SELECTION OF WINTER HABITAT BY BOBCATS (*LYNX RUFUS*) ON THE QUABBIN RESERVATION, MASSACHUSETTS

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ABSTRACT.—Selection of winter habitat by bobcats (*Lynx rufus*) was studied by trailing during winter on the Quabbin Reservation, Massachusetts. A selection index was obtained for 13 cover types by comparing the per cent of kilometers traveled in a cover type with its per cent occurrence. Roads, cliffs, spruce plantations, and hemlock-hardwoods had the highest index values. Information on prey abundance and distribution, food habits, hunting and feeding methods, snow avoidance behavior, and general environmental conditions were used to explain selection in each cover type.

This paper describes selection of winter habitat by *Lynx rufus* and identifies the important factors of selection in different cover types. Habitat preference of bobcats has never been intensively studied, but these cats generally inhabit broken country with some dense cover, conifer stands, and rocky ledges (Seton, 1929; Rollings, 1945; Pollack and Sheldon, 1951; Erickson, 1955; Young, 1958). Rollings (1945) thought prey abundance, protection from severe weather, availability of rest shelters, dense cover, and freedom from disturbance were the important factors in habitat selection.

About half of the data I present here are from cats of known sex and age that I had radio-collared (10 cats) and toe-clipped (eight). Immature and mature individuals of both sexes were followed.

STUDY AREA

The study was conducted on the Prescott Peninsula, Quabbin Reservation, Franklin Co., Massachusetts. The Quabbin Reservation was closed to public use in 1936 when the area (352 square kilometers) was being developed as a water reservoir for metropolitan Boston. All buildings were removed and most of the old pastures and cultivated farm lands were planted to white pine (*Pinus strobus*), red pine (*Pinus resinosa*), and Norway spruce (*Picea abies*). The area is transected with dirt roads.

Prescott Peninsula (60 square kilometers) extends south 16 kilometers into the center of the reservoir. The peninsula ranges in width from 1.6 to 4.8 kilometers at the south and north ends, respectively. The topography is rolling hills down the center with cliffs along both shores. Elevation ranges from 162 meters at the shore up to 390 meters.

Eighty-nine per cent of the peninsula is forested, and 97 per cent of the trees are more than 6 meters tall. The dominant deciduous species are red maple (*Acer rubrum*), oak (*Quercus* sp.), ash (*Fraxinus* sp.), and birch (*Betula* sp.). White pine (*Pinus strobus*) and eastern hemlock (*Tsuga canadensis*) are commonly found mixed with hardwoods, but some pure stands occur. The understory vegetation is sparse owing to the closed canopy and heavy browsing by deer. The only significant ground vegetation occurs along the exposed shore where young stands of aspen and cottonwood (*Populus* sp.), and birch (*Betula* sp.) are becoming established, but the lower limbs of the dense spruce plantations provide ground level cover.

There is no management of deer in the study area. Herd mortality factors include predation by bobcats and dogs (*Canis familiaris*), starvation, and limited illegal hunting.

TABLE 1.—*Selection of cover type based on a comparison of the per cent kilometers traveled by* Lynx rufus *in each cover type with the per cent occurrence of the cover type.*

Cover type	Average per cent of kilometers traveled	Per cent occurrence	Selection index
Road	10	1	10.00
Spruce plantation	12	1.5	8.00
Cliff	4	0.5	8.00
Hemlock-hardwood	13	6	2.17
Hemlock	5	4	1.25
Plantation pine	11	9	1.22
Wet areas	1	1	1.00
Hardwood	25	41	0.61
Exposed shore	4	7	0.57
Pine-hardwood	10	19	0.53
Abandoned field	1	2	0.50
Pine	2	9	0.22
Reservoir ice*	2	—	—

* There are approximately 52 square kilometers of ice around the peninsula.

MATERIALS AND METHODS

I divided the study area into 13 cover types (Table 1) adapting methods from MacConnell and Archey (1969). All data on height and crown closure were grouped for each cover type because of the uniform size and understory of the forest. The classification allowed as much as 20 per cent hardwoods in the pine cover type and trees of uneven age appeared randomly distributed. Pine plantations were separated from the pine cover type because in the former the trees are all one species, of even age, and uniformly spaced. The wet areas include all ponds and marshes (frozen during study).

Bobcats were followed during favorable snow conditions from December through March and their trails were plotted on 1966 aerial photographs (scale, 1 centimeter = 240 meters). I avoided affecting behavior by back-tracking fresh trails. If I disturbed a cat, or if a radio-equipped cat was in the area I abandoned the trail.

Habitat use was determined by measuring the approximate distance traveled in each cover type with a linear map measure. The average per cent use (Table 1) was obtained by adding the total kilometers traveled in a cover type and dividing by the total kilometers traveled in all cover types both winters. Pine and hemlock trees were not separated the first year, so the total kilometers traveled in the pine, hemlock and pine-hardwood, hemlock-hardwood cover types was calculated by applying the ratio of pine to hemlock use, or pine-hardwood to hemlock-hardwood use during the second winter to the total kilometers traveled both winters in the combined pine and hemlock, or pine-hardwood and hemlock-hardwood cover types. The average per cent use of a cover type was divided by its per cent occurrence to obtain the selection index (Table 1).

The tracks of prey species crossing a bobcat trail were recorded in each cover type to obtain an index to prey abundance, availability, and distribution. Only tracks judged as fresh or fresher than those of the bobcat were recorded.

Deer killed by bobcats were distinguished from dog kills by the method of attack as described by V. D. Stiles (unpublished data), and by signs at the kill-site. All kills I could not definitely attribute to bobcats were recorded as carrion.

Two cup anemometers placed 0.5 meters above the snow were used to compare wind in two cover types from 28 January to 11 February 1971.

Statistical tests used included the chi-square test of independence, chi-square test of goodness of fit to a 50-50 null hypothesis, and the Fisher exact probability test (Siegel, 1956).

Results and Discussion

I followed 22 and 26 bobcat trails 79 kilometers and 88 kilometers during the winters of 1969–1970 and 1970–1971, respectively, and found no difference in behavior except for an increased use of roads (4 to 15 per cent) the second winter.

Selection of Cover Type

The road, cliff, spruce plantation, and hemlock-hardwood cover types have the highest selection index values (Table 1), and are the preferred winter cover types. Bobcats selected against the hardwood, exposed shore, abandoned field, pine, pine-hardwood, and reservoir ice cover types, but there appears to be no preference for or against the pine plantation, hemlock or wet areas.

Prey Abundance and Distribution

Prey was most abundant in the hemlock-hardwood and spruce plantation cover types (Table 2). The distribution of each prey species was the same both winters, but there was a substantial decline in snowshoe hare (*Lepus americanus*, 60 per cent) and gray squirrel (*Sciurus carolinensis*, 30 per cent) tracks in 1970–1971. White-tailed deer (*Odocoileus virginianus*) tracks were not counted the first winter because I considered them too numerous. The abundance of all other prey tracks were the same both winters except for raccoon (*Procyon lotor*), which rose from one track the first winter to 44 the second.

Of the total tracks observed in 1970–1971, deer accounted for 53 per cent, mice (*Peromyscus* sp. and *Clethrionomys gapperi*) 12 per cent, snowshoe hare 11 per cent, gray squirrel 10 per cent, and porcupine (*Erethizon dorsatum*) 4 per cent.

Scat Analysis

I collected forty-three scats while trailing bobcats. Of these, 79 per cent contained traces of deer, remains of gray squirrels occurred in 23 per cent, small birds and mice in 5 per cent, and raccoon, chipmunk (*Tamias striatus*), and snowshoe hare were trace items of the sample. Vegetation was found in 35 per cent of the scats.

Feeding and Hunting Behavior

The high occurrence of deer in the scat samples was the result of predation and not scavenging on carrion deer carcasses. I define carrion as any animal the bobcat did not kill. Cached prey is defined as a bobcat kill, usually covered with snow. If a cat visited another bobcat's kill it was recorded as a visit to carrion. Cats frequently visited carrion deer (17 times) and cached deer (16 times), but fed more often on visits to cached prey (79 per cent) than carrion

TABLE 2.—*Prey track intercepts of* Lynx rufus *per kilometer of cover type observed on 88.5 kilometers of trail during 1970 to 1971.*

Prey species	Prey track intercepts per kilometer of *L. rufus* track									
	Hemlock-hardwood	Spruce plantation	Hardwood	Pine hardwood	Road	Cliff	Pine plantation	Pine	Exposed shore	Hemlock
Mammals										
Odocoileus virginianus	43.68	22.25	21.62	15.51	11.30	7.24	16.09	4.25		2.65
Lepus americanus		27.26	0.13	2.47	0.99		2.14	8.49		
Sylvilagus sp.									5.18	
Sciurus carolinensis	7.88	1.26	5.44	9.01	0.99	0.66	0.80	4.25		
Tamiasciurus hudsonicus	1.19	1.26								0.66
Tamias striatus			0.24							
Erethizon dorsatum	3.35	0.76	1.35	0.31	1.19	3.96	1.34			
Peromyscus sp.*	1.95	8.00	7.79		5.95	0.66	1.08	2.12	0.74	
Procyon lotor	3.35	0.50	1.35			9.88			1.48	
Mephites mephites								2.12	1.48	
Birds										
Meleagris gallopavo				1.54	3.77				5.18	
Bonasa umbellus	0.24	0.26					0.27			
Other birds			0.24						6.65	
Totals	61.64	61.55	38.16	28.84	24.19	22.40	21.72	21.23	20.71	3.31

* May include some *Clethrionomys gapperi* tracks.

(18 per cent; chi-square = 12.94; df = 1, $P < .001$). Marston (1942) also found *L. rufus* killing and feeding on deer, but the deer that most authors reported in scat or stomach samples usually was carrion (Hamilton and Hunter, 1939; Rollings, 1945; Pollack, 1951; Erickson, 1955).

Cached deer frequently were found (96 per cent) in the coniferous cover types of which hemlock-hardwood contained the most with six (38 per cent). Visits to carrion deer were well distributed among the coniferous cover types.

White-tailed deer was the prey species on which attempts most frequently were made (Table 3), with 44 per cent of the attempts occurring in the hemlock-hardwoods where deer were abundant (Table 2). However, there were more attempts to secure prey in the spruce plantations than any other cover type (Table 3) and the most abundant prey species, snowshoe hare, accounted for half of the attempts (Tables 2 and 3).

Bobcats actively hunt deer in their bedding areas, but attempts may be made in any opportune situation. On 3 January 1971, I was following an old female bobcat (8.6 kilograms) along the edge of a pine plantation when she came to a hardwood opening and stopped. She apparently had seen a deer bedded on the opposite edge of the opening. She retraced her steps and circled, approaching the deer in the pine plantation but from the other side. There was little ground cover though she used every bit available in stalking within 2.6 meters of the bedded animal. In one jump the cat was on the deer as was apparent from the struggle marks and deer hair in the snow. The deer gained its feet and escaped with the cat pursuing only four jumps. Sixty-six per cent of the deer on which attempts were made (Table 3) were bedded, and 66 per cent of the visits to cached deer were in bedding areas. Marston (1942) and Erickson (1955) also found *L. rufus* usually attempted to take bedded deer.

TABLE 3.—*Attempts at prey by cover type for each prey species found on 167 kilometers of trail followed in the winters of 1969–1970 and 1970–1971.*

Prey	Attempts						
	Totals	Spruce plantation	Hemlock-hardwood	Pine plantation	Exposed shore	Pine-hardwood	Hardwood
Odocoileus virginianus	9	2	4	1			2
Lepus americanus	3	3					
Sylvilagus sp.	1				1		
Sciurus carolinensis	3					2	1
Peromyscus sp.	2	1				1	
Procyon lotor	1			1			
Bonasa umbellus	1				1		
Totals	20	6	4	2	2	3	3

When *Lynx* hunt moving prey such as snowshoe hares, gray squirrels, and cottontails (*Sylvilagus* sp.) they frequently stop, sit or make "hunting beds" or "lookouts" (Rollings, 1945; Saunders, 1963; Marshall and Jenkins, 1966; and Nellis and Keith, 1968). The number of beds, sittings, and standing stops per kilometer of spruce plantation was nearly three times higher than in any other cover type (Table 4). This bed count includes "hunting beds." I found 12 of 34 beds in the winter of 1969–1970 to be "hunting beds"; 58 per cent occurred in spruce plantations and 25 per cent in hardwoods.

Bobcats hunt stationary prey such as bedded deer with few stops, sittings, and hunting beds. Deer commonly bedded in the hemlock-hardwoods and the number of beds, sittings, and stops by cats was low for the cover type (Table 4).

Once a deer has been killed, the cat may feed on it for a long period. I observed marked bobcats remaining in the general vicinity of a kill for 3 to 4 days and the cached deer was only partly eaten. Marston (1942) and Erickson (1955) also found *L. rufus* revisiting cached deer to feed. On 14 March 1970, I followed a marked cat that was apparently hunting in a large spruce plantation. The cat continuously circled and often stopped, sat, or bedded for short periods, but I did not find any attempts at prey. I had to leave at dark and a snow that night obliterated the track. However, the next morning the same animal was hunting in the spruce plantation and had killed a mouse (*Peromyscus* sp.). The marks in the snow indicated the bobcat had played with the mouse and then returned to hunting the spruces without caching the uneaten prey. Later the track led me to a partly consumed cached deer. The bobcat had eaten, but again returned to hunting in the plantation. Haglund (1966:295) stated ". . . in the reindeer region, the lynx (*L. lynx*) shows surplus hunting activity, not necessary for their livelihood. The surplus hunting does not occur in the other regions (where smaller game is taken)." I found four other instances of bobcats hunting in the spruces while they had fresh deer cached.

TABLE 4.—*Number of beds, standing stops, and sittings per kilometer of selected cover types as observed on 167 kilometers of trail followed during the winters of 1969–1970 and 1970–1971. No beds, standing stops, or sittings were observed on reservoir ice.*

Cover type	Beds per kilometer	Standing stops per kilometer	Sittings per kilometer
Spruce plantation	2.62	14.85	7.74
Hemlock-hardwood	0.70	5.44	2.96
Hardwood	0.61	6.52	2.79
Exposed shore	—	3.06	—
Roads	—	0.95	1.11

Bobcats cached hind quarters of a cottontail and a gray squirrel, and the one mouse mentioned above was not eaten. Of the six successful attempts at non-deer prey, half were not eaten or only partially eaten and cached. Nellis and Keith (1968) found *L. canadensis* only cached prey when food was abundant. Another indication of the availability of food was the number of attempts at prey per kilometer. I observed 0.12 attempts per kilometer whereas Nellis and Keith (1968) reported 0.37 and Saunders (1963) reported approximately 0.16 attempts on hares alone. Although these results are not strictly comparable because prey abundance could vary, I believe the low number of attempts at prey may represent a reduction of serious hunting effort.

Environmental Conditions

Generally the winter factors that cause an animal to expend more energy traveling in one cover type than another are snow depth, wind, air temperature, radiation, and humidity (Moen, 1968; Porter and Gates, 1969). Snow depth, radiation loss and wind are reduced by increased cover whereas night temperatures are generally higher (Rasche, 1958; Brander, 1965; Geiger, 1957). Therefore a bobcat can conserve more energy in conifers and mixed conifers than in hardwoods or open cover types.

I recorded the kilometers of wind per week for two weeks during the winter of 1970–1971 in the hardwood and spruce plantation cover types. Hardwoods averaged 163 kilometers per week whereas the spruce plantation averaged only 16 kilometers per week.

Nellis and Keith (1968) and Haglund (1966) suggested "bearing strength" or "consistency" of the snow was an important factor in the ability of lynxes to capture prey. I collected data on snow depth at each attempt, but I found so few successful attempts the results were inconclusive.

Changes in snow avoidance behavior in deep snow.—I followed four bobcats in 1969–1970 that walked normally in snow below 15 centimeters deep, but each time (six instances) the cats entered a drift above that depth they retreated and circled the area or bounded through it. Marston (1942) found that movements of *L. rufus* were restricted in snows above about 13 centi-

meters deep. Therefore, when bobcats sank into the snow 15 centimeters or more I referred to the snow conditions as deep, and all snow depths below 15 centimeters were referred to as shallow.

Bobcats can avoid the effort of walking in unaltered snow by walking in trails of other animals, on logs, or in plowed roads or snowmobile paths. When snow depths are shallow, trails, logs, and roads are used only when convenient, but when deep the avoidance routes are used at every opportunity.

I followed cats in deep snow 40 per cent of the total kilometers tracked in 1970–1971, and they walked on logs 72 times in the deep snow and 33 times in the shallow snow (chi-square = 38.44; df = 1; $P < .001$). Logs walked on per kilometer was highest in the hemlock-hardwood and hardwood cover types, where the average snow depth at the log was 18 and 16 centimeters, respectively. Fifty-six per cent of the logs walked on were in the hardwoods and 35 per cent were in the hemlock-hardwood.

Walking in trails of other animals also was more common in the deep snow period of 1970–1971 than in the shallow snow. Bobcats walked in trails of other animals 2.6 kilometers (7 per cent of total) in the deep snow period as compared to only 1.0 kilometers (2 per cent of total) in the shallow snow. Use of other animal trails was highest in the hardwoods (1.8 kilometers) and hemlock-hardwoods (0.6 kilometers) and the average depth of the snow avoided was 18 and 17 centimeters, respectively.

Bobcats walked in the worn trails of deer and porcupines, but they also utilized the tracks of single animals in avoiding unaltered snow. The distance traveled in the tracks or trails of other animals during 1970–1971 was highest for white-tailed deer (1.9 kilometers), porcupines (1.0 kilometers), and other bobcats (0.5 kilometers).

Ninety-six per cent of the 16.4 kilometers traveled in roads was in plowed roads or snowmobile paths. The other 4 per cent occurred when the snow depth was less than 1.5 centimeters. In the deep snows of 1970–1971, 12.1 kilometers were traveled in roads compared to 1.5 kilometers in the shallow snows.

The distance traveled in trails of other animals, on logs, and in roads for the deep and shallow snow periods of winter 1970–1971, divided by the total kilometers traveled in those periods, yielded the per cent of kilometers bobcats avoided the effort of walking in unaltered snow for each period. Forty per cent of the kilometers were in trails of other animals, on logs, or in roads in deep snow as compared to only 4 per cent in shallow snow.

Effects of logging.—Spring and summer logging did not appear to affect the winter distribution of deer or cats, but in 1970–1971 deer began feeding heavily on tops left from the late autumn thinning of an 11-acre pine plantation. This feeding area was surrounded by spruce plantations where the deer bedded. In 1969–1970 the area was not used by deer or bobcats, and was 0.8 kilometers south of the main route between two cliffs that cats used ex-

tensively. All six bobcats I followed from one cliff to the other in 1969–1970 crossed north of the unthinned plantation, but in 1970–1971 the three cats I followed crossed at the plantation (Fisher test, $P = .012$). I found two cached deer and one attempt to take a deer in the spruces surrounding this feeding area, but deer use of this single spruce plantation was not typical of the whole study area.

Conclusions

The importance of prey abundance and environmental conditions in meeting the physiological requirements of a bobcat are not sufficient to completely explain selection of cover type. Behavioral factors are frequently important in choice of habitat by bobcats. The secretive nature of hunting habits may dictate the use of heavy cover to avoid being seen by potential prey, or social interaction may draw cats to some areas or exclude them from others. I shall not attempt to quantify the importance of physiological or behavioral factors in selection of cover type, but only to identify what I consider to be the most important factors.

Food appeared to be readily available on the study area. Bobcats cached or did not eat much of the small prey killed; they had to revisit a deer carcass many times to consume the usable food; and carrion deer were often visited but seldom used. Another possible indication of the availability of food is the low number of attempts at prey species per mile.

Hemlock-hardwood.—This cover type was selected for its high density of prey, particularly white-tailed deer, the primary winter food of bobcats in the study area. The hemlock-hardwoods were generally used by deer to feed and bed and bedded deer are more available to bobcats. Kills and attempts at deer were higher here than in any other cover type.

Spruce plantation.—Bobcats were resting and hunting in the spruces because the number of rest beds and attempts at prey were the highest of any cover type. Snowshoe hares were the prey species at which attempts most often were made, and hunting beds, standing stops, and sittings were frequent, indicative of the slow hunting methods employed for this species. However, I never found a successful attempt to take a hare. Moreover, bobcat use did not change after an estimated 60 per cent drop in the hare population, and the species was only a trace item in scat samples. Inasmuch as I often observed hunting before and after feeding on a cached deer, it seems that much of the hunting was unnecessary and more important as a behavioral requirement than a physiological necessity.

The spruce plantations provide a high density of prey and was the cover type where the least amount of energy would be expended in meeting the apparent behavioral requirements of hunting.

Cliffs.—This cover type also has behavioral reasons for selection as well as the obvious physiological advantages of shelter. I have data suggesting the

importance of the cliffs during the breeding season (McCord, 1974) and in other social interactions.

Roads.—The use of roads is purely a matter of conserving energy by avoiding the effort of walking in deeper snow. Cats used roads to move between rest areas and food sources or hunting areas.

Hardwoods.—Hardwoods were selected against, probably because of the increased energy losses owing to the effort of traveling in the deeper snows, the increased wind, and the radiation losses and lower temperatures at night in this cover type. Snow avoidance methods of walking on logs and in trails of other animals were most common in the hardwoods. Although prey abundance was high, open cover types are not as conducive to the stalk-hunting employed by bobcats.

Exposed shore and reservoir ice.—These cover types had wide extremes in environmental conditions, but prey abundance was generally low. Sometimes bobcats traveled several kilometers along the exposed shore or the edge of ice, but this was usually on calm days after the wind action had cleared snow from these open areas. The same factors that cause selection against the hardwoods probably cause bobcats to avoid these cover types as well.

Pine and pine-hardwood.—These cover types were selected against probably because of low prey populations. Bobcats do not actively avoid these cover types, but prey was more abundant elsewhere.

Hemlock, wet areas, and pine plantations.—There did not appear to be any selection for or against these cover types and bobcats traveled and hunted them indifferently.

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