areas using an even-aged approach to forest management, and these models would likely perform poorly if used within an uneven-aged forest management system. Because high prey abundance can be achieved within an uneven-aged forest management system, bobcat-habitat relationships within uneven-aged forested systems warrant investigation.

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UTILITY OF BOBCAT OBSERVATION REPORTS FOR DOCUMENTING PRESENCE OF BOBCATS

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Abstract: New York has had regulated hunting and trapping seasons for bobcat *(Lynx rufus)* in approximately 33% of the state since 1976. To assess bobcat distribution in other parts of New York, we solicited observations of this species throughout the state for a 3-year period beginning in 1995. The observations document bobcat presence in towns scattered across New York except Long Island. Frequency of observations was greatest for towns with records of bobcat harvest, suggesting that bobcat densities were lower outside harvested areas. By comparing the incidence of observation reports with bobcat harvest data, we infer that the use of our observational data provides a conservative approach to document presence of this species.

Key words: bobcat, distribution, *Lynx rufus*, New York, population status, range, sightings.

Bobcats are present in much of North America (Wilson and Ruff 1999), but reportedly absent from an area in the northcentral United States including western New York, western Pennsylvania, Ohio, Indiana, and parts of Tennessee, Michigan, Illinois, Wisconsin, Iowa, Missouri, and South Dakota (Deems and Pursley 1978). According to DeKay (1842), the bobcat was common at the time of European settlement in what is now New York, including Long Island, but was extirpated from some parts of the state by the mid-19th century.

Prior to 1976, the bobcat was unprotected in New York and could be killed at any time and by any method. Bobcats also were subject to bounties in several counties until 1971. In 1976, state law provided protection by classifying the bobcat as a small game species. Regulated hunting and trapping seasons were established the following year in those areas where bobcat populations could support harvest. Central and western New York were closed to harvest at that time. Seasons have continued with minor modifications in areas and dates until the present (Fig. 1). Several references indicate that bobcats are absent from the St. Lawrence valley and western New York (Deems and Pursley 1978, McCord and Cardoza 1982, Wilson and Ruff 1999); however harvest records confirm their presence in much of the St. Lawrence valley.

In those parts of New York occupied by bobcats, population density varies but is low compared to values ranging from 0.04–2.74/km^2 reported for other parts of the United States (McCord and Cardoza 1982). Late-winter densities in New York during 1977–81 ranged from 0.02/km^2 in the central Adirondacks to 0.06/km^2 in the western Catskills (Fox 1990). Consistent with the low density in the central Adirondacks, exceptionally large home ranges and indications of marginal climate and habitat conditions for this species were found.

The secretive nature of bobcats and their low densities in many areas means that they are observed infrequently relative to many other carnivores. Because of this, harvest assumes a key role in documenting occupied bobcat range. In areas that are closed to harvest, observations and road kills are typically used to document their presence. However, prior to 1995, few bobcat observations were reported from parts of New York closed to harvest. We assumed these few observations were of immigrants from other states or from parts of New York known to be populated by bobcats. Nevertheless, farmland abandonment and vegetative succession in these areas had created habitat conditions similar to those in areas already occupied by bobcats. We estimated that there could be up to 17,000 km^2 of suitable but poorly occupied habitat in the state and developed this study to improve our understanding of statewide bobcat distribution.

METHODS

Beginning in 1995, we solicited reports of bobcat observations from several types of outdoor recreationists using department publications, postcards to individual trappers and houndsmen, and letters to birding groups and licensed hunting guides. We also obtained bobcat sightings from archery deer hunters in several parts of the state. Reports from all sources were reviewed for completeness and credibility. To qualify as complete, reports needed the name of an observer, a date including year, and a location identifiable as a valid town within the state. We excluded reports based on bobcat vocalizations, tracks (except those from trappers or houndsmen), and all second-hand reports for which we could not contact the

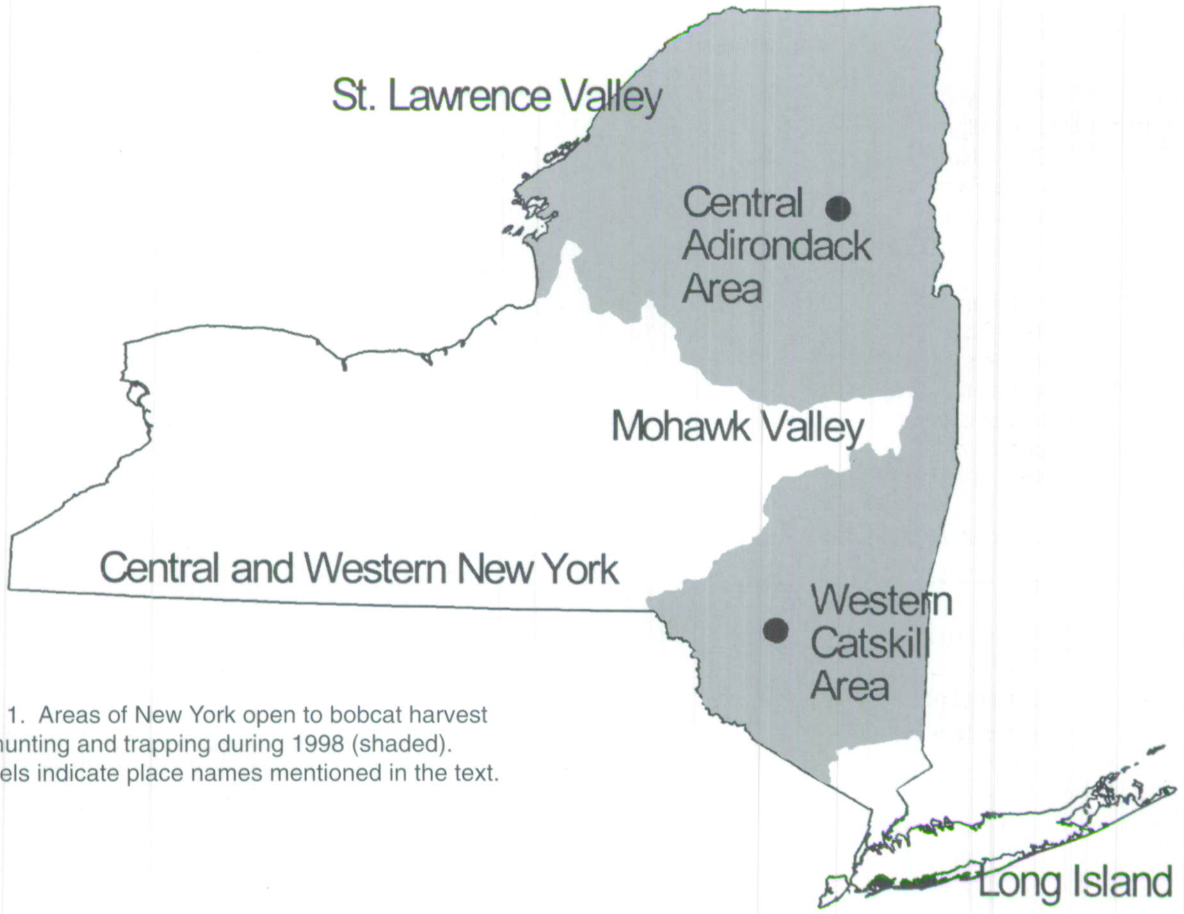

Fig. 1. Areas of New York open to bobcat harvest by hunting and trapping during 1998 (shaded). Labels indicate place names mentioned in the text.

original observer. Observations by trappers and houndsmen and the majority of records from areas already known to be occupied by bobcats were assumed accurate. For observations from other sources and outside known bobcat range, we attempted to interview observers by telephone or mail about the circumstances of the observation. Based on the follow-up interviews we excluded records with doubtful species identification from files used for mapping. However, to prevent bias due to non-random selection of reports for follow-up, all complete records, incuding those with doubtful species identifications, were retained for analysis in this report.

Observations ranging from 1994 to 1999 were summarized by town according to a list of 944 jurisdictions in New York. We used the criteria of observations during all 3 years of the study to confirm a town as bobcat range. Towns with observations in 2 years were considered probable bobcat range, and towns with bobcat observation reports in only one year were considered possible bobcat range.

Bobcat harvest was tabulated by means of a regulation that requires all hunters and trappers who harvest a bobcat to submit the untanned pelt or carcass to department personnel to be affixed with a locking plastic tag. Location and date of harvest were recorded at this time.

We tabulated the number of years with ≥ 1 observation report(s) for towns in 3 groups as follows: (1) towns with harvest of ≥ 1 bobcat(s) over the duration of this study (H+), (2) towns open to bobcat harvest with no harvest occurring over the duration of this study (H-), and (3) towns closed to harvest (C). We calculated 2-way chi-square tests of observation reports vs. harvest and confirmation vs. harvest, respectively, combining H- and C groups to perform these tests. To investigate the likelihood of confirming occupied bobcat range by observation reports, we assessed whether observation reports would have confirmed bobcat occupation in each of the 247 (H+) towns during the period from the 1994–95 through the 1998–99 harvest seasons.

RESULTS

We received 938 complete reports of bobcat observations that occurred between 1994 and early 1999. Observations occurred in 394 towns scattered throughout New York except Long Island (Fig. 2). This represents 42% of the jurisdictions on our list and 51% of the land area. More than half of the towns with observations ($n = 213$) were in the H- or C group; however, occurrence of observation reports for a town was related to occurrence of harvest ($X^2 = 136.8$, $P < 0.0001$). The association with harvest also was strong

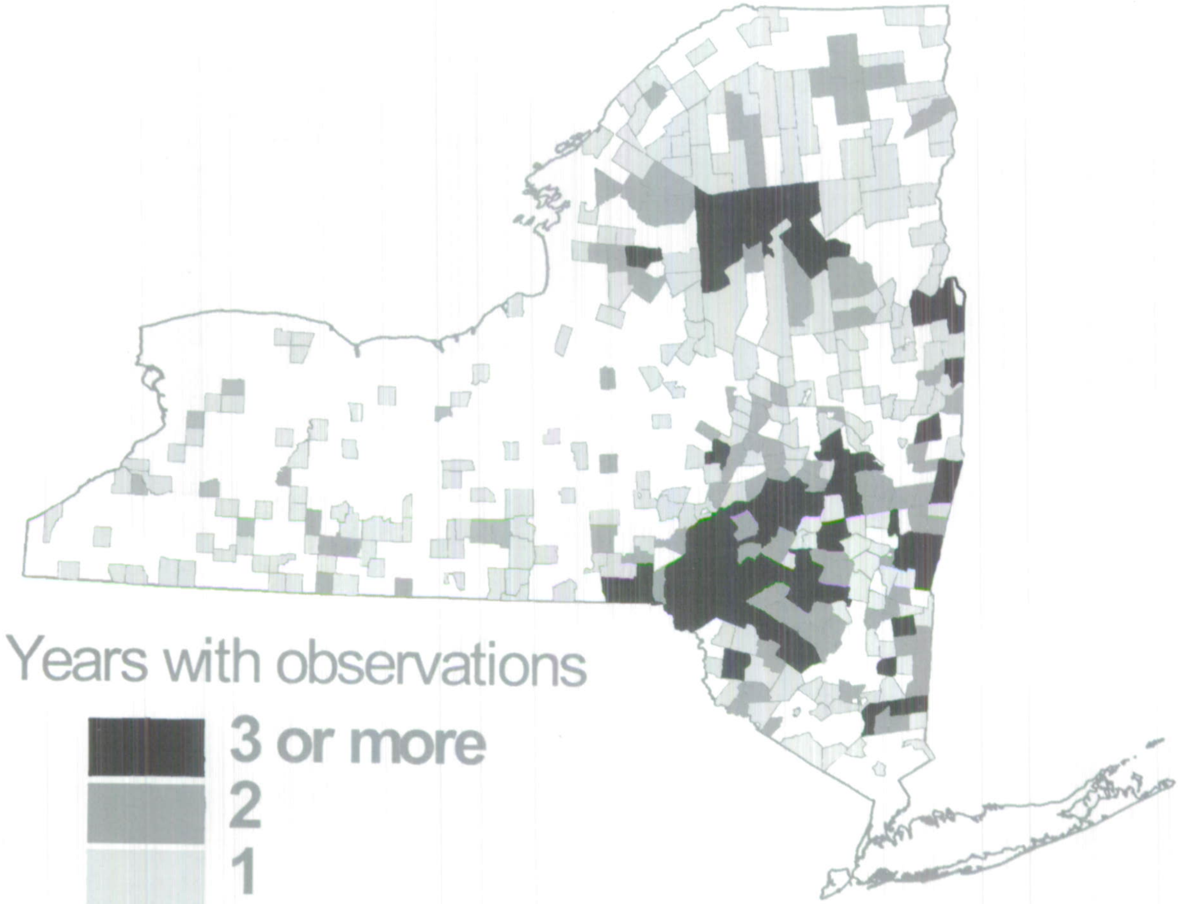

Fig. 2. Towns with bobcat observation reports in New York, 1994–99. Reports with doubtful species identifications were excluded.

for towns with observation reports in ≥3 years (X^2 = 55.3, $P < 0.0001$).

Of the 247 towns with bobcats harvested over the duration of the study (Fig. 3), 73.2% had ≥1 bobcat observation reports. However, only 19.4% of these towns would have been confirmed as occupied by bobcats using the criterion of ≥3 years with observation reports. An additional 20.2% would have been classified as probable occupied range, and another 33.6% as possible range.

During 1996–97, we calculated numbers of observation reports relative to hunting license sales within 3 portions of the state (Table 1). Results indicated a higher proportion of observations in the southeast section of the state than the northern or western portions.

Table 1. Observation reports vs. hunting license sales (big game and sportsmen licenses) for 3 areas of New York, 1996–97.

Area	Observations	Sales	Observations/10^4 licenses
North	49	85,738	5.72
Southeast	134	129,773	10.33
West	54	301,648	1.79

DISCUSSION

Observation reports are commonly used to document presence of bobcats in areas not open to harvest (Woolf and Nielsen 1999). We found that soliciting reports through the state hunting and trapping regulations guide was highly effective, with roughly half of reports being stimulated by this means.

For consistency with harvest information, we used town or city as reporting entities to tabulate observations. Other landscape units, including counties, are often used to document presence of vertebrate species. Choice of a reporting entity affects precision of subsequent analysis. Under equivalent conditions, larger areas are more likely to produce an occurrence within their boundaries than are smaller areas. Jurisdictions in our list of towns varied in area from 2.8–1,294 km^2. This variation in size contributed to the frequency of observation reports in a town. Towns having observation reports or harvest reports were larger than average ($\bar{x}$ = 169.1 km^2 for towns with observation reports, 209.7 km^2 for harvested towns, and 138.9 km^2 for all towns on our list).

Although we used harvest as a standard for documenting areas occupied by bobcats, several factors affect the likelihood of harvest in towns where

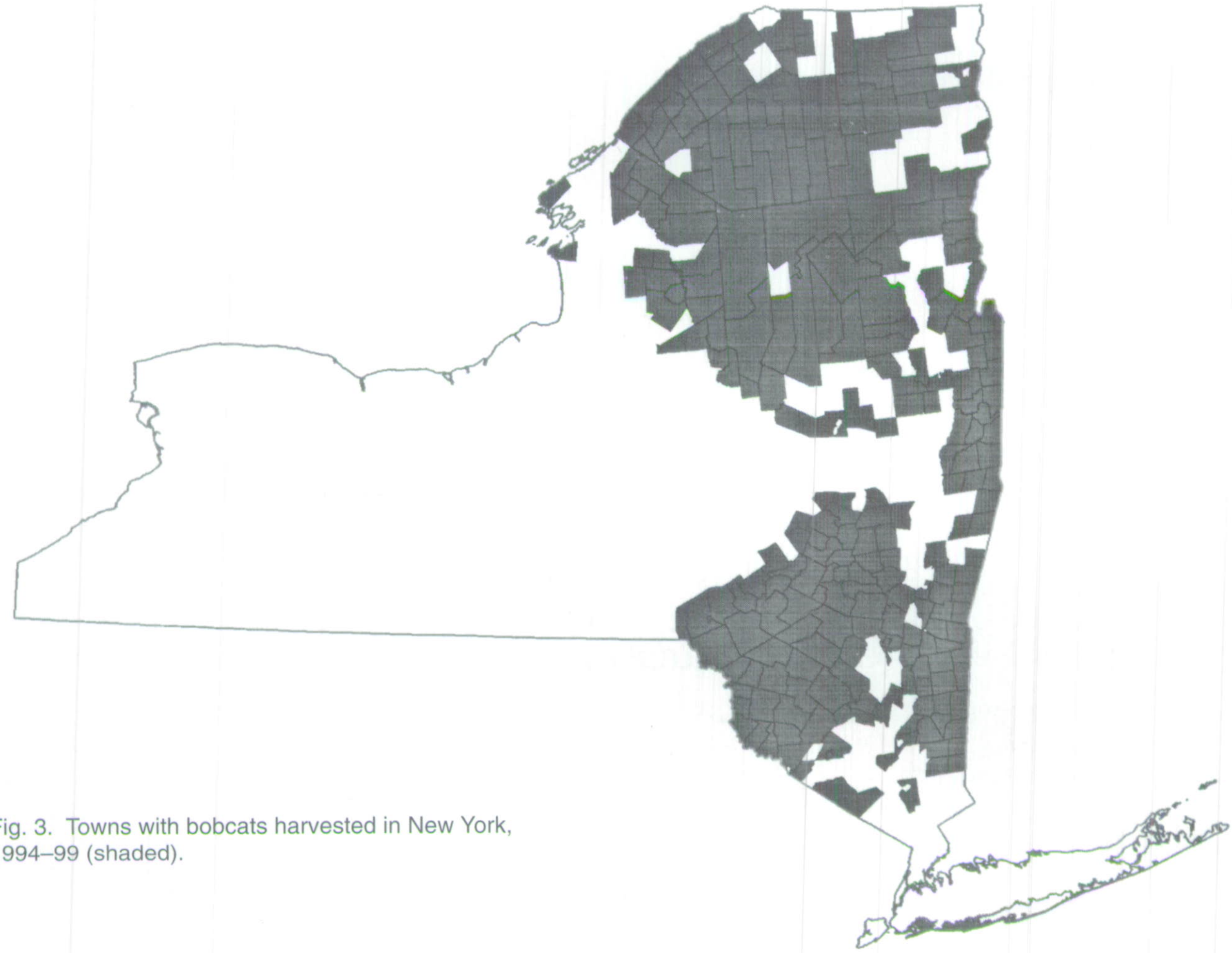

Fig. 3. Towns with bobcats harvested in New York, 1994–99 (shaded).

bobcats occur and bobcat harvest seasons are held. As with observation reports, town size influences the likelihood of harvest in that town. Other influences include length and timing of the harvest season, amount of land area open to bobcat harvest, and number and distribution patterns of potential bobcat harvesters.

Hunting and trapping seasons for bobcat are set on the basis of 85 Wildlife Management Units (WMUs). For the WMUs open to bobcat harvest, season length in a typical year varied from 37 to 149 days. Season timing is more significant than season length however, because much of the bobcat harvest occurs during the deer hunting season when large numbers of hunters are afield. Bobcat seasons in all WMUs open for bobcat harvesting currently overlap with deer hunting seasons. Because deer hunters are dispersed throughout all parts of the state except metropolitan areas, harvest data can be used to represent bobcat occurrence for areas where bobcat seasons are open.

A greater problem arises on the margins of the open areas. Since WMU boundaries rarely conform to town boundaries, many towns are split between ≥2 WMUs. Along the edge of the area open for bobcat harvest, towns are commonly split so that only part of the town is open to bobcat harvest. For our analysis, towns partly open were considered open to harvest. Some of these towns had <10% of the land area included in the open area. This accounts for several towns which had no harvest over the period of the study but did have observation reports.

While a single record of harvest could confirm a town as occupied bobcat range, our criterion for observations required 3 years with an observation report to confirm a town as occupied by bobcats. Where bobcat range is expanding, our criterion of continuity over time provides some protection from mistaken town confirmations due to errors in species identification or observations of transient individuals. While the possibility of transient animals or location errors exists even for harvested bobcats, species identification by department staff with a carcass or pelt in hand eliminates a large source of the uncertainty in documenting resident populations.

Comparison of the observation and harvest maps (Figs. 2 and 3) suggests the limitations and strengths of observation data and the town classification criterion. Observation reports, screened for reliability, provide a source of data that is independent of bobcat harvest and covers a broader geographic area in New York. Despite this, we found much overlap between towns confirmed by multiple years of observations and delineation of occupied range based on harvest. While towns across the state were classified as possible or probable bobcat range based on 1 or 2 years of observations, those towns that qualified as confirmed by observations were clustered near areas where harvest occurred. Of the 64 towns classed as confirmed by observations, all but 4 overlapped or were adjacent to towns where harvest occurred.

We examined or controlled for the influence of 3 factors potentially contributing to the association of observation reports and harvest. These factors included the possibility of redundant observation and harvest reports for a single animal, the increased level of scrutiny given to reports from outside known bobcat range, and a possible higher density of observers within areas open to harvest. To examine the influence of redundancy in our methodology, we searched for redundant reports in the observation and harvest databases. Less than 1% of all observation reports appeared to refer to a harvested animal, based on criteria of similar dates and locations and names of the person reporting. To eliminate bias due to scrutiny of observation reports in non-traditional areas, we used all complete observation reports for calculation, including the 7% overall ($n = 67$) that were evaluated by follow-up interview as dubious species identifications.

Both human population density and hunter density contributed to observer density and varied widely throughout New York. The majority of our observers were hunters, suggesting that an index of hunter density would be useful in interpreting the relative number of observation reports from different areas. When we related numbers of observation reports to hunting license sales within 3 large areas of the state, results ranked consistently with our preconceived notion of relative bobcat abundance based on the most recent density estimates available for eastern New York. For the northern, central, and western areas of the state, incidence of observations over this period was roughly equivalent, but potential observers based on license sales varied threefold. We conclude that low bobcat density is the most likely explanation for the relatively low number of observation reports from most areas outside traditional bobcat range in New York.

MANAGEMENT IMPLICATIONS

This study provides evidence of bobcat occurrence throughout central and western New York and the Mohawk River valley with a consistency too great to be attributed to immigration. However, the relative rarity of observations in these areas, along with relatively high density of potential observers, suggests that bobcat population densities are lower than in traditionally occupied areas of eastern New York.

Systematic collection and evaluation of observation reports is valuable in documenting bobcat distribution, especially in areas where bobcat harvest seasons are not established. Active solicitation of observation reports is a relatively economic means of documenting presence of this species. Three years of solicitation from outdoor recreationists resulted in observation reports in about 75% of the 247 towns where harvest occurred. Our more conservative occupation criterion, requiring 3 years of observation reports to confirm a town as occupied range, classified <20% of towns with harvest as occupied range. Jurisdictions which depend on observation reports from the public to document occurrence of relatively uncommon species will benefit from the considerations in this report.

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EVOLUTION OF WISCONSIN'S BOBCAT HARVEST MANAGEMENT PROGRAM

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Abstract: Wisconsin's bobcat (*Lynx rufus*) harvest management program has changed dramatically during the past 4 decades. The state paid bounties on bobcats until 1964 and some counties continued bounty payments for several years thereafter. In 1970, the bobcat harvest season was reduced from all year to 5.5 months. Since then, harvest regulations became increasingly restrictive. Currently, Wisconsin's bobcat harvest season is only 2.5 months long and restricted to the northern third of the state. A limited number of harvest permits are issued each year to hunters and trappers selected through a preference lottery system. Concomitant with the increased restrictions on harvest has been increased agency and public concern about the status of the species and increased research and surveys on bobcat population dynamics, including mandatory harvest registration, carcass analyses, harvester and agency questionnaires, snow-track surveys, and population modeling. Wisconsin's management program was challenged in 1990 when the Coalition for Bobcat Preservation petitioned the state to list the bobcat as a threatened species. We summarize the Wisconsin Department of Natural Resources' (WDNR's) response to this petition and the subsequent legal proceedings that culminated in the Wisconsin Supreme Court affirming the agency's decision not to list the bobcat as a threatened species. In addition, we will review the available scientific information upon which the agency's harvest management decisions are based.

Key words: animal rights, bobcat, harvest, lawsuit, *Lynx rufus*, management, monitoring, population, threatened species, Wisconsin.

Changes in societal attitudes toward predators during the past 40 years have been reflected in dramatic changes in the management of bobcat harvests in Wisconsin. We describe the changes in the Wisconsin Department of Natural Resource's (WDNR's) population monitoring program and harvest management strategies during this period. Despite increasing knowledge about bobcat population status and increasingly restrictive harvest regulations, Wisconsin's management program was challenged in 1990 when the state was petitioned to list the bobcat as a threatened species. We summarize the WDNR's response to this petition and the subsequent legal proceedings. In addition, we review the available scientific information upon which the agency's harvest management decisions are currently based.

BOUNTY YEARS

Bobcats were apparently distributed throughout Wisconsin at the time of European settlement in the mid-1800s (Jackson 1961). The first attempt to manage bobcat harvest in Wisconsin was in 1867 when a $10.00/animal bounty was offered by the state (Keener 1971). Bounty payments were reduced to $5.00 in 1923. During the next 40 years the number of bobcats bountied each year fluctuated widely from <50 to over 1,000 (Fig. 1). The average number of bobcats bountied per year during this period was 425. The distribution of bobcats in Wisconsin was largely reduced to the northern third of the state by the mid-1900s. The state discontinued bounty payments in 1964, but some counties continued them until 1970.

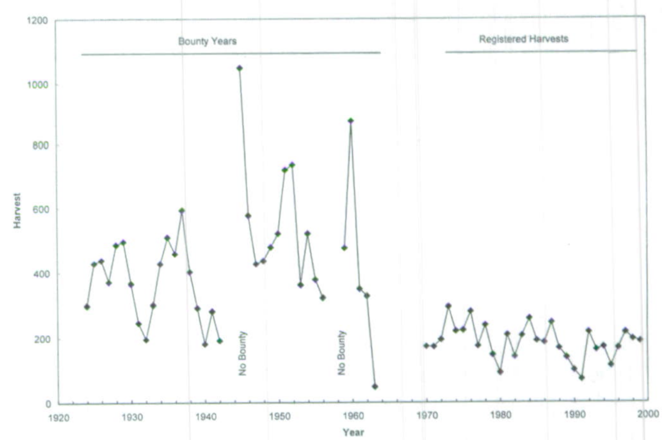

Fig. 1. Estimated number of bobcats harvested in Wisconsin, 1923–99. Estimates prior to 1964 were based on bounty payments, those after 1973 on mandatory harvest registration.

ERA OF INCREASING PROTECTION

Although the state no longer paid bounties after 1963, bobcats were still unprotected and year-round hunting or trapping was allowed until 1970. Because of increasing WDNR and public concerns about their status in Wisconsin, in 1970 the harvesting of bobcats was restricted to a 5.5-month open season (mid-Sep–Feb). There was no daily or seasonal bag limit. In 1972 the season was reduced to 4.5 months.

In 1973, the Endangered Species Committee of the WDNR considered the status of bobcats to be questionable (Creed and Ashbrenner 1976). That year registration (inspection and tagging by WDNR staff) of all harvested bobcats was mandated. In addition, research on distribution, relative abundance, and habitat associations of bobcats was initiated. Beginning in 1976, experimental winter track count surveys were conducted in 3 counties to assess the potential of this survey technique for monitoring bobcat population trends (Klepinger et al. 1979). The hunting and trapping season was further restricted to 3 months in 1978. Winter track surveys were expanded to 17 northern counties in 1977.

Since 1980, harvesting of bobcats has been restricted to the portion of the state north of state highway 64, approximately the northern one-third of the state (Creed and Ashbrenner 1983). In addition, the open season was reduced to 2 months, a seasonal bag limit of 1 was established, and hunters and trappers were required to apply for a permit prior to the season. However, there was no limit on the number of harvesters who could receive a permit. In 1983, the season was lengthened to 2.33 months to make the opening concurrent with the general trapping season in northern Wisconsin. During the 1970s and early 1980s, harvests of bobcats averaged 201 but fluctuated between 90 and 296 (Fig. 1). Creed and Ashbrenner (1983) recommended that annual bobcat harvests be limited to ≤200.

Also in 1983, the WDNR began requiring that bobcat hunters and trappers surrender the carcass of harvested bobcats for determination of age, sex, and reproductive history. Information from collected carcasses was combined with information on size of harvest in a population model. The model was originally developed by the Minnesota DNR and was patterned after the POP-II big game population model (Bartholow 1986).

During 1985–87, scent-station transects were evaluated as a potential index to bobcat population trends. Bobcat visitation rates were fairly low and it was concluded that the survey lacked the power to detect bobcat population changes of moderate size with a reasonable amount of effort. Consequently, scent-station transects were discontinued.

MANAGEMENT SYSTEM CHALLENGED

In March 1990, the Coalition for Bobcat Preservation petitioned the WDNR to list the bobcat as a state-threatened species. The petitioners noted that the number of bobcat harvest permits issued increased from 1,840 in 1980 to >5,000 in the late 1980s, while the number of bobcats harvested/1,000 permits declined from an average of 56 bobcats/1,000 permits in 1980-87 to 30 bobcats/1,000 permits in 1988 and 26 bobcats/1,000 permits in 1989 (Fig. 2). They concluded from these data that the population was in jeopardy. They argued that in light of uncertainty about the size of the population it would be prudent to "err on the side of caution" and stop legalized killing. They further argued that killing bobcats deprived non-consumptive users the opportunity to observe bobcats in the wild, and that trapping and hunting bobcats were unethical and irresponsible activities and were in conflict with positive, progressive wildlife ethics.

In response to the petition, the WDNR conducted an environmental analysis of scientific evidence presented in the petition and all other information available about the status of bobcats in Wisconsin in accordance with Wisconsin Environmental Protection Act processes. As part of the analysis, the WDNR requested that Lloyd B. Keith and Stanley A. Temple, professors in the Department of Wildlife Ecology at the University of Wisconsin, and William E. Berg, a furbearer research biologist for the State of Minnesota, review the available information and comment about Wisconsin's management system and the proposal to list bobcats as a threatened species. Information reviewed included harvests during 1973–89, age and sex-structure of harvest, pregnancy rates and litter size, winter track counts, scent-station surveys, and the population model.

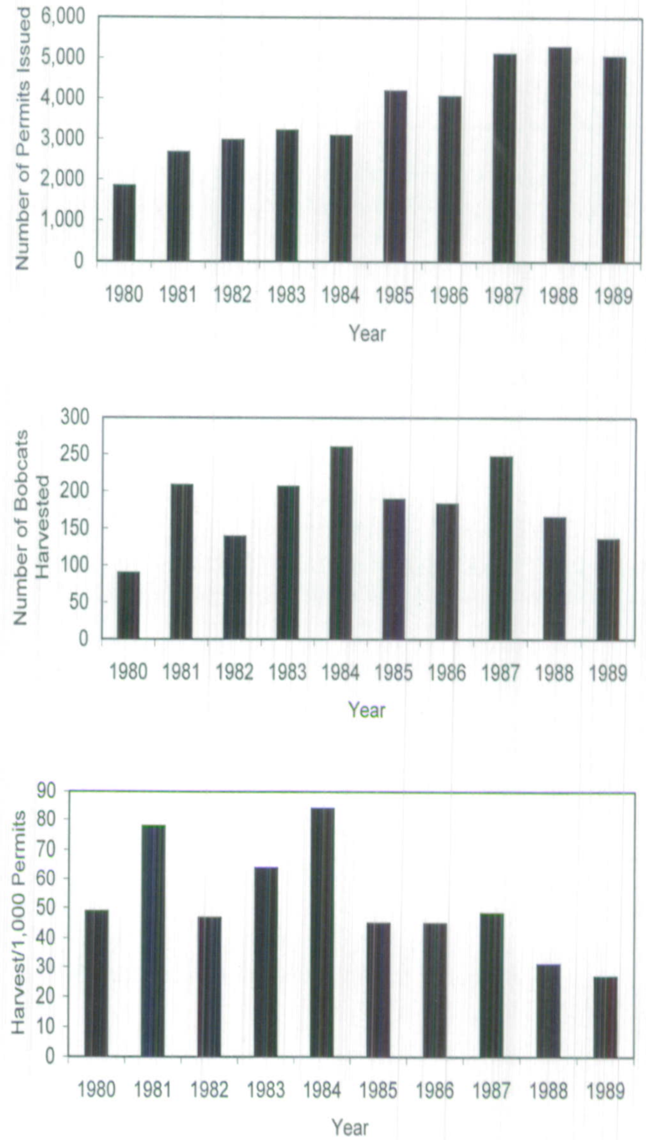

Fig. 2. Harvest success analysis used by the Coalition for Bobcat Preservation as the basis for their petition to list the bobcat as a threatened species.

Both university professors concluded that available information did not support the claim of the petitioners that the bobcat population was threatened. However, they also stated there was insufficient evidence to conclude that the population was stable. They felt none of the available indices of bobcat population trends were capable of detecting changes in the population with current levels of sampling. They both expressed concern about an increasing percentage of kittens in the harvest during the mid-1980s, suggesting one possible reason for this could be overharvest of adults. Both professors attempted to calculate estimates of population size from the available data. The resulting estimates varied considerably with several estimates considerably lower than the WDNR's estimate that was based on simulations using the Minnesota population model. In contrast, the Minnesota furbearer biologist concluded that the available data indicated to him that the population was close to stable but he recommended that Wisconsin intensify its population surveys.

Based on reviews by these independent experts, and its own analyses, the WDNR's Environmental Analysis concluded in 1991 that it was not necessary to list the bobcat as a threatened species. This conclusion was based on surveys that suggested relative population stability (winter track counts, observations of live bobcats by WDNR field personnel, reported numbers of bobcats run/day by hunters using dogs, and age and reproductive data from carcasses of harvested bobcats). The WDNR questioned whether the decline in harvest per permit issued during the 1980s (the basis of the petitioners' claim of a declining population) accurately reflected population trends, because harvest permits were free during this period and many people obtaining permits may not have actively pursued bobcats. The WDNR believed that any population decline could be offset with modification of harvest and recommended the development of a quota system to limit the number of harvest permits issued. The department informed the petitioners of its decision to not list the bobcat as a threatened species. A new harvest permit quota system was approved by the legislature and implemented in 1992.

The original petitioners joined with The Fund for Animals and petitioned the Dane County Circuit Court for a Review of an Administrative Decision. Wisconsin statutes permit a court to set aside or modify an agency's action if the agency has erroneously interpreted a provision of law or if the factual finding is not supported by substantial evidence. The petitioners claimed that the WDNR's decision to not list the bobcat as a threatened species was contrary to the intent of the Wisconsin Endangered Species Act (WESA) and the decision was not supported by substantial evidence. They cited the university professors' conclusions that the available evidence was inconclusive regarding population trend and the scientific uncertainty over population estimates and claimed that the legislative intent behind the WESA was to err on the side of protecting a species if there was uncertainty regarding its fate. Further, they argued that the WDNR's decision should be reversed because there was no scientific evidence to support the agency's conclusion that the bobcat was not threatened.

The Circuit Court's ruling in September 1992 affirmed the WDNR's decision not to list the bobcat as a threatened species. The court concluded that the petitioner's claim that the WDNR's decision was not supported by substantial evidence was groundless. The court found that the agency's decision was made after soliciting the opinion of a variety of scientific experts and a careful review of data on harvest, reproductive rates, and age- and sex-structure of the population. The court acknowledged that different interpretations of the data were possible, but believed there was substantial evidence to support the WDNR's decision. The Circuit Court concluded that lack of information was not a basis for listing a species as threatened.

The petitioners appealed the Circuit Court's decision to the Wisconsin Court of Appeals. In July 1993, the Court of Appeals concluded that the WDNR's interpretation of the WESA was reasonable and its decision in this matter was entitled to great deference because the agency had substantial experience in protecting threatened and endangered species, employed persons with the requisite technical competence and specialized knowledge in wildlife management, and had specialized knowledge related to the bobcat population in Wisconsin. The court found that the legislative intent of the WESA was to delegate listing decisions to the WDNR, and therefore the WDNR's interpretation of the statue was entitled to deference. Wisconsin statute requires the court to give due weight to agency decisions and to uphold them if they are reasonable, even if an alternative view is also reasonable. The appeals court concluded that the burden was upon the petitioners to establish that the agency's decision was not credible; the WDNR was not required to show the credibility of its decision. Finally, the appeals court concluded that the implementation of the quota harvest system accounted for many of the petitioners' concerns, as well as ensuring that the WDNR would continue to be able to make decisions based on the best available scientific data.

The petitioners then appealed to the Wisconsin Supreme Court. In June 1994, the Supreme Court affirmed the WDNR's decision. The Supreme Court concluded from the language of the WESA that the legislature intended for the WDNR to use its sound discretion in making species listing decisions and that the agency's decision was not outside the range of discretion delegated to it or an erroneous exercise of discretion. The court stressed that the WESA mandated that listing decisions are to be based on scientific data. The court found that the available scientific evidence on the status of Wisconsin's bobcat population was inconclusive; it did not support the petition's claim that bobcats were threatened, nor did it demonstrate that the bobcat population was healthy. The court rejected the petitioner's interpretation of the WESA that the state should err on the side of protection in the face of scientific uncertainty. The court stated that the WDNR had an implicit responsibility to monitor potentially declining animal populations so that scientific evidence would be available and concluded there was no indication in this case that the WDNR abdicated this responsibility.

SCIENTIFIC BASIS FOR HARVEST MANAGEMENT

The legal challenge to Wisconsin's bobcat harvest management was one stimulus that contributed to a recent evaluation by the WDNR of the scientific basis for management decisions. Key questions in the analysis were whether the level of scientific knowledge was reasonable for the agency's management responsibilities and whether the scientific knowledge should be bolstered to make better decisions. The resulting report included a conceptual framework for the evaluation of the information needed to manage a harvested wildlife species (Wisconsin Department of Natural Resources 1995). This framework recommended indices of harvest and population change and user statistics for all harvested species. Additional information needs were identified if the species was a habitat specialist; was limited by environmental extremes, diseases, or contaminants; or had a low reproductive potential and was vulnerable to harvest. When this framework was used to evaluate bobcats, the following information needs were identified: mandatory harvest registration, population index, population model, user statistics, market value survey, and periodic habitat inventory.

The WDNR has required mandatory registration of harvested bobcats since 1973. Registration has provided timely information on the size, date, location, and method of harvest. Currently, harvesters are required to register bobcats ≤5 days after the close of the season. Beginning in 2001, successful hunters and trappers must register their animal ≤5 days after the month of harvest. The WDNR has emergency authority to close the season early if in-season registrations indicate that harvests are likely to exceed the harvest quota.

WDNR primarily relies on winter track surveys as an index to bobcat population changes. Track surveys have been conducted annually across northern Wisconsin since 1977 (Fig. 3). However, bobcat encounter rates are relatively low and during the 1980s varied considerably from year to year. As a consequence, the power of the survey to detect moderate levels of population change is relatively low. Interestingly, it appears that during the 1990s, annual variability has been lower and an increasing trend in track encounters is suggested. Track surveys have been supplemented with indices of the number of bobcats run by dog hunters (Fig. 4) and sightings of bobcats by WDNR personnel (Fig. 5). The number of bobcats run by dog hunters has been positively correlated with track counts ($n = 18$, $r = 0.56$, $P = 0.015$). In contrast, bobcat sightings by WDNR personnel have not been correlated with the other two indices (winter track count: $n = 17$, $r = -0.06$, $P = 0.82$; dog hunters: $n = 12$, $r = 0.28$, $P = 0.37$). Pilot studies have been conducted on a bowhunter wildlife observation survey, but to date the survey has not become operational.

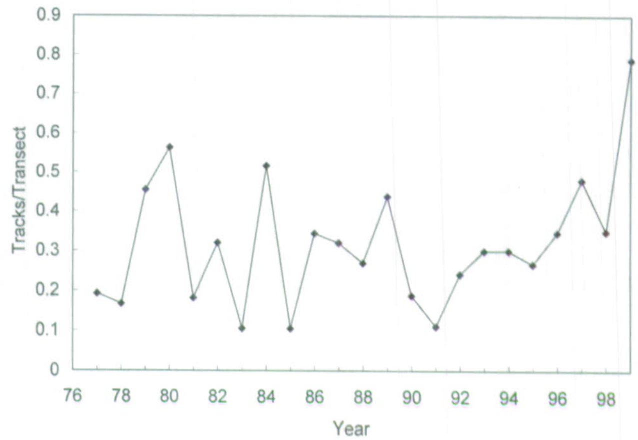

Fig. 3. Number of bobcat tracks/transect on winter track surveys in northern Wisconsin, 1977–99.

Fig. 4. Number of bobcats run/hunter day by successful hound hunters in Wisconsin, 1973–99.

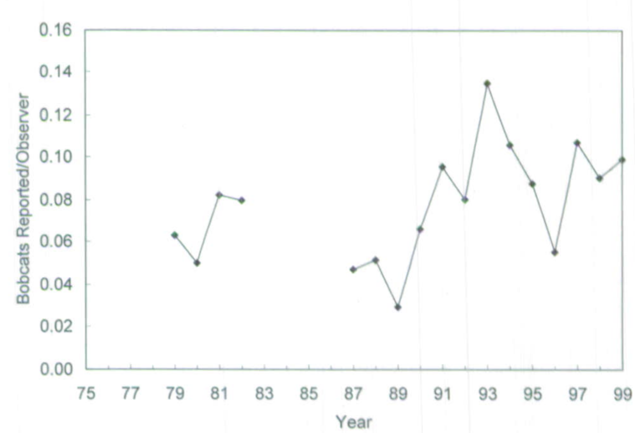

Fig. 5. Number of bobcats reported as observed by Wisconsin DNR personnel, 1979–99.

The WDNR continues to use the Minnesota furbearer model for modeling Wisconsin's bobcat population. The model combines information on the size and sex- and age-structure of the harvest with estimates of age-specific reproductive rates and non-harvest mortality rates. Mandatory carcass collections have provided information on harvest age- and sex-structure along with estimates of reproductive rate that are used as model inputs. Nearly 2,300 carcasses have been examined since 1983. Based on model simulations, we estimate that the fall bobcat population in northern Wisconsin has recently fluctuated from a low of about 1,500 in the mid-1980s to a high of about 2,200 in the last couple of years (Fig. 6). However, simulated population trends generated by the model are very sensitive to small changes in initial population size. The model is most useful when it can be calibrated to an independent trend index or to estimates of absolute population size. Because population density has only been estimated in one telemetry study of limited scope (Lovallo 1993) and questions remain about the accuracy of current indices, the results from the population model should be interpreted with caution.

Since 1980, the number of applicants for permits and number of permits issued have been annually documented. During 1973–89, successful bobcat harvesters were surveyed to estimate effort. Since 1993, all permit recipients have been surveyed to estimate their participation and effort in pursuing bobcats. The market value of bobcat pelts sold in Wisconsin is estimated annually via a survey of fur buyers. However, estimates of the number and value of bobcats pelts sold directly to Canadian auction houses are not currently available, nor are estimates of the number and value of taxidermy mounts. Although bobcats occur in a wide variety of habitats throughout their geographic range, in Wisconsin they are primarily limited to the northern third of the state. Lowland conifer stands and recent aspen clearcuts with abundant snowshoe hares appear to be their preferred habitat in Wisconsin. Forest inventory data are periodically reviewed to assess potential changes to bobcat habitat suitability. In addition, changes in the abundance of snowshoe hares are monitored with the winter track survey and harvest by small game hunters.

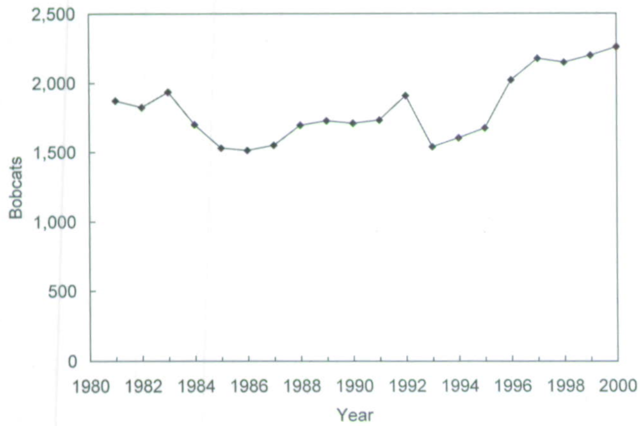

Fig. 6. Estimated trends in the Wisconsin bobcat population, 1981–2000, based on the Minnesota Furbearer Population Model.

The WDNR's Furbearer Advisory Committee annually reviews available population and harvest information and makes recommendations on future harvest and permit quotas. Because the Wisconsin Ojibwa tribes retained their rights to hunt, fish, and gather in the portion of northern Wisconsin that was ceded to the United States government in the mid-1800s, they are entitled to a portion of the allowable harvest. The tribes are represented on the Furbearer Advisory Committee by the Great Lakes Indian Fish and Wildlife Commission, whose staff assist the WDNR in reviewing population information and determining annual harvest quotas.

CONCLUSIONS

During the past 40 years Wisconsin's management of bobcat harvests has evolved from unrestricted bounty payments to a carefully regulated limited quota system. These changes have been driven by reductions in the occupied range in Wisconsin, concerns about the status of bobcats within the WDNR, and changing public attitudes about the role of predators in ecosystems. Once considered a varmint, bobcats are now largely viewed as an important component of Wisconsin's northern forest and as a prized species by Wisconsin's hunters and trappers.

As harvest management strategies have become more restrictive during the past 40 years, the information needed to support management decisions has increased greatly. Wisconsin's harvest management system recently survived intense judicial scrutiny. However, the outcome of the story may have been different if the courts found that WDNR had the burden of proof to show that the population was stable.

Adequate monitoring of the relatively low-density bobcat population remains a challenge for resource managers. With this in mind, we have been carefully restricting harvest during the past decade to <220 bobcats/year to help ensure the long-term stability of the population. We recommend that the current population monitoring program and restrictive harvest strategies be continued. We also recommend the implementation of a bowhunter wildlife observation survey to strengthen the monitoring program.

ACKNOWLEDGMENTS

We thank the many hunters, trappers, wildlife managers, and law enforcement personnel who provided much of the information on Wisconsin's bobcats during this period. We especially want to acknowledge W. A. Creed, J. E. Ashbrenner, and B. J. Dhuey who coordinated, analyzed, and interpreted the various bobcat studies and surveys during the past 30 years. C. M. Pils and R. L. Jurewicz coordinated the WDNR's response to the petition, reviewed an earlier draft of this manuscript, and provided many helpful comments. J. S. Christenson and P. Peterson provided legal council during the litigation. Funds for much of the research and surveys were provided through Federal Aid in Wildlife Restoration Project W-141-R.

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PERSPECTIVES ON BOBCAT MANAGEMENT IN ILLINOIS

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Abstract: Long considered rare in Illinois, bobcats (*Lynx rufus*) were protected from harvest in 1972 and listed as a state threatened species in 1977. Recent (1995–99) studies showed a widespread distribution and a trend toward increasing relative abundance. About 30–40% of the state was classified as good to excellent habitat. Based on these findings, bobcats were removed from Illinois' list of state threatened species in 1999. Long-term (1992–98) trends in the Archer's Index were similar for Illinois, Indiana, and Missouri, suggesting that cooperative efforts to collect and analyze data might improve the precision of estimates for annual changes in abundance in the lower Midwest. Preliminary estimates of density, survival, and other demographics suggest that Illinois' population could sustain a limited harvest. While biological integrity is an important consideration, we recognize the fate of such a proposal will be decided by broader public policy.

Key words: bobcat, furbearer, Illinois, *Lynx rufus*, wildlife management.

The bobcat's (*Lynx rufus*) historic range extended from southern Canada to central Mexico (Hall and Kelson 1959). Early management programs afforded little protection and often included bounties (Hubert 1982, Phelps 1990, Stiver 1990) or predator control activities (Cain 1971, Melchior et al. 1987). Few changes occurred in the following decades. For example, Faulkner (1971) listed the bobcat as unprotected in 40 of the 48 conterminous United States and subject to bounties in 10.

Thirty-five states allowed the harvest of bobcats in 1976 (Deems and Pursley 1978), the same year a Presidential Executive Order created the Endangered Species Scientific Authority (ESSA) to oversee U.S. compliance with the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) (Johnson 1984). The ESSA's primary responsibility was to review applications for permits allowing the import or export of species listed in the treaty and determine whether trade was detrimental to their survival (Gluesing et al. 1986). Initially, information required by ESSA for a "no detriment" finding included population trends, harvest levels, distribution of harvest, and habitat evaluation (Gluesing et al. 1986, Rolley 1987). Few states could provide the information for bobcats, which were listed in Appendix II of the treaty and required a permit for export (Gluesing et al. 1986). This situation catapulted research and management activities (Dyer 1979, Berg 1990, Distefano 1990), as did rising fur prices and harvest levels (McCord and Cardoza 1982). For example, the average annual harvest of bobcats in the U.S. increased from about 10,000 in the 1950s and 1960s to 44,000 in the 1970s (Obbard et al. 1987) and peaked at >86,000 in 1979–80 (Novak et al. 1987).

This historical background is pertinent because research and management programs share a similar evolution and focus in most states. Ironically, many states that protected bobcats completely because of their rare status made comparatively little headway. Such was the case in Illinois, where bobcats were protected since 1972 (Illinois Revised Statutes 61, § 2.31). We describe recent efforts to upgrade Illinois' program, compare it to other states, and discuss some of the challenges and opportunities that lie ahead.

HISTORICAL STATUS AND MANAGEMENT OF BOBCATS IN ILLINOIS

Bobcats were common and distributed widely in Illinois during the 1700s and early 1800s (Cory 1912, Hoffmeister 1989). They declined dramatically by the mid-1800s because of habitat destruction and unregulated harvest during European settlement (Mohr 1943). Considered rare by the early 1900s, bobcats were thought to occur in only a few of the southernmost counties (Brown and Yeager 1943).

Little was known about the bobcat's status in the mid-1900s except for occasional records that confirmed their presence (Thom 1981). Illinois' Endangered Species Protection Board listed the bobcat as a state threatened species in 1977. The designation probably reflected a paucity of data on the bobcat's status rather than any compelling evidence it was "likely to become endangered in the wild in Illinois within the foreseeable future" as defined by the Illinois Endangered Species Protection Act (§520 Illinois Compiled Statutes 10/2). The listing afforded additional protection under state law (§520 Illinois Compiled Statutes 10/3), but it also split responsibilities for management between "game" and "non-game" interests. As elsewhere (Alverez 1994), this organizational barrier hampered progress in research and management activities.

RECENT MONITORING, RESEARCH, AND MANAGEMENT

Rhea (1982) compiled 89 reports of bobcat sightings from 52 counties during 1979–82. Few sightings were documented after Rhea's assessment (Herkert 1992), but anecdotal reports suggested that the bobcat's distribution and abundance increased during the mid- to late 1980s. This rekindled interest in the species' status. Early efforts to quantify observations began in the early 1990s and relied on existing data collection procedures. The Cooperative Wildlife Research Laboratory at Southern Illinois University at Carbondale later compiled this data and conducted field studies under a Federal Aid in Wildlife Restoration project. Objectives of the study, initiated in 1995, included: (1) determining the bobcat's relative abundance and distribution in Illinois, (2) mapping and estimating the area and relative quality of habitat types that support, or have potential to support, bobcat populations, and (3) developing criteria for assessing bobcat status in Illinois.

Standardized data on distribution and relative abundance were collected for the first time in 1991 as part of an Archer's Index. Hamilton et al. (1990) described the index, computed as the number of sightings per 1,000 hrs by archery deer hunters who volunteered to keep logs of their observations and activities. Sightings of bobcats were relatively infrequent and distributed unevenly, contributing to large confidence limits at sampling intensities adequate for other species (Ver Steeg and Warner 1997). While this limited our ability to detect annual changes in abundance, the method proved useful for monitoring long-term trends (Woolf and Nielsen 1999). For example, Hubert and Bluett (1999) reported a linear increase from 1992 (0.53 bobcat sightings/1,000 hrs) through 1998 (1.10 sightings/1,000 hrs).

We also collected sighting data from successful firearm deer and spring turkey hunters when they registered their kills at check stations. These sources provided 1,842 records during 1992–98 (Woolf et al. 2000). Sightings by successful firearm deer hunters were most common (n = 1,447), and increased from 0.35/1,000 hrs of effort in 1992 to 1.69/1,000 hrs of effort in 1998 (Woolf et al. 2000). Woolf and Nielsen (1999) noted that sightings by firearm deer hunters were a cost-effective way to monitor long-term trends in relative abundance but, like the Archer's Index, probably failed to provide an accurate measure of annual changes.

Sighting reports from archery and firearm deer hunters along with other sources were widespread, occurring in 99 of 102 counties (Gibbs 1998). Seventeen counties had >30 sightings from 1982 through 1998, considered indicative of a high resident population (Woolf et al. 2000). Thirteen of these counties were located in the southernmost portion of Illinois, 3 in the west-central part of the state, and 1 in extreme northwestern Illinois.

Two habitat models were constructed from sighting locations and digital landscape data. The first predicted presence or absence in a county based on proportion of woods, patch density of woods, and proportion of slope ≥18% (Woolf and Nielsen 1999). Another predicted the relative abundance of bobcats in a county using proportion of woods, proportion of slope ≥18%, and density of rural roads (Gibbs 1998). Outputs were consistent with independent sighting locations used for validation and suggested that bobcats occurred in moderate to high numbers in about 40% of the state (Woolf and Nielsen 1999). Habitat suitability models constructed with logistic regression predicted that 31% of Illinois offered good to excellent habitat distributed in a pattern similar to locations used for validation and that predicted by county-wide models (Woolf and Nielsen 1999). The models provided a resolution that was course (e.g., compared to those based on habitat preferences of radiocollared animals), but appropriate for planning and management activities, which are usually implemented at statewide or regional scales.

Radiocollared bobcats (n = 96) provided reliable information on movements, survival, social organization, and other demographics (Kennedy 1999, Woolf and Nielsen 1999). The project was continued in 1999 with the following new objectives: (1) estimate the number of bobcats living south of Interstate 64, (2) evaluate or develop population models capable of detecting changes in bobcat abundance and provide estimates of input variables, and (3) determine population genetics of bobcats in the central United States. We believe that this body of work will set a solid foundation for state and regional conservation efforts.

Bobcats were removed from Illinois' list of state threatened species in April 1999 (17 Illinois Administrative Code, Chapter I, Section 1010). They are currently protected by the Wildlife Code (§520 Illinois Compiled Statutes 5/2.2), which prohibits hunting and trapping of this species (§520 Illinois Compiled Statutes 5/2.30).

COMPARISONS WITH OTHER STATES

Woolf and Hubert (1998) reported that 10 states prohibited the harvest of bobcats in 1996. Pennsylvania will offer a limited harvest season in 2000–01 (V. Ross, Pennsylvania Game Commission, personal communication), leaving Illinois among a dwindling minority. Despite this distinction, many of our research and management objectives parallel those expressed by managers in other states (Table 1).

Lacking any direct measure of bobcat densities over large geographic areas, managers have turned to surveys and indices of abundance (Table 2). Validation and precision of these methods are as much a concern today as they were in the past (McCord and Cardoza 1982), so most states (94%) use ≥2 methods as recommended by Rolley (1987). Illinois' use of hunter/trapper surveys, sighting reports, and an archer's index is typical of the region. Methods used by adjacent states (IN, KY, WI, MO, IA) include sighting reports (n = 4), archer's indices (n = 2), employee opinions (n = 2), hunter/trapper survey (n = 1), scent station index (n = 1), road-kill survey (n = 1), sign/track survey (n = 1), and prey survey (n = 1) as well as methods linked directly to harvest (n = 5) (A. Woolf, unpublished data).

Table 1. Research and management needs identified by bobcat managers in the conterminous United States[a], 1996 (A. Woolf, unpublished data).

Rank	Research needs	Management needs
1	Reliable survey methods	Control harvest to better match geographic/temporal difference in abundance
2	Demographics (e.g., mortality, recruitment)	Monitor abundance
3	Distribution and abundance	Protect or improve habitat
4	Habitat availability and use	Improve public knowledge of and support for managemennt activities
5	Interactions with coyotes and other carnivores	Evaluate effectiveness of/need for federal oversight

[a]State agencies were surveyed as described by Woolf and Hubert (1998).

Table 2. Methods used to monitor the abundance of bobcats in the conterminous United States[a], 1996 (A. Woolf, unpublished data).

Method	No. of states
Hunter/trapper surveys	31
Harvest data (e.g., catch per hunter/trapper, pelt sales/ tagging)	26
Employee opinion	20
Sighting reports	19
Life table analysis	13
Computer population model	13
Archer's Index	8
Sign/track survey	8
Scent station survey	6
Prey survey	4
Spotlight survey	2
Landowner/rural mail carrier survey	2
Mark-recapture	1
Road-kill survey	1
Incidental catches	1
Bobcats taken by damage control agents	1
Summer roadside survey	1
Radiotelemetry and habitat mapping	1

[a]State agencies were surveyed as described by Woolf and Hubert (1998).

PERSPECTIVES ON MANAGEMENT

Monitoring the abundance of bobcats is a key activity and concern of managers in most states. Our research contributed little in the way of new approaches for accomplishing this task. However, we demonstrated similar long-term trends for independent results of the Archers Index and surveys of firearm deer hunters. Some critics might argue that neither method has been validated against populations of known size. We believe this expectation is unrealistic because estimating population size with methods like mark-recapture is neither practical nor appropriate for geographic scales best suited for comparisons (i.e., statewide or possibly by management zone, each of which encompasses >50,000 km^2).

While we are confident in the ability of these techniques to detect long-term, statewide trends in the relative abundance of bobcats, especially when used together or with other indices, we recognize that neither the Archers Index nor surveys of firearm deer hunters appear suitable for tracking local or annual fluctuations. Increasing our sample size to improve precision is not an option for surveys of successful firearms deer hunters because we presently collect data from all successful hunters when they register their kills (n = 95,608 in 1998). Mail surveys of unsuccessful hunters might be possible, but we suspect differences in timing and methodology would preclude the use of these data to augment those collected at check stations.

Hamilton et al. (1990) estimated sample sizes and costs needed to obtain specified levels of precision with the Archers Index. They concluded that desired levels of precision could be obtained for bobcats at the statewide level and in some, but not all, regions of the state. We suggest that a similar approach would be useful for determining whether data from Illinois, Indiana, and Missouri (Table 3) might collectively provide a more precise and cost-effective way to monitor annual changes in abundance than individual efforts. Other managers have noted apparent changes in abundance that occurred on large (i.e., multi-state) geographic scales (Fox et al. 1990), lending credence to the theory that cooperative efforts to monitor annual fluctuations and long-term trends might be meaningful as well as convenient.

One of the greatest changes in the past 20 years has been a fundamental shift in social and political attitudes toward our role as managers (Sparrowe 1995). Once viewed as a tenet in decision-making, good science has given way to greater public involvement (Decker and Chase 1997). Managers are now faced with international treaties (Hamilton et al. 1998), citizen-sponsored ballot measures (Minnis 1998), litigation (Olson 1995), legislation (The Wildlife Legislative Fund of America 1999), and public opinion (Andelt et al. 1999, Manfredo et al. 1999) as well as their traditional responsibilities. Based on research (Woolf and Nielsen 1999, Woolf and Heist 2000), which shows a widely distributed, increasing population currently at moderate densities (preliminarily, a minimum estimated density of 0.27 bobcats/km^2 in the southern part of the state), we believe that bobcats could sustain a limited harvest in Illinois. Implementing a harvest season is consistent with state statutes that authorize and encourage the Department of Natural

Table 3. Archer's Index for bobcats in Illinois, Indiana, and Missouri, 1992–98.

(No. bobcats sighted/1,000 hrs)			
Year	Illinois[a]	Indiana[b]	Missouri[c]
1992	0.53	0.30	2.92
1993	0.65	0.26	3.16
1994	0.40	0.43	3.36
1995	0.81	0.60	3.77
1996	0.80	0.88	4.09
1997	1.34	1.00	4.45
1998	1.10	0.89	4.36

[a]Hubert and Bluett (1999).
[b]L. Lehman, Indiana Department of Natural Resources, personal communication.
[c]Hamilton and Fantz (1999).

Resources to provide opportunities for regulated hunting and trapping (§520 Illinois Compiled Statutes 5/1.3, §20 Illinois Compiled Statutes 801/1-15). However, we decline to speculate on the outcome of such a proposal in a legislative forum that can be influenced as much or more by public policy than biological integrity.

Forest cover types are an integral part of the bobcat's ecology in Illinois (Gibbs 1998, Woolf and Nielsen 1999, Woolf and Heist 2000). These habitats have increased by 41% since 1926 (Illinois Department of Energy and Natural Resources 1994), and currently comprise about 1.6 million ha, or 11.3% of the state (Illinois Department of Natural Resources 1996). While classified as wetlands, bottomland forests and swamps comprise an additional 328,000 ha (Illinois Department of Natural Resources 1996). The density of forest cover types is greatest in the southern part of the state and along the Illinois and Mississippi rivers (Illinois Department of Natural Resources 1996), especially where poor soils and steep terrain discourages land use like agriculture (Roseberry and Woolf 1998). Large (>200 ha) tracts of forest are rare in Illinois (Holland et al. 1972), leading Robinson (1991) to characterize forest tracts as "small, isolated, and dominated by edge habitats." Ownership is mostly private (>90%), and comprised of small ($\bar{x}$ = 8.6 ha) parcels (Iverson 1991) maintained predominantly for recreation or aesthetics (Young et al. 1984, Hubert et al. 1999).

Direct loss of habitat is not an immediate concern because recent trends show stable to slightly increasing amounts of forest cover (Iverson et al. 1989). Some emerging issues that might affect habitat suitability include the spread of exotic, invasive species, residential development, and changes in dominant cover types (Illinois Forestry Development Council 1999). Maples (*Acer* spp.) and other shade-tolerant species are replacing traditional oak-hickory (*Quercus-Carya*) communities, especially on mesic sites (Ebinger 1986, Nelson and Sparks 1998). This conversion has been dramatic, with a 41-fold increase in the acreage of maple forests since 1962 (Illinois Department of Energy and Natural Resources 1994). Probable causes include fire suppression and inadequate use of silvicultural practices needed for regeneration of oaks (Parker 1989, Abrams 1992, Roovers and Shifley 1997, Larson et al. 1999).

Many ecologists (e.g., Graber and Graber 1976) consider maple forests less suitable for wildlife than oak-hickory communities. While we agree and encourage more active management of Illinois forests to maintain their productivity and diversity, we recognize that our position is not supported by any direct evidence that prevailing trends are detrimental to bobcats. Studies in forested landscapes suggest that a diversity of tree species and age classes is beneficial for bobcats, mainly because prey availability is greatest in heterogenous habitats (Hall and Newsom 1978, Miller 1980, Hamilton 1982, Rolley and Warde 1985, Leopold et al. 1995). We hesitate to apply these findings directly to a landscape characterized by small tracts (< 50 ha) of forest cover. For example, conversion of oak-hickory communities to those dominated by maples might have a negligible effect on bobcats if forest cover is more important structurally than for prey, which bobcats obtain in nearby grasslands and agricultural fields. Experimental application of silvicultural practices (e.g., controlled burning, timber stand improvement, group or shelterwood harvest systems) and long-term, broad-based monitoring of responses by flora and fauna, including animals at high trophic levels like the bobcat, would help to resolve this uncertainty and guide public policies on management of fragmented forests.

Illinois' bobcat management program is a work in progress. To date, we have established the bobcat's range, relative abundance, and habitat distribution in the state. Ongoing research will provide modeling capabilities that incorporate estimates of the bobcat's density and demographics in the southern part of the state. Collectively, this information exceeds legal and professional standards previously proposed for management of bobcats (Gluesing et al. 1986, Mech 1978). Our efforts yielded little in the way of new strategies or tools for managing bobcats, but we are encouraged by the possibilities of cooperative efforts to monitor their relative abundance in the lower Midwest. Given a stable to increasing population and habitat base, the prospects for a regulated harvest appear good from a biological perspective. However, such a proposal is likely to be controversial and its outcome will be determined in public forums that preclude a forecast. Sentiments expressed by Leopold (1933:vii) seem relevant given recent attempts to prohibit the harvest of bobcats in his home state of Wisconsin (Olson 1995), "The conservation movement has sought to restore wild life by the control of guns alone, with little visible success. Management seeks the same end, but by more versatile means."

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STATUS AND MANAGEMENT OF BOBCATS IN PENNSYLVANIA

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Abstract: Bobcats (*Lynx rufus*) were widely harvested in Pennsylvania prior to their protection in 1970. During the past 30 years, bobcat populations have expanded geographically and numerically throughout the state and hunters and trappers have expressed interest in participating in a limited bobcat harvest season. The Pennsylvania Game Commission has conducted intensive research and monitoring programs since 1985 designed to assess habitat relationships and availability and detect changes in bobcat distribution and relative population levels. A recent assessment of harvest feasibility suggested a limited number of bobcats could be harvested from high density regions while maintaining stable to increasing bobcat populations. Current monitoring and harvest management procedures are discussed.

Key words: bobcat, distribution, harvest, *Lynx rufus*, population monitoring.

Public attitudes concerning predators and the management of the bobcat (*Lynx rufus*) in Pennsylvania have changed dramatically during the last century. Bobcats and other predators were considered vermin in the 1700s and 1800s. As early as 1819 a $1 bounty was established to promote the harvest of bobcats in the commonwealth. This bounty was increased to $15 during 1916 and >7,000 bobcats were killed for bounty during 1916–37 (Fig.1). A realization that bounties were ineffective for controlling predator populations resulted in the removal or reduction of bounties on many predators. The bounty was removed from bobcats in 1937, but they remained unprotected and were widely harvested until classified as a game animal in 1970. This reclassification occurred in response to concerns for bobcat populations and was implemented to allow populations to expand throughout the commonwealth. Reclassification empowered the Pennsylvania Game Commission (PGC) to set regulations to manage bobcat populations. There was no legal harvest of bobcats in Pennsylvania during 1970–99.

During the past 15 years, Pennsylvania trappers and hunters have witnessed dramatic geographic and numeric expansion of bobcat populations and have continually requested PGC to assess harvest feasibility. Sixty percent of 2,056 licensed furtakers surveyed during 1994 indicated they would like to participate in a regulated bobcat harvest season (Lovallo 2000). During this period, the PGC conducted intensive field research to assess factors affecting bobcat density and distribution, and implemented surveys and carcass collection programs to monitor distribution and to assess population characteristics. Here, I summarize information contained in a recent version of PGC's bobcat management plan (Lovallo 2000). Annual management, research, and harvest recommendations have focused on the PGC bobcat management goals to maintain, conserve, and promote sustainable bobcat populations in regions of Pennsylvania that provide suitable habitat conditions and to provide recreational opportunities for consumptive and non-consumptive users of bobcats (Lovallo 2000).

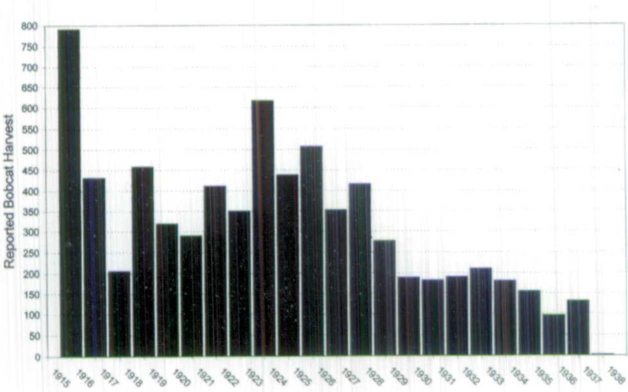

Fig 1. Numbers of bobcats harvested for bounty in Pennsylvania during 1916–38.

During April 2000, the PGC board of commissioners approved a highly regulated and limited bobcat harvest season to be conducted in select regions of the commonwealth. This bobcat hunting and trapping season provided Pennsylvanians with their first opportunity to harvest a bobcat in the state since 1970. Herein, I summarize survey data and research results as they relate to the assessment of bobcat harvest feasibility.

DISTRIBUTION

The geographic range of bobcats includes most of the contiguous United States, with the exception of major agricultural regions of the Midwest, and Mexico (Anderson 1987). Pennsylvania's bobcat population is important regionally as it provides a critical link between established populations in New York to those of West Virginia, Virginia, and southern Ohio. Recent reports of bobcat abundance and distribution in Pennsylvania suggest that established populations extend throughout the northern, central, and southwest regions and that the range of established populations has increased since 1970 (Giles 1986, Merritt 1987, Lovallo 1999) (Fig. 2).

POPULATION STRUCTURE

Because there was no legal harvest of bobcats in Pennsylvania during 1970–99, the majority of PGC's data regarding population structure came from vehicle-caused bobcat mortalities. The sex ratio of bobcats collected in Pennsylvania due to bobcat-vehicle mortalities during

Fig. 2 Wildlife Conservation Officer estimates of bobcat distribution and population status in Pennsylvania during 1998.

1986–1999 was 1:1, whereas sex ratio estimates from harvested bobcat populations typically show a preponderance of males (Anderson 1987).

The proportion of yearlings in a bobcat population is closely related to the intensity of harvest and may result from high reproduction or high adult mortality (Anderson 1987). In harvested populations, the percentage of yearlings in the harvest sample generally exceeds 50% and may reach 76% in areas of relatively low bobcat density and high harvest pressure (Fredrickson and Rice 1979). Lembeck and Gould (1979) estimated 16% yearling composition in an unharvested population in California, compared to 43% yearlings in a harvested population occurring in similar habitats. Analyses of the age distribution of Pennsylvania's bobcat population suggest that <20% of the bobcat population are yearlings (Fig. 3). Age distributions for males and females were similar. Age-distribution data and the occurrence of older individuals (>10 yr) in the population are consistent with that of an unharvested population.

MORTALITY

The primary cause of bobcat mortality, in both harvested and unharvested populations, is usually human-related (Anderson 1987). Predation, from coyotes (*Canis latrans*), wolves (*Canis lupus*), and mountain lions (*Felis concolor*) has been reported, but is rare. Instances of cannibalism have also been reported (Gashwiler et al. 1961, Litvaitis et al. 1984), and several studies reported bobcat mortalities resulting from porcupine quills (Fuller et al. 1985). Bobcats are susceptible to a variety of diseases including rabies and panleukopenia (feline distemper). Fox (1982) reported that panleukopenia may be a significant mortality factor for bobcats in southern New York. Although cases of rabies and panleukopenia have been documented in Pennsylvania, the impact of disease on the bobcat population is unknown. During the past 30 years, vehicle collisions were likely the primary source of bobcat mortality in Pennsylvania. The majority of vehicle-caused bobcat mortality occurred during September through November (Lovallo 1999).

Age-distribution data from road-killed bobcats in Pennsylvania suggest that adult survival rates range from 50–87% until age 5 when survival increases to greater than 80% and remains constant (Fig. 3). Annual estimates of adult survival typically range from 50–70% in harvested populations (Anderson 1987). Because survival estimates are often calculated from harvest-related data, there are very few reports from unharvested populations. However, Bailey (1974) reported 97% annual survival in an unharvested population in Idaho.

There is evidence of sex-related differences in survival in harvested bobcat populations; male survival is generally lower than females, particularly during the first

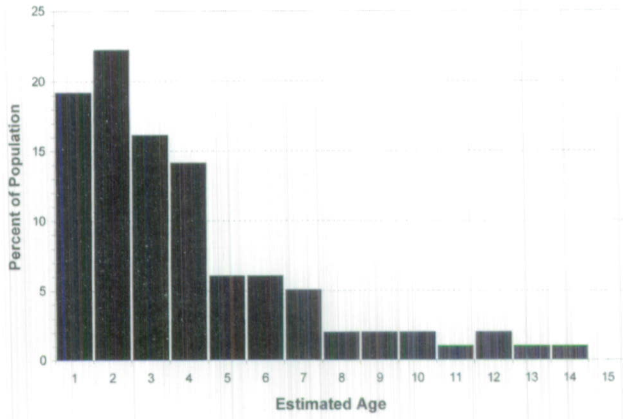

Fig. 3. Estimated age distribution of bobcats in Pennsylvania during 1986–99.

several years. Males may be more susceptible to human-related mortality because of their extensive movements and larger home ranges. Knick (1990) found the proportion of males in the harvest increased throughout the harvest season and attributed this to increased movement by males prior to breeding. The 1:1 sex ratio observed for vehicle-caused bobcat mortalities in Pennsylvania did not suggest that sex-specific differential mortality is occurring.

POPULATION MODELING

The PGC developed a bobcat population model to project population growth and to assess the potential impact of regulated harvest. Age-specific survival and fecundity were estimated from field research studies in Pennsylvania or from available bobcat literature. When a range of parameter estimates was available, the most conservative estimate was used (e.g., low survival and fecundity).

Initial population estimates (population size at time 0) were determined from habitat suitability estimates (Table 1), analyses of potential female home ranges, and statewide distribution data based on surveys of field personnel, incidental captures, and vehicle-caused bobcat mortalities. The model considered a maximum 80% occupancy rate of suitable habitats within potential female home ranges in areas (i.e., Wildlife Conservation Officer districts) known to support established bobcat populations . Based on these methods, we determined an initial population size of 3,156 adult resident bobcats. Initial estimates of population size were conservative; the PGC has substantial evidence (observations, vehicle-caused mortalities, and incidental captures) that bobcats currently occupy habitats beyond the geographic extent identified in these analyses.

Age-specific survival rates for adult bobcats were estimated from age distribution data collected from vehicle-caused bobcat mortalities (Crowe 1975). The population model used a 33% survival rate for juveniles. This rate was based on values in the literature and is thought to be very conservative for an unharvested population. Age-specific fecundity was estimated from available literature on litter size and pregnancy rates. The bobcat population model used a 65% pregnancy rate and a mean litter size of 1.5 kittens for yearling bobcats (<2 yr) and an 80% pregnancy rate and mean litter size of 2.5 kittens for adult bobcats (≥2 yr).

The population model incorporated stochastic parameters to develop confidence intervals for model projections. The model used a coefficient of variation to express the variation of vital parameters. The coefficient of variation was based on a standard deviation of ±5% of parameter estimates. The model also considered demographic stochasticity (variations in sex ratios and age distributions) in model output. The model was replicated 500 times to assess stochastic effects.

The population model indicated that Pennsylvania's bobcat population is increasing at an annual rate of ≥4–6%. The population model assumed no compensatory (density-dependent) response to increased mortality due to harvest although the potential for a compensatory response exists. Also, the model considered harvest mortality to be 100% additive to other causes (e.g., vehicle-caused mortalities). Simulated effects of varying harvest levels on population growth indicated that a harvest of <220 adult bobcats would result in stable to increasing populations. These procedures served as the analytical basis for the establishment of an annual harvest objective of 175 bobcats during initial seasons.

Table 1. Predicted area (km^2) of suitable habitat for male and female bobcats and percent composition of female habitat and potential female home range area (km^2) within Pennsylvania Game Commission Furbearer Management Units in Pennsylvania.

		Suitable habitat				
Unit	Unsuitable habitat	Male only	Male and female	Female only	Total female(%)[a]	Potential female home range area (%)[a]
1	7,378	1,767	1,313	165	1,478 (12)	1,019 (8)
2	12,253	5,257	4,575	523	5,099 (18)	7,952 (29)
3	7,946	3,127	3,263	426	3,689 (20)	6,851 (37)
4	17,787	4,324	3,625	576	4,201 (14)	2,427 (8)
5	12,765	4,159	3,584	604	4,188 (17)	5,888 (23)
6	16,381	2,799	2,204	497	2,701 (11)	2,137 (9)

[a]Percent of Furbearer Management Unit.

POPULATION MONITORING

Survey of Wildlife Conservation Officers

The PGC used a combination of mail surveys and field methods to monitor the range of established bobcat populations and to assess bobcat population trends. For law enforcement efforts, 67 Pennsylvania counties are divided into 135 Wildlife Conservation Officer (WCO) districts. The Furbearer and Farmland Wildlife Section of the Bureau of Wildlife Management surveys WCOs periodically concerning evidence relating to the status, distribution, and population trends of bobcats in their respective districts. The survey is mailed to WCOs after trapping seasons to insure that incidental captures attributed to trapping are reported. In districts where WCOs were relatively new, they were advised to request information from the previous WCO or from WCOs in surrounding districts.

During the most recent survey (1998), bobcat populations were reported as stable within 59 districts (49%), increasing within 36 districts (30%), and declining in 1 district (<1%). Nineteen of 35 districts in northcentral and northeastern regions (Furbearer Management Zones 2 and 3) reported increasing bobcat populations. (Fig. 4)

Vehicle-caused Mortalities

Wildlife Conservation Officers use a standardized kill report form to provide information on observed bobcat mortalities (e.g., vehicle-caused, illegal harvest, disease). When possible, carcasses are collected and examined to determine sex and age and to estimate productivity. The PGC uses a 3-year running average to monitor changes in the number of vehicle-caused mortalities (Fig. 5). A running average approach is used to temper effects of WCO position vacancies. There has been a steady increase in the number of reported vehicle-caused mortalities each year since this effort began in 1986.

Game Take Surveys

The PGC uses a mail survey to poll approximately 2% of licensed hunters and 10% of licensed furtakers to assess hunter and trapper effort and to estimate harvest rates. During recent years, furtakers were asked to report the number of bobcats captured incidentally in traps set for other furbearers. There has been a general increase in the numbers of bobcats captured and released during 1990 to present (Table 2). If the number of bobcats captured per trapper is extrapolated to all licensed trappers, these surveys suggest that since 1994 trappers captured and released from 460 to >1,000 bobcats annually.

Winter Track Counts

The PGC has developed a winter track survey that will be conducted by cooperators along fixed survey routes in Furbearer Management Zones 2, 3, and 5 beginning during 2000–01. Pilot projects of winter track counts were initiated in northeastern Pennsylvania during 1999 to train personnel and to develop effective protocols for statewide survey implementation. Pennsylvania Game Commission staff detected bobcat tracks along each route surveyed and encountered 17 unique sets of bobcat tracks during 4 pilot surveys. The mean detection rate was 0.27 tracks/km surveyed. Bobcat detection rates for each of the 4 surveys were: 0.25, 0.13, 0.19, and 0.50, respectively. For comparison, mean detection rates for coyote, fisher (*Martes pennanti*), and gray fox (*Urocyon cineroargenteus*) were 0.17, 0.08, and 0.03, respectively.

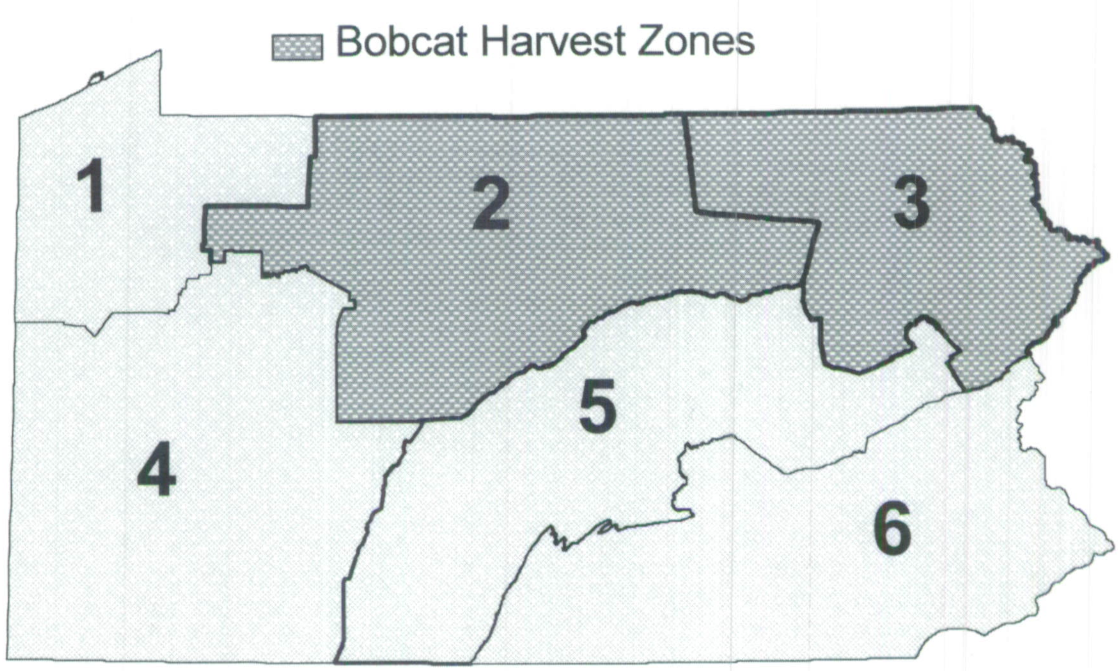

Fig. 4. Furbearer management zones and year 200 bobcat harvest zones in Pennsylvania.

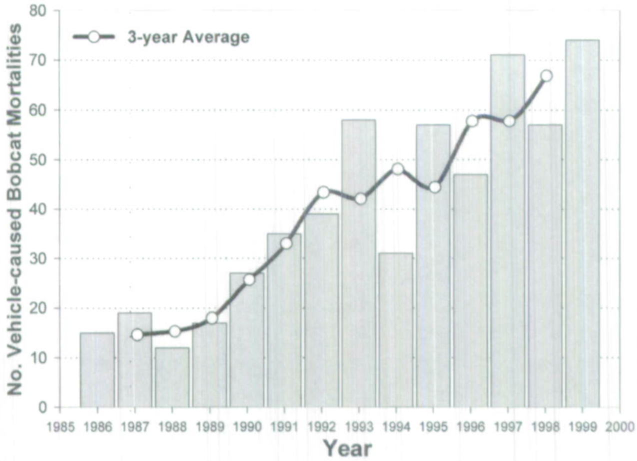

Fig. 5. Reports of vehicle-caused mortalities in Pennsylvania during 1986–99.

HARVEST REGULATION

During April 2000, the PGC adopted a permit-based quota system to regulate the harvest of bobcats by hunters and trappers in the commonwealth. Under this system, the annual permit allocation was to be determined annually as the product of the harvest success rate (estimated from the previous year) and a harvest objective based on habitat assessment, annual evaluation of abundance indices, and annual refinements to the bobcat population model. An initial 2000–01 permit allocation of 290 permits was based on a harvest objective of 175 bobcats and a conservative 60% estimate of harvest success by permit holders. During the 2000–01 hunting and trapping seasons, harvest was restricted to Furbearer Management Zones 2 and 3 in northcentral and northeastern Pennsylvania. The daily possession limit and season bag limit was set as 1 bobcat by permit only. Because bobcats are regularly captured incidentally in traps set for other legal furbearers and because participation was limited by permit allocation, the bobcat harvest season was set concurrent with coyotes, foxes, opossums, raccoons, skunks, and weasels (mid-Oct to mid-Feb).

Applicants for 2000–01 bobcat harvest permits were required to purchase a furtaker license and to submit a $5 non-refundable application fee. A total of 3,274 applications were received and 290 permits were randomly allocated by public drawing during early September 2000. The PGC included a survey on the application form to assess hunter and trapper characteristics. Eighteen percent of applicants indicated that this was the first year they had purchased a furtaker license and 12% indicated they had bought a furtaker license primarily to apply for a bobcat permit. When asked to report their intended method of harvest, 63% indicated they would employ trapping, 55% indicated predator calling techniques, and 6% indicated hunting with dogs. Twenty-eight percent indicated they had experience hunting or trapping bobcats in other states or had experienced incidental bobcat captures in Pennsylvania.

Successful permit applicants received a bobcat harvest permit and a carcass tag to be attached to the bobcat immediately upon possession. Under current regulations, this tag must remain attached to the bobcat until the pelt is sealed by a commission representative prior to 10 days after the season close. Sealing consists of application of a permanent locking PGC pelt tag as well as a CITES export tag (the PGC received CITES export status for bobcat during October 2000). All bobcat carcasses are currently being collected for research purposes and will be used to refine reproductive estimates and to assess harvest effects.

REGIONAL AND ECONOMIC SIGNIFICANCE

The conservation and management of Pennsylvania's bobcat population is of interest to hunters, trappers, and non-consumptive users alike. Bobcats are a highly regarded carnivore and represent the essence of wilderness for many people. Because bobcats are secretive predators and are rarely observed in the wild, seeing a bobcat in Pennsylvania's forests heightens the wilderness experience sought by outdoor enthusiasts (e.g., hikers, bird watchers, campers).

Table 2. Numbers of incidental bobcats captured and released as estimated by the Pennsylvania Game Commission Furtakers Survey.

Year	No. survey respondents	No. furtaker licenses sold	No. bobcats released	Projected no. bobcat captures
1990–91	2,302	20,377	40	354
1991–92	2,361	20,215	24	205
1992–93	1,652	20,345	26	320
1993–94	2,175	19,246	16	142
1994–95	2,056	21,905	101	1,076
1995–96	2,181	21,840	46	460
1996–97	2,363	25,636	62	673
1997–98	2,233	27,413	46	565
1998–99	2,466	25,877	108	1,133
1999–2000	1,557	17,414	62	693

Bobcat depredation on pets or livestock is uncommon in the northeastern U.S., but there have been reports of depredation on domestic cats and poultry. In the western U.S., bobcat depredation is thought to comprise <10% of all livestock losses (Virchow and Hogeland 1994). Bobcat harvests in North America produce up to 28,000 pelts annually valued at approximately $820,000. Approximately 3,200 bobcats, valued at $75,000, are harvested annually in the northern U.S. and upper Midwest. Bobcat pelts are used for coats, trim, and accessories, with the spotted fur of the belly being most valuable. Many hunters and trappers have indicated they would mount via taxidermy or tan the pelt of the first legal bobcat they harvest.

CONCLUSIONS

Bobcat populations in Pennsylvania have persisted and prospered under a wide spectrum of management approaches over the past century. These approaches included unlimited harvest prior to 1970 (a period of population declines), complete protection during 1970–99 (a period of geographic and numeric population expansion), and highly limited and regulated harvest beginning in 2000. Recent assessments of harvest feasibility suggest that a limited number of bobcats can be harvested while maintaining stable to increasing bobcat populations on a statewide basis. The PGC has adopted a conservative approach to harvest implementation and is continuing efforts to monitor trends in bobcat distribution and relative density.

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I thank the many biologists, Wildlife Conservation Officers, and volunteers who participated in the research described in this report. In particular we thank Jack Giles, who coordinated bobcat field research during 1985–97. Bobcat habitat suitability models resulted from a cooperative effort among the Pennsylvania Game Commission, The School of Forest Resources at The Pennsylvania State University, and The Pennsylvania Cooperative Fish and Wildlife Research Unit.

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ABSTRACTS

CHANGES IN SPACING PATTERNS WITH INCREASING POPULATION DENSITY OF AN INSULAR REINTRODUCED BOBCAT POPULATION

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Abstract: We reintroduced bobcats (*Lynx rufus*) to Cumberland Island, Georgia, USA, and monitored their spacing patterns as we increased population density. In 1988 we introduced 14 bobcats, and in 1989 we reintroduced an additional 17 bobcats. During 1989–91, bobcat densities increased from 0.13 to 0.35 bobcats/km^2. We used the delta statistic (average distance between all possible pairs of locations) as a measure of home range size. For bobcats reintroduced in 1988, we found no trends in annual home range size over years ($P = 0.28$), but male home ranges were larger than female home ranges ($P = 0.01$). For bobcats reintroduced in 1989, we detected little evidence of a trend in home range size ($P = 0.07$) and no difference between sexes ($P = 0.75$). An index to intrasexual home range overlap indicated no change in home range overlap among bobcats reintroduced in 1988 ($P = 0.29$); however, the index showed a decline in home range overlap among bobcats reintroduced in 1989 ($P < 0.01$). We found that bobcats exhibited spacing patterns consistent with a prior-rights land tenure system, but they did not maintain exclusive home ranges. Consequently, we had no evidence that exclusive home ranges could serve as a mechanism to regulate population size.

DEER HERD TRENDS, BOBCAT FOOD HABITS, AND VEGETATION CHANGE OVER 18 YEARS ON CUMBERLAND ISLAND, GEORGIA

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Abstract: We released bobcats (*Lynx rufus*) on Cumberland Island National Seashore during 1988 and 1989 to restore an extirpated predator to the island. We monitored prey abundance and use during 1988–90. During 1997–98, we repeated the prey use surveys. We also analyzed white-tailed deer (*Odocoileus virginianus*) harvest data collected during 1980–97, repeated deer abundance surveys, and repeated measurements of live oak (*Quercus virginiana*) recruitment at plots established in 1985. During 1988–90, white-tailed deer comprised 20–38% of the seasonal diet of bobcats. During 1997–98, white-tailed deer comprised only 7–31% of bobcats' diets. Deer abundance indices decreased after the reestablishment of bobcats on Cumberland Island, and eviscerated weights of all deer age-sex classes except yearling females increased. After no significant change in height during 1986–89, mean oak sprout heights doubled between 1989 and 1997, and sprout densities increased. Our results are consistent with the hypothesis that predation by bobcats on white-tailed deer caused a decline in deer densities on Cumberland Island, which resulted in increased deer size and a release of vegetation from browsing pressure.

AUTHOR BIOGRAPHICAL SKETCHES

Bobcat research and management: have we met the challenge?

ALAN WOOLF is the director of the Cooperative Wildlife Research Laboratory (CWRL) and a professor of zoology at Southern Illinois University at Carbondale. He received his B.S. degree from Cornell University, his M.S. degree from Colorado State University, and returned to Cornell for his Ph.D. Alan's research interests are varied, but his professional emphasis centers around graduate programming, research, and education. He has served the CWRL for the past 21 years and has been director since 1987.

CLAY NIELSEN is a post-doctoral research fellow at the Cooperative Wildlife Research Laboratory at Southern Illinois University at Carbondale, where he received his Ph.D. studying habitat use and population dynamics of bobcats. Clay received his B.S. in Natural Resources at the University of Nebraska-Lincoln and his M.S. in Environmental and Forest Biology at State University of New York, College of Environmental Science and Forestry. Clay recently co-founded a consulting business called Holterra Wildlife Management that provides communities with management plans for wildlife.

Multivariate models of bobcat habitat suitability for Pennsylvania landscapes

MATTHEW J. LOVALLO is furbearer biologist with the Pennsylvania Game Commission. Matt received a Ph.D. in Wildlife and Fisheries Science at The Pennsylvania State University where his doctoral work addressed the use of remotely sensed data and geographic information systems to model bobcat habitat suitability in Pennsylvania.

GERALD (Jerry) L. STORM (retired) is a former wildlife biologist with the Biological Resources Division, USGS, and the U.S. Fish and Wildlife Service, and Adjunct Associate Professor of Wildlife Managementt at The Pennsylvania State University. He received a Ph.D. in Ecology from the University of Minnesota. His research interests are in wildlife and habitat interactions and linkages between landscape use and conservation of biotic resources.

DAVID KLUTE is currently Assistant Non-game Migratory Bird Coordinator for the USFWS in Denver. He received a Ph.D. from The Pennsylvania State University, an M.S. from Kansas State University, and a B.S. from the University of Missouri. His interests include avian conservation and management and the incorporation of spatial dependence into habitat models.

WALTER TZILKOWSKI has been a Professor of Wildlife Science at The Pennsylvania State University since 1978. Dr. Tzilkowski teaches wildlife management, population dynamics, and biometrics.

Impacts of reestablished fishers on bobcat populations in Wisconsin

JONATHAN GILBERT is Wildlife Section Leader with the Great Lakes Indian Fish and Wildlife Commission in Wisconsin. Jonathan received his B.A. from Washington and Jefferson College, his M.S. from Michigan State University, and his Ph.D. in Wildlife Ecology from the University of Wisconsin-Madison. He has been an active member of The Wildlife Society since 1977.

LLOYD B. KEITH is Professor Emeritus, Department of Wildlife Ecology, University of Wisconsin-Madison. Dr. Keith has had a long and distinguished career working primarily with snowshoe hares in boreal forest ecosystems. He and his students have published numerous articles detailing the population dynamics of cyclic hare populations and the predators that depend on them.

Spatial resource overlap of bobcats and gray foxes in urban and rural zones of a national park

SETH RILEY grew up in Washington, D.C., and began working in wildlife biology there in 1987 at the National Park Service's Center for Urban Ecology. He received his B.A. in Human Biology with a concentration in Animal

Behavior and Ecology from Stanford University in 1988. He worked as a wildlife biologist at the Center for Urban Ecology from 1988–90, studying raccoon population and disease ecology, raccoon family relationships, and other urban wildlife issues including white-tailed deer impacts on vegetation. He attended graduate school at the University of California-Davis and received his Ph.D. in Ecology in 1999, conducting dissertation research on the ecology of bobcats and gray foxes in urban and rural zones of Golden Gate National Recreational Area. He then worked as a post-doctoral researcher in population genetics at University of California-Davis, studying hybridization between native and introduced tiger salamanders. He is currently with the National Park Service as the wildlife ecologist at Santa Monica Mountains National Recreational Area in southern California. He continues to be interested in urban wildlife ecology and the ecology and conservation of mammalian carnivores and reptiles and amphibians.

Bobcat habitat use relative to human dwellings in southern Illinois

See Nielsen and Woolf bios above...

Spatio-temporal relationships among adult bobcats in central Mississippi

MICHAEL J. CHAMBERLAIN is an Assistant Professor within the School of Forestry, Wildlife, and Fisheries at Louisiana State University. He received his Ph.D. in Forest Resources at Mississippi State University (MSU), an M.S. in Wildlife Ecology from MSU and a B.S. in Forestry and Wildlife Science from Virginia Tech. His research interests include upland avian ecology and management, influences of forest management on wildlife communities, predator-prey relationships, carnivore population ecology, and GIS applications to natural resource management. Mike currently serves as an Associate Editor for The Wildlife Society Bulletin and is faculty advisor for the Louisiana State University chapter of The Wildlife Society.

BRUCE D. LEOPOLD received his B.S. from The Pennsylvania State University in 1977 in Forest Science, his M.S. from Mississippi State University in 1979, and his doctorate in Wildlife Ecology in 1984 from the University of Arizona. Currently, Bruce holds the title of Sharp Professor Wildlife Ecology in the College of Forest Resources at Mississippi State University. Bruce's research interests include predator-prey relationships, habitat management and quality assessment, wildlife biometry, population ecology, wildlife population monitoring, and forest-wildlife management.

Multivariate habitat models for bobcats in southern forested lanscapes

MIKE CONNER recieved his B.S. at the Univeristy of Tennessee-Martin and his M.S. and Ph.D. at Mississippi State University. Upon finishing his dissertation work, he became assistant professor at Arkansas Technical University. Mike is currently an assistant scientist at the Joseph W. Jones Ecological Research Center, where he studies predator ecology and forest-wildlife realtionships.

See Leopold and Chamberlain bios above...

Utlity of bobcat observation reports for documenting presence of bobcats

MARIE KAUTZ has worked over 20 years for the New York State Department of Environmental Conservation (NYSDEC), specializing in furbearer management for the last 7. She completed her B.S. in Wildlife Science at Cornell University and received an M.S. in Wildlife Biology from Colorado State University.

CHARLES "Buzz" DEVAN received his B.S. in Wildlife Management from the College of Environmental Science and Forestry at Syracuse University in 1969 and has worked for NYSDEC since 1972, specializing in wetland biology, waterfowl, furbearers, and land management. He is currently leader of the NYSDEC Bureau of Wildlife Land Management team.

BILL SHARICK graduated from Cornell University and has also been with the NYSDEC since 1972. He has spent most of his career working with waterfowl and furbearers. He is married with two children and his hobbies include trapping amd waterfowl and turkey hunting.

Evolution of Wisconsin's bobcat harvest management program

ROBERT E. ROLLEY is a wildlife population ecologist with the Wisconsin Department of Natural Resources. His responsibilities include research and consultation on the population ecology of Wisconsin wildlife, especially ungulates and furbearers, monitoring wildlife population trends, and modeling population response to management strategies. He previously (1983–92) worked as a wildlife biologist for the Indiana Division of Fish and Wildlife. He graduated in 1977 with a B.S. from the University of California at Davis and he received his M.S. from the University of Wisconsin-Madison (1979) and his Ph.D. from Oklahoma State University (1983).

BRUCE E. KOHN received his B.S. and M.S. degrees in Wildlife Management from the University of Minnesota. He has been employed as a research biologist for the Wisconsin Department of Natural Resources since 1970. Most of his research has involved developing and improving population monitoring and harvest programs for furbearers, bears, and wolves.

JOHN F. OLSON graduated from University of Wisconsin-Stevens Point with a B.S. in Wildlife Management in 1973. He worked with the Wisconsin Department of Natural Resources Forest Management and Wildlife Management programs in northern Wisconsin becoming the Forest Habitat Coordinator for northwestern Wisconsin in 1978. From 1979 to 1989, he was a field wildlife biologist for the WDNR located in northern Wisconsin with special emphasis on forest habitat and endangered species. From 1990 to 1993, he was an area wildlife supervisor in southwestern Wisconsin. In 1994, he became the Treaty Wildlife Biologist and in 1995 the statewide WDNR Furbearer Specialist.

Perspectives on bobcat management in Illinois

ROBERT D. BLUETT has worked for the Illinois Department of Natural Resources since 1989 and supervised its furbearer program since 1993. Program responsibilities include oversight of nuisance wildlife control activities, coordinating furbearer research and restoration, monitoring furbearer populations and harvest levels, and recom mending appropriate regulations for fur hunting and trapping. Bob received his B.A. in Biology from Ripon College and M.S. in Wildlife Management from the University of Wisconsin-Stevens Point. He is a certified Wildlife Biologist and served as president of the Illinois Chapter of The Wildlife Society from 1997 to 1998.

GEORGE F. HUBERT, JR. has been a wildlife biologist with the Illinois Department of Natural Resources' Fur bearer Program for 24 years and an affiliate research scientist in the Center for Wildlife Ecology, Illinois Natural History Survey, for 10 years. He has an M.S. in Wildlife Biology from Colorado State University and is a certified Wildlife Biologist. George's current professional interests include the ecology and management of furbearers, trap technology, and public outreach associated with fur hunting and trapping.

See Woolf bio above...

Status and management of bobcats (*Lynx rufus*) in Pennsylvania.

See Lovallo bio above...

NOTES

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