

# Diurnal Habitat Relationships of Canada Lynx in an Intensively Managed Private Forest Landscape in Northern Maine

JENNIFER H. VASHON,<sup>1</sup> *Maine Department of Inland Fisheries and Wildlife, 650 State Street, Bangor, ME 04401, USA*

AMY L. MEEHAN, *Maine Department of Inland Fisheries and Wildlife, 650 State Street, Bangor, ME 04401, USA*

JOHN F. ORGAN, *United States Fish and Wildlife Service, 300 Westgate Center Drive, Hadley, MA 01035, USA*

WALTER J. JAKUBAS, *Maine Department of Inland Fisheries and Wildlife, 650 State Street, Bangor, ME 04401, USA*

CRAIG R. MCLAUGHLIN, *Utah Division of Wildlife, 1594 W North Temple, Suite 2110, Salt Lake City, UT 84114, USA*

ADAM D. VASHON, *United States Department of Agriculture, Wildlife Services, 79 Leighton Road, Suite 12, Augusta, ME 04330, USA*

SHANNON M. CROWLEY, *University of Northern British Columbia, International Center, 3333 University Way, Prince George, BC V2N 4Z9, Canada*

**ABSTRACT** In March 2000, Canada lynx (*Lynx canadensis*) were listed as a federally threatened species in 14 states at the southern periphery of their range, where lynx habitat is disjunct and snowshoe hare (*Lepus americanus*) densities are low. Forest conditions vary across lynx range; thus, region-specific data on the habitat requirements of lynx are needed. We studied lynx in northern Maine, USA, from 1999 to 2004 to assess quality and potential for forests in Maine to sustain lynx populations. We trapped and radiocollared 43 lynx (21 M, 22 F) during this period and evaluated diurnal habitat selection by 16 resident adult lynx (9 M, 7 F) monitored in 2002. We evaluated lynx selection of 8 habitats at multiple spatial scales, and related lynx habitat selection to snowshoe hare abundance. Lynx preferred conifer-dominated sapling stands, which supported the highest hare densities on our study site ( $\bar{x} = 2.4$  hares/ha), over all other habitats. The habitats where lynx placed their home ranges did not differ by sex. However, within their home ranges, males not only preferred conifer-dominated sapling stands, but also preferred mature conifer, whereas females singularly preferred conifer-dominated sapling stands. Approximately one-third of Maine's spruce-fir forest and nearly 50% of our study area was regenerating conifer or mixed-sapling forest, resulting from a disease event and intensive forest management (e.g., large clear-cuts). Our findings suggest that current habitat conditions in Maine are better than western montane regions and approach conditions in boreal forests during periods of hare abundance. We recommend that forest landowners maintain a mosaic of different-aged conifer stands to ensure a component of regenerating conifer-dominated forest on the landscape. (JOURNAL OF WILDLIFE MANAGEMENT 72(7):1488–1496; 2008)

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**KEY WORDS** Canada lynx, diurnal habitat selection, early seral conifer, *Lepus americanus*, *Lynx canadensis*, Maine, snowshoe hare.

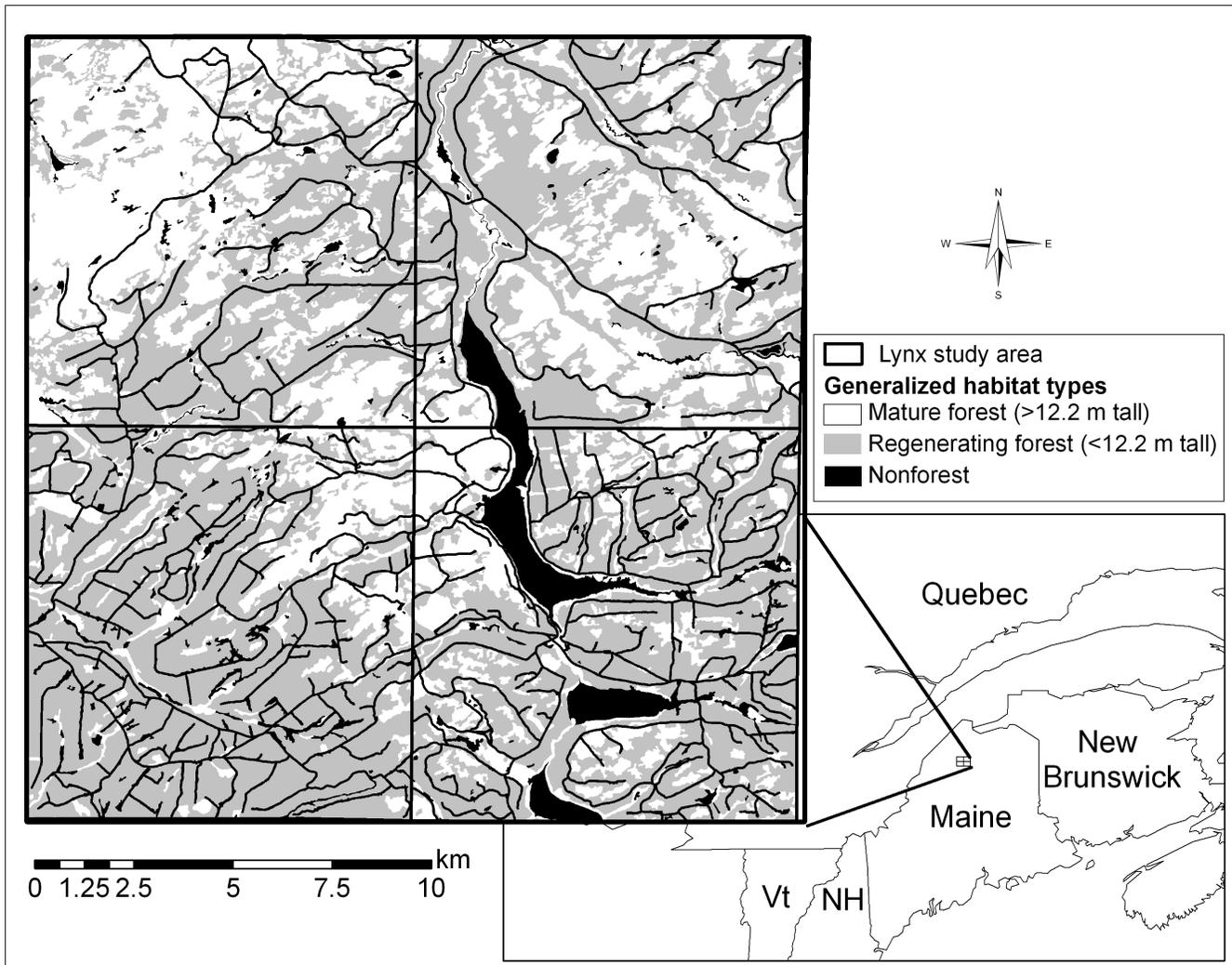
Canada lynx (*Lynx canadensis*) occur in boreal and montane forests of North America and their range extends southward into subalpine forests in the western United States and transitional boreal-temperate forests in the eastern United States and Canada (McCord and Cardoza 1982, Agee 2000). Canada lynx distribution coincides with distribution of their primary prey, the snowshoe hare (*Lepus americanus*; Mowat et al. 2000) and lynx select habitats where hares are most abundant (Parker 1981, Koehler 1990, Mowat et al. 2000, O'Donoghue et al. 2001). Snowshoe hare densities are strongly correlated with dense, early seral coniferous stands (Litvaitis et al. 1985, Koehler 1990), which provide 3 times the cover of deciduous stands (Litvaitis et al. 1985).

In the taiga, simple species composition and age structure combined with periodic stand replacing disturbances result in contiguous stands of early seral conifers across large areas (Seymour and Hunter 1992, Agee 2000). For example, approximately 74% of a study area in the southwest Yukon, Canada, was comprised of early seral forest and supported high hare and lynx densities (12 ad lynx/100 km<sup>2</sup>; Slough and Mowat 1996, Mowat and Slough 2003). Until recently,

understanding of lynx habitat selection at the southern extent of the range was limited to studies in Washington, USA (Brittall et al. 1989, Koehler 1990, McKelvey et al. 2000) and Nova Scotia, Canada (Parker 1981). In Washington, habitats were marginal and more patchily distributed (Aubry et al. 2000) with <10% of that study area comprised of early seral conifers, supporting low hare (1–1.8/ha; Koehler 1990, Hodges 2000) and lynx densities (2.3 ad lynx/100 km<sup>2</sup>; Koehler 1990). Conversely, Nova Scotia supported high hare (10/ha) and lynx densities (8.3 ad lynx/100 km<sup>2</sup>), despite the similarly low amount of early seral conifers in the study area (Parker 1981, Parker et al. 1983). The Washington study led to the hypothesis that lynx demographics at the southern edge of their range are similar to lynx at the core of their range during hare lows (Koehler 1990, Apps 2000, Aubry et al. 2000).

Forests in Maine, USA, represent a transition from the boreal forests to the north and temperate forests to the south and are dissimilar to both western subalpine forests and northern boreal forests in their topography, climatic conditions, soils, disturbance regimes, and forest successional pathways (Buskirk et al. 2000). Lynx range in Maine encompasses the northwestern part of the state and is

<sup>1</sup> E-mail: Jennifer.Vashon@maine.gov



**Figure 1.** Map of the Musquacook Lake lynx study area in northern Maine, USA, 1999–2004, showing the distribution of mature and regenerating forest and nonforested habitat. The study area encompassed 4 townships (386 km<sup>2</sup>) within approximately 2.2 million ha of Maine’s commercial forestland.

comprised mainly of large tracts of privately owned and intensively managed forest. Currently, 33% of Maine’s spruce–fir forest is now in the sapling stage resulting from heavy salvage logging following a spruce budworm (*Choristoneura fumiferana*) outbreak in the 1970s and 1980s (McWilliams et al. 2005). Research results from studies of western montane lynx populations may not be applicable to the eastern United States, because the current distribution and abundance of early successional conifer forest in Maine may result in higher quality habitat. Our objective was to describe diurnal habitat selection of a radiocollared sample of an unexploited lynx population in northern Maine as it relates to hare densities.

## STUDY AREA

The study area encompassed 4 townships (386 km<sup>2</sup>) in the Musquacook lakes region of northwestern Maine (Fig. 1). The area ranged in elevation from 250 m to 550 m and was characterized by rolling hills and wide valleys. Regenerating white (*Picea glauca*) and red spruce (*P. rubens*) and balsam fir (*Abies balsamea*) stands dominated the area. This spruce–fir

forest was interspersed with lowlands comprised of black spruce (*P. mariana*), tamarack (*Larix laricina*), and northern white cedar (*Thuja occidentalis*) and ridges dominated by sugar maple (*Acer saccharum*), and birch (*Betula* spp.). Much of the area (approx. 46% or 17,562 ha) was clear-cut in the 1980s to salvage trees harmed by the spruce-budworm epizootic and to prevent further expansion of the spruce-budworm. Nearly half of Maine’s 6.8 million ha of forest, most of Maine’s lynx range, and our entire study area were owned by large timber companies and were intensively managed for forest products (Seymour and Hunter 1992). Land-management activities in the study area included timber harvesting, herbicide applications to promote conifer regeneration, precommercial thinning to enhance stand growth, and road construction. Human settlements were limited to seasonal camps and logging operations, and most roads were unimproved dirt roads used primarily for wood harvest and transportation. The land was privately owned but public access was allowed and regulated by the North Maine Woods Association, a non-profit organization of

**Table 1.** Conversion of stand-development classification systems by 3 landowners into standard habitat types used in the generation of a base map to compare selection of habitat by lynx in northern Maine, USA, in 2002 and percentage of each habitat type within the availability polygon created by buffering each lynx location by 5.3 km.

Development <sup>a</sup>	Ht (m)			Habitat variable <sup>b</sup>	Acronym	% available
	Landowner 1 (63,849 ha)	Landowner 2 (43,568 ha)	Landowner 3 (14,445 ha)			
Early regen	0.0–3.0	0.9–3.0	Recent cut <sup>c</sup>	All seedling cover-types	OR	9.0
Mid regen	3.4–7.3	3.0–7.0	0.3–6.1	Coniferous & coniferous–deciduous sapling	CCDSAP	15.0
Late regen	7.3–12.2	>7.0	6.4–12.2	Deciduous–coniferous sapling	DCSAP	9.0
				Deciduous sapling	OR	4.0
				Coniferous and mixed pole	POLE	4.0
Mature	>12.2	>12.2	≥12.5	Deciduous pole	OR	1.0
				Coniferous & coniferous–deciduous mature	CM	17.0
				Deciduous & deciduous–coniferous mature	DM	24.0
Wetland				Nonforest	NF	8.0
Road				Logging roads (buffered by 30 m on each side)	RD	9.0

<sup>a</sup> Regen = regeneration.

<sup>b</sup> Deciduous = pure deciduous forest; deciduous–coniferous = ≥75% deciduous and ≤25% coniferous forest; coniferous = pure coniferous forest; coniferous–deciduous = ≥75% coniferous and ≤25% deciduous forest.

<sup>c</sup> Stands that were either clear-cut or shelterwood-harvested between 1994 and 2002 (i.e., <10 yr old).

landowners established to manage access on 1.4 million ha of private forestland in northern Maine.

## METHODS

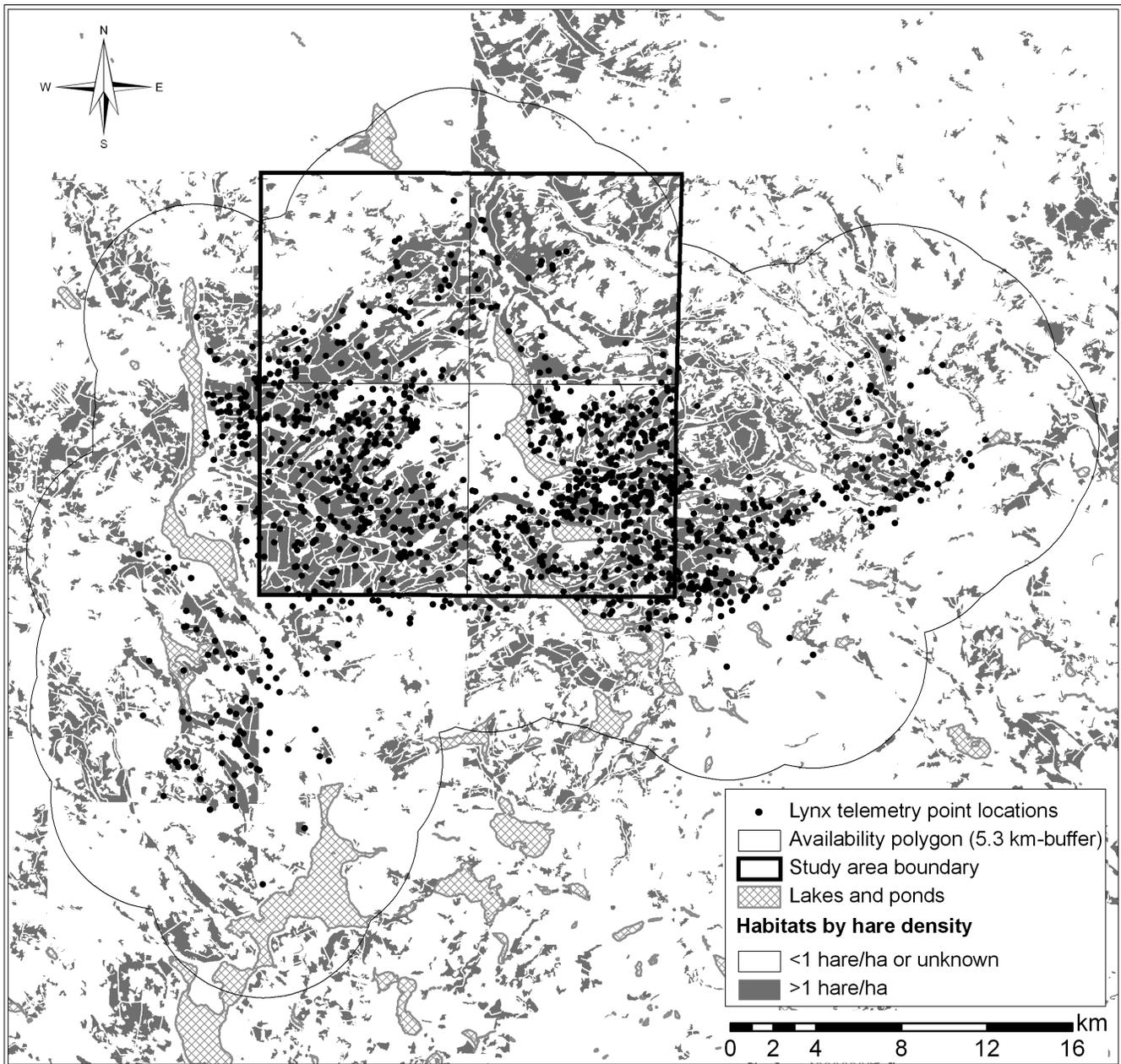
The methodology for capture and telemetry monitoring is described in Vashon et al. (2008). Animal capture and handling procedures conformed to guidelines established by the American Society of Mammalogists (American Society of Mammalogists 1998).

To describe habitat conditions on the study area, we obtained stand type data from the 3 landowners within and surrounding the study area and developed a Geographic Information System (GIS) base layer from their vector coverages. These coverages were derived from stereoscopic interpretation of 1:15,840-scale color infrared aerial photographs, collected in 1997, 2002, and 2004. Each landowner used the same cover-type classification but had slightly different definitions of development classes. We worked with the landowner GIS analysts and foresters to convert the 3 classifications into a common and compatible scheme that combined cover-type and development stage (Table 1) and merged the resulting 3 coverages. The 2 major ownerships in our study area had been typed in 1997 and 2002; therefore, we adjusted the age of regenerating stands by adding an average-height growth rate of 0.3 m/year for conifers and 0.5 m/year for deciduous trees for the ownership typed in 1997 (D. Berube, Irving Woodlands, personal communication). Although the third landowner's stand maps were typed 2 years following our study, we did not adjust stand ages because this landowner constituted only 12% of the land in or surrounding our study area, and much of this ownership (74%) was classified as mature forest (>12.2 m tall). We classified habitat based on foraging, traveling, and denning needs of lynx, which resulted in 8 habitat classes that included 4 regenerating forest types (<12.2 m tall), 2 mature forest types (>12.2 m tall), and 2 nonforest types (Table 1). Ground-truthing of

stands in the study area showed an average typing accuracy of 70% ( $n = 114$ ) and most errors were associated with the mapping of stand boundaries. We processed all data using ARC/INFO GIS version 9.2.

In 2002, we documented winter snowshoe hare densities in different habitats (cover type and stand development) within our study area by establishing 1.5-m<sup>2</sup> rectangular snowshoe hare fecal-pellet plots in 18 forested stands, following methods described by Homyack et al. (2006). We sampled 42 plots at 40-m intervals along 4 400-m parallel transects (Homyack et al. 2007) in 7 stands classified as conifer-dominated sapling (CCDSAP), 3 stands classified as deciduous-dominated sapling (DCSAP), 4 stands classified as conifer or mixed pole (POLE), 2 stands classified as mature deciduous (DM), and 2 stands classified as DM with a regenerating mixed deciduous forest understory (Table 1). Mature conifer stands (CM) were small and linear in shape and subtypes (all seedling cover-types, deciduous sapling, or deciduous pole) within the other regeneration (OR) classification were rare; thus, we did not sample these stands. We evaluated habitat differences in hare densities using one-way analysis of variance and Duncan's multiple-range test for pairwise comparisons.

We used a Euclidean distance-based approach following the methods of Conner and Plowman (2001) to evaluate diurnal habitat selection of adult lynx at multiple spatial scales: selection at the home range scale (Johnson's second order; Johnson 1980), selection within home ranges (Johnson's third order), and selection at the core-area level (50% kernel) within the home range. We created an availability polygon for second-order selection by buffering all telemetry locations by 5.3 km (average radius of a M lynx 100% min. convex polygon home range). We used the 95% fixed-kernel home range polygon to identify what habitats were available to lynx at the third-order and within-core-area scales. The methodology for home range estimation is described in Vashon et al. (2008) with the exception of our

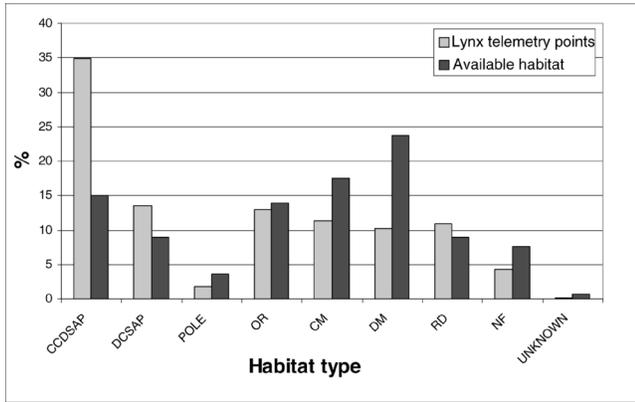


**Figure 2.** Distribution of habitats with the highest observed winter hare densities and lynx telemetry locations within the availability polygon around the Musquacook Lake lynx study area in northern Maine, USA, 2002. We created the availability polygon by buffering the lynx telemetry points by 5.3 km.

selection of the outer contour for assessing habitat selection. We selected the 85% fixed contour to approximate lynx home ranges because it best encompassed where lynx spent the majority of their time (Vashon et al. 2008). However, we did not want to exclude locations outside this extent for characterizing lynx use of habitat (Erikson et al. 2001). Thus, for within-home-range (third-order) habitat selection we used the 95% fixed kernel.

We generated random locations within the availability polygon ( $n = 3,750$ ) and in each home range ( $n = 750$ ) and calculated the average distance from random locations to each habitat type, using the ARC/INFO NEAR command. To assess second-order selection, we created distance ratios for each habitat type by dividing the average distance from

random points in the home range by the average distance from random points in the availability polygon. For third-order selection, we calculated distance ratios by dividing the average distance from animal locations within the home range ( $\bar{x} = 79$  points/animal) by the average distance from random locations ( $n = 750$ ) to each habitat type within the home range. To assess selection in core areas, we divided the average distance from animal locations within the core area ( $\bar{x} = 37$  points/animal) by the average distance from random locations ( $n = 750$ ) within the home range. If the mean of these distance ratios differed from a vector of one using multivariate analysis of variance, then it indicated non-random use of habitat and we then used univariate  $t$ -tests to determine which habitat types were used disproportionately.



**Figure 3.** Percentage of lynx radiotelemetry points in each habitat type versus the percentage of available habitat types (conifer-dominated sapling [CCDSAP], deciduous-dominated sapling [DCSAP], conifer or mixed pole [POLE], other regeneration [OR], mature conifer [CM], mature deciduous [DM], road [RD], nonforest [NF]) within the availability polygon around the Musquacook Lake lynx study area in northern Maine, USA, 2002. We created the availability polygon by buffering the lynx telemetry points by 5.3 km.

Mean distance ratios significantly  $<1$  indicated preference for that habitat type, whereas a mean distance ratio significantly  $>1$  indicated avoidance of that habitat type (Conner and Plowman 2001, Conner et al. 2003, Perkins and Conner 2004). We used SAS software (SAS Institute, Cary, NC) to conduct statistical analyses and set  $\alpha = 0.05$ .

## RESULTS

We captured and radiocollared 43 lynx (21 M, 22 F) from March 1999 to December 2004. Aerial radiotelemetry error varied with aircraft pilots but in all cases was  $<80$  m ( $n = 28$ ). From March 1999 to April 2003, we used one pilot and his telemetry error averaged 44.3 m ( $SE = 5.5$  m,  $n = 22$ ). Only 22 radiocollared lynx (11 M, 11 F) were residents and monitored sufficiently to produce annual estimates; most lynx were monitored for  $>1$  year. To avoid biasing results from lynx collared for multiple years, we analyzed habitat selection for year 3 (15 Nov 2001–14 Nov 2002), which had the largest sample of resident collared lynx (9 M, 7 F). We excluded one female lynx from the analysis, because her habitat selection pattern (distance ratios) was substantially different from all other lynx. Her home range was twice the

average size of female lynx home ranges in this study and her subsequent movement patterns (e.g., settled and denned 29 km to the SW the following yr) suggest that she was a temporary resident to the study area and was thus unlikely to use the landscape in a comparable way to other females in our sample.

The number of telemetry locations/animal ranged from 64 to 83 ( $\bar{x} = 79$ ,  $SE = 1$ ) and were evenly distributed throughout the year with approximately 8 locations/animal/month. In year 3, female 95% kernel home ranges averaged 35.3 ( $SE = 5.2$ )  $km^2$  and male 95% kernel home ranges averaged 84.0 ( $SE = 12.1$ )  $km^2$ . The mean female 50% kernel home range was 2.2 ( $SE = 0.4$ )  $km^2$  and the mean male 50% kernel home range was 19.8 ( $SE = 3.7$ )  $km^2$ .

Winter snowshoe hare densities differed among habitat types ( $F = 8.07$ ,  $P = 0.002$ ). The CCDSAP supported hare densities ( $\bar{x} = 2.4$  hares/ha,  $SE = 0.1$ ,  $n = 294$  plots) that were 4–8 times the hare densities in open- and closed-canopy mature deciduous stand types, which supported the lowest hare densities ( $\bar{x} = 0.6$ /ha,  $SE = 0.1$ ,  $n = 84$  plots, and  $\bar{x} = 0.3$ /ha,  $SE = 0.02$ ,  $n = 84$  plots, respectively). We observed intermediate hare densities in mixed deciduous sapling and mixed coniferous pole stands ( $\bar{x} = 1.4$ /ha,  $SE = 0.1$ ,  $n = 126$  plots, and  $\bar{x} = 1.5$ /ha,  $SE = 0.1$ ,  $n = 168$  plots, respectively), which contained 5 times the densities found in closed canopy mature deciduous stands. Habitats with  $>1$  hare/ha (not all habitat types were sampled) encompassed  $\geq 46\%$  of the forested habitat in the study area and 28% of the availability polygon and were well-distributed (Fig. 2).

Mature deciduous-dominated forest was the most prevalent habitat class in the availability polygon, followed by mature conifer-dominated forest and conifer-dominated sapling stands (Table 1; Fig. 3). Although mature ( $>12.2$ -m tall) forest types encompassed 41% of the availability polygon, only 21% of lynx telemetry locations occurred in mature forest (DM [10%] or CM [11%]). Conversely, CCDSAP encompassed only 15% of the availability polygon, but  $>30\%$  of lynx locations occurred in this habitat type (Figs. 2, 3).

Lynx selected habitat at all spatial scales ( $F_{8,6} = 138.52$ ,  $P < 0.001$ ;  $F_{8,6} = 11.53$ ,  $P = 0.004$ , and  $F_{8,6} = 23.41$ ,  $P < 0.001$ , respectively). Sex did not affect selection at the second-order scale ( $F_{8,6} = 0.44$ ,  $P = 0.86$ ). Males selected

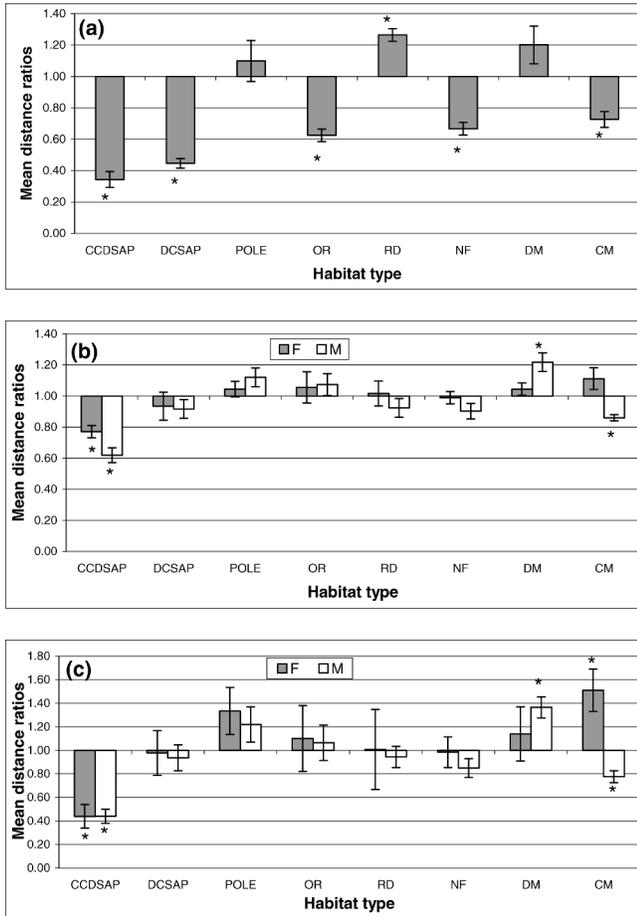
**Table 2.** Habitat-ranking matrix ( $P$ -values)<sup>a</sup> from pairwise univariate  $t$ -tests between habitat-type distance ratios for home-range habitat selection<sup>b</sup> for lynx in northern Maine, USA, using 95% fixed kernels from 15 November 2001 to 14 November 2002.

Habitat <sup>c</sup>	DCSAP	POLE	OR	RD	NF	DM	CM
CDSAP	0.025	$<0.001$	0.002	$<0.001$	$<0.001$	$<0.001$	$<0.001$
DCSAP		$<0.001$	0.006	$<0.001$	$<0.001$	$<0.001$	$<0.001$
POLE			0.006	0.199	0.009	0.384	0.028
OR				$<0.001$	0.487	$<0.001$	0.147
RD					$<0.001$	0.633	0.002
NF						0.001	0.192
DM							0.002

<sup>a</sup>  $P$ -values from  $t$ -tests of the null hypothesis that the distance to the row habitat minus the distance to the column habitat equals zero.

<sup>b</sup> Average distance from random locations within home ranges divided by average distance from random locations throughout the availability polygon.

<sup>c</sup> CCDSAP = coniferous–deciduous sapling; DCSAP = deciduous–coniferous sapling; POLE = conifer or mixed pole; OR = other regeneration; RD = road; NF = nonforest; DM = mature deciduous; CM = mature coniferous.



**Figure 4.** Mean distance ratios (and associated SEs) by habitat type (conifer-dominated sapling [CCDSAP], deciduous-dominated sapling [DCSAP], conifer or mixed pole [POLE], other regeneration [OR], mature conifer [CM], mature deciduous [DM], road [RD], nonforest [NF]) at the second-order (a), third-order (b), and within-core-area (c) scales for lynx in northern Maine, USA, 15 November 2001 to 14 November 2002. Mean distance ratios equal average distance from use points divided by average distance from random locations at a given scale. Significant mean ratios <1 indicate habitat preference and those >1 indicate habitat avoidance (denoted by bars with an asterisk).

habitats differently than females at both the third-order and core-area scales ( $F_{8,6} = 7.10, P = 0.01, F_{8,6} = 10.10, P = 0.006$ ).

When selecting a home range (i.e., second-order selection), lynx preferred CCDSAP above all other habitats, followed by DCSAP (Table 2, Fig. 4). The CCDSAP and DCSAP habitat types had the highest hare density estimates and encompassed 24% of the availability polygon. Lynx also preferred OR, CM, and NF, however there was no difference in preference among these 3 types (Table 2; Fig. 4). Lynx avoided roads at this scale and were further from DM and POLE than expected (Fig. 4).

When selecting areas within the home range (i.e., third-order selection), adult female lynx preferred CCDSAP, although pairwise comparisons indicated that CCDSAP was not different from DCSAP (Table 3; Fig. 4). Males preferred CCDSAP and CM but preferred CCDSAP above all other types. Although males were significantly closer to CM than expected, pairwise comparisons indicated that CM was not different from NF, DCSAP, or RD (Table 3; Fig. 4). Males avoided mature deciduous forests (DM; Fig. 4).

Within core areas, adult female lynx preferred CCDSAP and avoided CM (Table 4; Fig. 4). We found no difference between CCDSAP and DCSAP, OR, or RD; however, high standard errors may have influenced these results (Fig. 4). Males preferred CCDSAP and CM but preferred CCDSAP above all other types. Although males were significantly closer to CM than expected, pairwise comparisons indicated that CM was not different from NF, DCSAP, RD, or OR, although this may have been influenced by low sampling intensity and high standard errors (Table 4; Fig. 4). Males avoided mature deciduous forests (DM) within their core areas (Fig. 4).

## DISCUSSION

In Maine, at the 3 spatial scales we examined, food appears to be a driving factor in lynx habitat selection. Both male and female lynx showed strong selection for conifer-dominated sapling forest, which contained the highest winter hare densities in our study area, consistent with earlier studies that indicated lynx selected for habitats with high hare abundance (Parker et al. 1983, McKelvey et al. 2000, Mowat and Slough 2003, Hoving et al. 2004, Fuller et al. 2007). Litvaitis et al. (1985) reported a strong relationship between hare density and stem cover units in Maine,

**Table 3.** Habitat-ranking matrix ( $P$ -values)<sup>a</sup> from pairwise univariate  $t$ -tests between habitat-type distance ratios for within home-range habitat selection<sup>b</sup> for lynx in northern Maine, USA, using 95% fixed kernels from 15 November 2001 to 14 November 2002.

Habitat <sup>c</sup>	DCSAP		POLE		OR		RD		NF		DM		CM	
	F	M	F	M	F	M	F	M	F	M	F	M	F	M
CCDSAP	0.204	<0.001	0.022	<0.001	0.027	0.001	0.026	0.012	0.001	0.007	0.008	<0.001	0.005	0.001
DCSAP			0.195	0.062	0.461	0.137	0.416	0.946	0.630	0.877	0.241	0.010	0.079	0.333
POLE					0.928	0.639	0.785	0.050	0.444	0.047	0.996	0.062	0.529	0.004
OR							0.803	0.180	0.444	0.022	0.901	0.149	0.688	0.018
RD									0.759	0.780	0.803	0.010	0.344	0.350
NF											0.362	0.003	0.236	0.447
DM													0.442	<0.001

<sup>a</sup>  $P$ -values from  $t$ -tests of the null hypothesis that the distance to the row habitat minus the distance to the column habitat equals zero.

<sup>b</sup> Average distance from telemetry locations within home range divided by average distance from random locations within home range.

<sup>c</sup> CCDSAP = coniferous-deciduous sapling; DCSAP = deciduous-coniferous sapling; POLE = conifer or mixed pole; OR = other regeneration; RD = road; NF = nonforest; DM = mature deciduous; CM = mature coniferous.

**Table 4.** Habitat-ranking matrix (*P*-values)<sup>a</sup> from pairwise univariate *t*-tests between habitat-type distance ratios in lynx core-area (50% kernel)<sup>b</sup> habitat selection in northern Maine, USA, from 15 November 2001 to 14 November 2002.

Habitat <sup>c</sup>	DCSAP		POLE		OR		RD		NF		DM		CM	
	F	M	F	M	F	M	F	M	F	M	F	M	F	M
CDSAP	0.071	0.001	0.016	0.003	0.067	0.003	0.228	0.004	0.042	0.003	0.043	<0.001	<0.001	<0.001
DCSAP			0.124	0.123	0.738	0.520	0.938	0.965	0.984	0.600	0.198	0.004	0.040	0.142
POLE					0.264	0.543	0.475	0.088	0.281	0.107	0.418	0.241	0.537	0.034
OR							0.868	0.576	0.749	0.068	0.912	0.147	0.243	0.076
RD									0.930	0.519	0.765	0.009	0.300	0.232
NF											0.629	0.005	0.109	0.441
DM													0.116	<0.001

<sup>a</sup> *P*-values from *t*-tests of the null hypothesis that the distance to the row habitat minus the distance to the column habitat equals zero.

<sup>b</sup> Average distance from telemetry locations within core areas divided by average distance from random locations within home range.

<sup>c</sup> CCDSAP = coniferous-deciduous sapling; DCSAP = deciduous-coniferous sapling; POLE = conifer or mixed pole; OR = other regeneration; RD = road; NF = nonforest; DM = mature deciduous; CM = mature coniferous.

where conifer saplings had 3 times the stem cover units of deciduous saplings, suggesting that conifer saplings were the most important determinant of hare density. Additional studies in Maine have also documented high hare densities (>1.5/ha) in regenerating conifer clear-cuts (Fuller and Harrison 2005, Homyack et al. 2007).

Despite supporting hare densities of 1.5/ha, lynx were further from POLE stands than expected at all spatial scales. There were few POLE stands in the study area and those present were small and scattered on the landscape, making it disadvantageous for lynx to seek out these stands when CCDSAP was prevalent, in larger patches, and contained higher hare densities. Thus, lynx selection of POLE stands may be different in landscapes of differing composition and configuration.

Females in our study showed a singular preference for conifer sapling forest. The small female home ranges observed (Vashon et al. 2008) indicate that the conifer-dominated sapling habitat adequately provided for the energetic demands of raising young, because all the females in our study were accompanied by kittens and kitten survival was high (78%; J. H. Vashon, Maine Department of Inland Fisheries and Wildlife, unpublished report).

Mature conifer forest in our study area occurs in linear patches along riparian zones and provides potential travel corridors for wildlife. Larger home ranges of males are associated with greater movements; thus, the high use of mature conifer by males likely reflects the value of these stand types for travel. Parker (1981) observed lynx using mature conifer stands for traveling. Avoidance of mature deciduous forest by males (at 2 spatial scales) and lack of preference for this habitat type by females suggests that mature deciduous forest is of little value for travel or forage by lynx.

Based on information from western montane regions, Aubry et al. (2000) hypothesized that southern lynx populations differed from those in boreal regions in quality and distribution of available habitat, with hare occurring at lower densities and habitats containing abundant snowshoe hare populations being more patchily distributed than in the taiga. Hare densities in the taiga ranged from 0.2/ha at the low to 14.7/ha at the peak (Ward and Krebs 1985). In the

western United States, hare densities ranged from 1.0/ha to 1.8/ha (Koehler 1990, Hodges 2000), whereas hare densities in conifer-dominated regeneration (sapling and pole) in our study ranged from 1.5/ha to 2.4/ha. Regenerating sapling and pole forest constituted ≥46% of our study area, representing more contiguous habitat and supporting higher hare densities than in the western United States. Maine and nearby Nova Scotia contain similar forest communities; although optimal winter snowshoe hare habitat in Nova Scotia was only 11.3% of the study area (Parker 1981), this area supported high hare densities (10/ha; Parker et al. 1983). Thus, generalizations about southern lynx populations based on information from western studies should be viewed with caution, especially when applied to the southeastern portion of lynx range.

The current abundance of conifer sapling forest in our study area resulted from large areas (>100 ha) of salvage harvesting using clear-cut and herbicide techniques during a spruce budworm epizootic in the mid-1970s and early 1980s. In 1989, the Maine legislature enacted the Maine Forest Practices Act, which placed restrictions on the size of clear-cuts. These restrictions resulted in a shift from clear-cutting towards partial and shelterwood harvesting in northern Maine, with partial harvesting becoming the predominant forest harvesting method (McWilliams et al. 2005). Increasingly, land ownership in northern Maine is shifting from forest industry owners to investment groups. It is unknown how this changing landownership pattern will affect the stability of the land base actively managed for forestry (McWilliams et al. 2005), but it offers the potential for permanent loss of forested habitat for lynx and other wildlife species. Further study is needed to determine if the change in forest management practices and landownership will provide sufficient snowshoe hare habitat to sustain lynx in Maine.

## MANAGEMENT IMPLICATIONS

The importance of conifer and mixed-conifer sapling forest, especially to female lynx and the potential importance of mature conifer for travel should be considered when developing forest management plans for lynx. Therefore, we recommend forest management strategies that 1) provide

a temporal and spatial mosaic of conifer-forest age classes to ensure a component of regenerating and mature conifer forest on the landscape, and 2) maintain contiguity of habitat, because this will facilitate travel between suitable habitats and benefit lynx and other species that are dependent on interior forest conditions. Our findings suggest that maintaining well-distributed conifer-dominated sapling forests can sustain lynx densities approaching those of northern boreal forests during periods of hare abundance.

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