

Within-Stand Selection of Canada Lynx Natal Dens in Northwest Maine, USA

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ABSTRACT Canada lynx (*Lynx canadensis*) were listed as threatened in the contiguous United States under the Endangered Species Act in March 2000. Little information on lynx ecology at the southern extent of their range was available at the time of listing, and no ecological studies had been conducted in the eastern USA. Between 1999 and 2004, we investigated habitat selection at natal dens in northern Maine to address questions on the importance of forest conditions to denning requirements. We compared within-stand characteristics of 26 den sites to general characteristics of the stands containing dens. We used logistic regression to identify components within stands that distinguished natal dens from the residual stand and used the information-theoretic approach to select models that best explained lynx den-site selection. The top-ranked model had 2 variables: tip-up mounds of blown-down trees and visual obscurity at 5 m from the den ($w_i = 0.92$). Within-stand structure was useful for predicting lynx den-site selection in managed forests in Maine and suitable denning habitat did not appear to be limiting. (JOURNAL OF WILDLIFE MANAGEMENT 72(7):1514–1517; 2008)

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The listing of Canada lynx (*Lynx canadensis*) as a threatened species under the United States Endangered Species Act (U.S. Fish and Wildlife Service 2000) was based largely upon a decline in the species' presumed historic range in the conterminous United States. Human-induced modification of forest conditions was among the factors identified as contributing to the decline. Murray et al. (2008) describe the perception that lynx denned in mature forest as weak and, with the exception of Slough (1999; $n = 39$), is based on small sample sizes (Bernie 1974, Koehler 1990, Squires and Laurion 2000). Only 2 studies investigated lynx dens in the southern extent of their range (Koehler 1990, Squires and Laurion 2000), and no research on lynx denning has been conducted in the eastern portion of their range. Based on Slough's (1999) findings in the northern boreal forest, Murray et al. (2008) speculated that cover was the primary habitat attribute selected by lynx for denning, and the presumed association between mature forest and lynx den sites was spurious. As part of a long-term ecological study of lynx in northwest Maine, USA, we investigated natal-den site selection of lynx at the southeastern extent of their range in North America. Our objectives were to describe within-stand habitat features associated with lynx dens and to develop a model to assess lynx den habitat. We intended to evaluate the hypothesis that within-stand structure could be used to predict lynx den-site selection in our study area.

STUDY AREA

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). Our study area encompassed 4 townships (386 km²) in the Musquacook lakes region of northwestern Maine, with our capture effort focused in the 2 southern townships (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 red cedar (*Thuja occidentalis*) and ridges dominated by sugar maple (*Acer saccharum*) and birch (*Betula* spp.). Much of the area (approx. 46% or 175 km²) was clear-cut in the 1980s to salvage trees affected by a spruce-budworm (*Archips fumiferana*) epizootic and to prevent further expansion of the budworm.

METHODS

Lynx capture and monitoring methodology were described by Vashon et al. (2008a). We located lynx den sites by intensive aerial telemetry monitoring of radiocollared female lynx from mid-May to early June and confirmed natal den sites by ground radiotelemetry where the investigator stalked within sight of the den; presence of kittens confirmed the den site. We recorded den site coordinates

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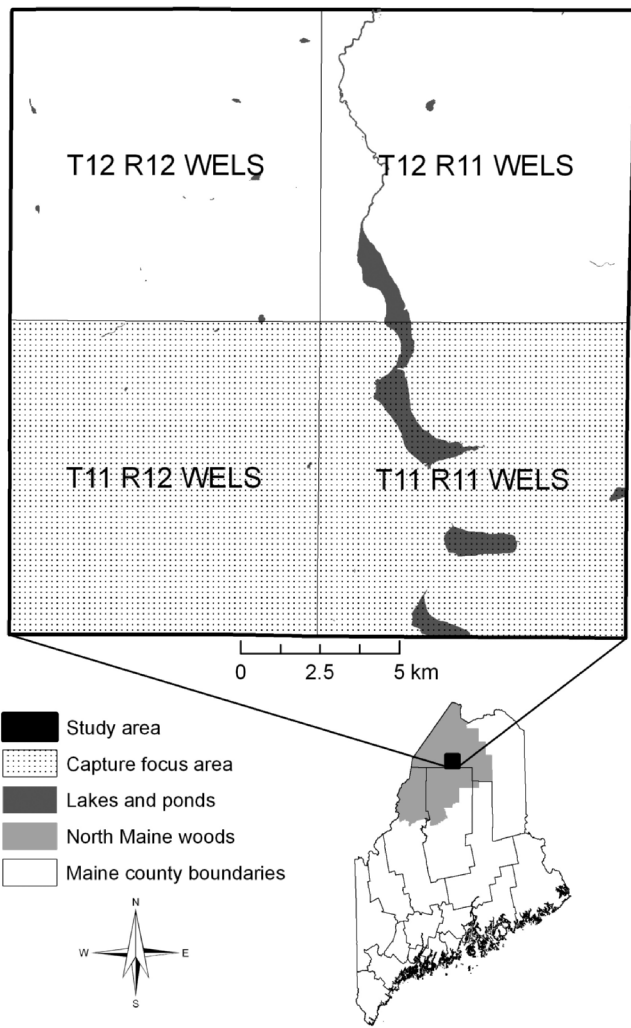


Figure 1. Map of the Musquacook Lake lynx study area in northern Maine, USA, 1999–2004. The study area encompassed 4 townships (inset; 386 km²) in the North Maine woods.

(Universal Transverse Mercator) with a Global Positioning System unit. We estimated distance between dens using the Distance Between Points (Within Layer) tool in the Hawth's Tools Extension for ARC/INFO Geographic Information System (GIS) Version 9.2 (Beyer 2004).

We assigned den sites a habitat class based on a GIS base layer we developed for describing habitat conditions obtained by using stand-type data from the 3 landowners within and surrounding the study area. These vector coverages were derived from aerial photo interpretation at a scale of 1:15,840. Landowners 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 (Vashon et al. 2008b). We sampled habitat attributes after the female lynx and kittens left the den site vicinity, typically in August. Within-stand sampling protocol followed methodology used by Brooks et al. (1998) where the den site was the center of the first sample plot and

Table 1. Habitat classes of radiomarked lynx dens in western Maine, USA, 1999–2004.

Habitat class	Ht class	% of study area	No. dens
Conifer-dominated sapling	3.0–6.1 m	12.9	12
Mature forest	>12.2 m	15.0	5
Seedling	0.0–3.0 m	14.5	4
Deciduous-dominated sapling	3.0–6.1 m	7.7	2
Pole	6.1–12.2 m	3.7	1
Conifer mature-sapling	Mixed	10.2	1
Deciduous mature-sapling	Mixed	18.9	1

up to 9 additional plots were sampled, depending on stand size, at 100-m intervals along a random azimuth. We estimated basal area and volume of tree species using 0.025-ha fixed plots (Brooks et al. 1998) and counted number of tip-up mounds of blown-down trees within each plot. We estimated volume of coarse woody debris (CWD) by species, decay class, size class, and whether on or off the ground using methodology developed by Brown et al. (1982) and modified for northern New England by Gore and Patterson (1986). We chose a sampling protocol that would discriminate between multiple types of CWD because we hypothesized that larger CWD that was above-ground and solid would provide better den structure than smaller CWD that was on the ground and decayed. We estimated visual obscuration using a 2-m cover pole with 2 readings each from random azimuths at 10 m and 5 m from plot center (Nudds 1977, Griffith and Youtie 1988, Haukos et al. 1998). We estimated hardwood and softwood stem density at each site within 2 15-m × 0.5-m plots originating from plot center (Litvaitis et al. 1985) and groundcover using 1-m² plots at 3-m intervals along 2 15-m transects, counting projecting plants at intersections of small frames (10 × 10 cm) at 0.5-m height (Ferron and Ouellette 1992). We estimated canopy closure at plot centers and 2 random sites 5 m from plot centers using a spherical densitometer according to methodology described by Ferron and Ouellette (1992).

We used logistic regression to predict within-stand habitat selected by lynx for denning. We selected variables for regression analyses based on hypothesized biological importance for den site selection and univariate *t*-tests at *P* < 0.05 (Table 2). We removed models containing coefficients with odds ratios < 1.0 (95% CI) from further analysis. We used Akaike's Information Criterion with a small-sample bias correction (AIC_c) to select the most parsimonious models (Burnham and Anderson 1998), and we calculated model likelihoods and AIC_c weights (*w_i*) for each model.

RESULTS

We located 27 natal den sites from 12 individual lynx between 1999 and 2004. We found den sites within conifer-dominated sapling stands (*n* = 12), mature forest (*n* = 5), seedling (*n* = 4), deciduous-dominated sapling stands (*n* = 2), pole-sized stands (*n* = 1), conifer mixed mature-sapling

Table 2. Variables measured at lynx den sites and residual stands in western Maine, USA, 1999–2004.

Variable	Den		Nonden		P
	\bar{x}	SE	\bar{x}	SE	
Canopy closure	32.10	5.2	26.0	3.5	0.34
Tip-up mounds ^a	4.27	0.55	2.34	0.27	0.003
Basal area	13.53	2.29	12.65	1.45	0.75
Deciduous SCU ^b	11.65	2.72	10.17	1.69	0.65
Conifer SCU	31.90	4.22	25.91	1.69	0.22
Total SCU	43.55	3.76	36.10	1.68	0.07
Cover at 5 m ^c	4.23	0.18	3.49	0.17	0.004
Cover at 15 m	4.90	0.04	4.80	0.04	0.09
CWD total ^d	384.95	49.30	258.24	21.62	0.02
CWD solid off-gd ^e	148.24	32.20	55.24	10.75	0.004
CWD decayed off-gd	105.65	18.70	48.04	7.02	0.004
CWD solid on-gd ^f	131.01	22.20	124.5	13.25	0.80
CWD decayed on-gd	46.64	11.30	29.88	9.41	0.27
Herbaceous cover	7.50	1.80	12.90	1.40	0.02
Humus	81.80	2.40	77.70	2.40	0.22
Ligneous cover	10.30	1.70	9.40	1.40	0.70

^a Tip-up mounds are root balls of blown-down trees.

^b SCU = stem cover units.

^c Distance at which horizontal cover was measured.

^d CWD = coarse woody debris.

^e off-gd = off the ground.

^f on-gd = on the ground.

($n = 1$), and deciduous mixed mature–sapling ($n = 1$; Table 1).

We evaluated 4 models for den site selection at the within-stand scale (Table 3). The model with the greatest support ($w_i = 0.92$) had 2 variables: visual obscurity at 5 m (estimate = 1.289, SE = 0.466) and tip-up mounds of downed trees (estimate = 0.557, SE = 0.201). The remaining 3 models did not have enough support to warrant acceptance.

DISCUSSION

As speculated by Murray et al. (2008), our analyses of lynx den-site selection suggest that within-stand structure is important and can be used to predict lynx den site selection. Squires et al. (2008) reported that lynx in Montana, USA, denned in stands with higher horizontal cover and CWD than was generally available, but that these dens were usually found in mature stands in their study areas, even though they also found abundant CWD in younger stands. Squires et al. (2008) stated that CWD alone was an insufficient predictor of den site selection. Coarse woody debris was not

a useful predictor of lynx den-site selection in our study area, despite its abundance. The combination of tip-up mounds of blown-down trees and visual obscurity represented the within-stand characteristic predictive of lynx den sites in our study area. Our results suggest that lynx select the densest available cover for den sites. Tip-up mounds occur when trees fall over and uproot. These blown-down trees are the primary source for CWD, and the resultant canopy opening typically promotes understory growth and horizontal cover. Thus, an abundance of tip-up mounds appears to indicate availability of within-stand structure that provides cover. All of the lynx we observed found denning sites in their usual home ranges (i.e., they did not have to search more widely on the landscape); thus, we do not believe that suitable denning habitat was a limiting factor in our study area. We believe lynx conservation measures in the northeast United States should focus on providing suitable habitat for snowshoe hare (*Lepus americanus*), the primary prey of lynx, and be less concerned with den habitat at the stand level.

We recognize that by including multiple natal-den observations from individual lynx in our analyses we violated the assumption of independence of observations. We used information from 26 natal dens of 12 individual female lynx in our analyses; individuals contributed 1 ($n = 5$; 19%), 2 ($n = 2$; 15%), 3 ($n = 3$; 35%), and 4 ($n = 2$; 31%) dens to our dataset. One lynx appeared to reuse a den. This animal apparently lost its initial litter in 2001 and re-bred after abandoning the den site, returning to the den it had used the previous year. We did not include the second year's observation in our analyses. Distance between natal dens for lynx that contributed multiple observations to our study ranged from 41 m to 5,028 m; the median distance ($n = 23$ pairs) was 1,938 m. We considered employing various modeling (see Squires et al. 2008) and subsampling methods to address this issue, but given the low number of animals in our sample we concluded that it would be more informative to use all of the data and allow the reader to interpret our results with caution.

MANAGEMENT IMPLICATIONS

We recommend that land managers in the northeast United States not focus on den habitat at the stand level. Within-stand structure was associated with lynx den-site selection in managed forests in Maine and silvicultural prescriptions can facilitate development of this structure through retention of

Table 3. Odds ratios, 95% confidence intervals, Akaike's Information Criterion value adjusted for small sample size (AIC_c), change in AIC_c value from the top model (ΔAIC_c), Akaike weight (w_i), model likelihood [$L(g_i|x)$], and number of parameters (K) for within-stand habitat models describing Canada lynx den sites in northwest Maine, USA, 1999–2004.

Model	Odds ratio	Upper 95% CI	Lower 95% CI	AIC_c	ΔAIC_c	w_i	$L(g_i x)$	K
Cover at 5 m	3.63	9.1	1.5	58.84	0	0.92	1	2
Tip-ups ^a	1.75	2.6	1.2					
Cover at 5 m	2.93	6.2	1.4	64.56	5.72	0.05	0.06	2
CWD ^b	1.01	1.02	1					
Tip-ups	1.54	2.1	1.1	67.07	8.23	0.02	0.02	1
Cover at 5 m	2.5	4.9	1.3	68.31	9.46	0.01	0.01	1

^a Tip-ups represent root mounds of blown-down trees.

^b CWD represents above-ground coarse solid woody debris >7.5 cm diam.

large-diameter snag trees as future sources of deadfall. However, female lynx home ranges encompass many different stands over several square kilometers; thus, even in an intensively managed forest landscape, suitable den sites should be available to individual females.

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