# Canada Lynx Assessment

**Maine Department of Inland Fisheries and Wildlife**

**Research and Assessment Section**

**Bangor, ME 04401**

Jennifer Vashon, Scott McLellan, Shannon Crowley,

Amy Meehan and Ken Laustsen[1]

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[1]Maine Forest Service

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# INTRODUCTION

Species Assessments are written by biologists in the Research and Assessment Section of the Maine Department of Inland Fisheries and Wildlife (MDIFW). These Assessments reflect the current state of knowledge about a particular species, or group of species, and are one of the core elements in MDIFW's species planning process. Assessments are used by public working groups and biologists to draft species' management goals for the next 15 years. They also serve as a reference for biologists and the general public interested in reviewing the ecology, management, or public use of a particular species. Assessments are based on the best available scientific information and the field experiences and judgments of professional wildlife biologists.

Species assessments cover subjects pertinent to a species' management in 5 sections. The Natural History section discusses biological characteristics of the species and important interactions with other species. The Management section contains historical and present-day records of regulations, management goals, and objectives. The Habitat and Population sections, in addition to reporting habitat relationships and historical and present-day information on numbers and trends, provide future projections for the species and its habitat. The assessment also includes a section that discusses public interest and use of a species from an historical and contemporary perspective, and speculates on future public use of a species. Finally, the Summary and Conclusions summarize the major points of the assessment.

The majority of information in this assessment is based on recent studies of lynx and snowshoe hares in Maine when there was an abundance of optimal habitat. Although the number of lynx in Maine has fluctuated, recent information is informative in assessing the upper bounds of lynx numbers. Our knowledge of the ability of lynx to persist when ideal habitat conditions are less abundant is limited to inference from historical data and studies outside Maine.

# NATURAL HISTORY

Description

The Canada lynx (*Lynx canadensis*) is a medium-sized cat that averages 33.5 inches (85 cm) in length and 25 pounds (11 kg) for males and 32 inches (81 cm) in length and 19 pounds (8.6 kg) for females (MDIFW unpublished data). Their winter coat is light gray and faintly spotted, and their summer coat is much shorter with a reddish-brown cast. Physical attributes that characterize lynx include: long ear tufts, distinct facial ruffs, long legs, large paws, and a black-tipped tail.

Although lynx often are confused with their close relative the bobcat (*Lynx rufus*), there are several identifying characteristics to differentiate between the two. Lynx are morphologically well adapted for living in colder climates with a lot of snowfall. They have large, well-furred feet, relative to their body mass that gives them low foot-loading (mass/in$^2$) to make traveling through snow easier. The bobcat has smaller feet with less fur that makes traveling in the snow more difficult. Lynx tend to weigh less than bobcats but can appear larger due to their noticeably longer legs, larger paws, and dense fur. Both lynx and bobcats have tufts of hair extending from the tips of their ears and facial hair extending down from their cheeks, but both the ear tufts (1-2 inches for lynx, absent to 1 inch for bobcat) and facial ruff are noticeably more prominent on lynx. The fur of a bobcat is generally more spotted than that of lynx. In addition, the fur on the lower portion of the rear hind leg on bobcats is generally dark charcoal gray to black, while on a lynx it is a light tan or beige. Finally, the tip of a lynx tail is completely black, while the tip of a bobcat's tail is black on top and white underneath. The dorsal side of a bobcat's tail often has several black bars running perpendicular to the tail length that are absent in lynx (Figure 1.1).

**Figure 1.1.** Canada lynx (left) are distinguished from bobcats (right) by longer ear tufts and facial ruff, shorter and completely black-tipped tail, large feet, and more uniform coat color (less spotted, buff colored hind legs, grey underbelly).

Lynx and bobcats can interbreed. Hybridization between these two species has been documented in Maine, Minnesota, and New Brunswick (Schwartz et al. 2004). The physical characteristics of the hybridized individuals in Maine appear to be intermediate between the two species. Using molecular genetic data, seven hybrids were determined to have lynx mothers. One female lynx/bobcat hybrid in Maine was observed with kittens (Homyack et al. 2008). It is still not known to what extent hybridization occurs between the two species, but it has probably occurred at low levels, especially at the southern edge of lynx range and northern edge of bobcat range where lynx and bobcat come into contact.

Distribution

Lynx are common in the boreal forests of Alaska and Canada, and their distribution coincides with their primary prey - the snowshoe hare (*Lepus americanus*). Lynx in the conterminous United States are at the southern edge of their range and were once found in 14 northern states in the Cascade and Northern Rocky Mountains, Western Great Lakes, and New England (USFWS 2000). New York marks the southern edge of lynx eastern historic range that includes Maine, New Hampshire, and Vermont. Although lynx were observed as far south as Pennsylvania (Hoving 2001), these observations were deemed to be dispersing individuals (USFWS 2000). Until recently, only five states (Maine, Washington, Montana, Minnesota, and Colorado) in the conterminous United States supported a resident breeding populations of lynx (Figure 1.2). Recent observations of lynx in Vermont and kittens in New Hampshire suggest that lynx are returning to former portions of their range in New England. Lynx there are part of a larger population that includes southern Quebec, most notably the Gaspe Peninsula, and western New Brunswick (Caroll 2005, Hoving et al. 2005). Herein we refer to lynx and hares as northern if they occur in the boreal forests of Canada and Alaska and as southern if they occupy forests in southern Canada and the conterminous United States.

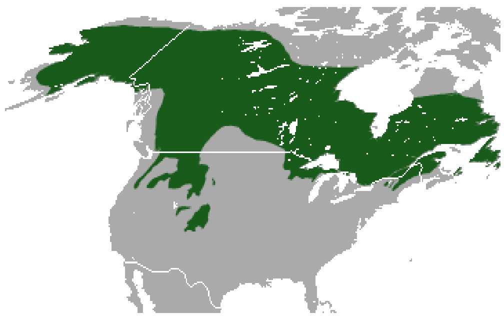


**Figure 1.2.** Geographic range (green) of Canada lynx from Chermundy IUCN Red List.

In Maine, written accounts from respected naturalists during the 1800s suggest that lynx were once found statewide but were more common in northern and western Maine (see Hoving 2001). By the late 1970s, lynx were found primarily north of Moosehead Lake, west of the West Branch of the Penobscot River, and West of the Upper Headwaters of the St. John and Allagash rivers (Hunt 1974). Recently, Hoving (2001) identified the past (1832-1998) distribution of Canada lynx in Maine from museum records, published articles, bounty records, interviews, and MDIFW winter snow track surveys (Figure 1.3a). The majority of these observations were in northern and western Maine. John Hunt (MDIFW furbearer biologist, personal communication) suggested that the southern observations may reflect the towns where a bounty payment was paid rather than where the lynx was harvested. It is also possible that these observations represented dispersing lynx.

More recently, we identified the current distribution of lynx in Maine based on reports of incidental takings of lynx (e.g., road mortalities and accidental trapping), illegal harvest, observations of lynx or lynx tracks by biologists or game wardens, radiotelemetry data (not included in Figure 1.3 see Figure 4.2), and snow track surveys collected from 1999-2010 (Figure 1.3b). Although there has been an increase in observations, there has been little change in lynx distribution with the majority of past and current observations occurring within 5 northern biophysical regions (Figure 1.3).

Food Habits

Unlike other carnivores, a lynx diet is narrow, comprised almost entirely of snowshoe hare. Thus lynx are considered a prey specialist and the status of lynx and snowshoe hare populations are closely tied (Elton and Nicholson 1942, Keith 1963, O'Donoghue et al. 1997, Slough and Mowat 1996). Snowshoe hares constitute between 43-100% of the biomass of the Canada lynx diet (Nellis et al. 1972, Brand et al. 1976, O'Donoghue et al. 1998). When snowshoe hares are abundant, lynx feed almost exclusively on hares (Aubry et al. 2000).

Although lynx will opportunistically feed on other prey sources, the variety of prey in the lynx diet increases during the summer months (Saunders 1963, Parker et al. 1983, Mowat et al. 2000). Alternate sources of prey include red squirrels (*Tamiasciurus hudsonicus*), northern flying squirrels (*Glaucomys sabrinus*), grouse species (*Bonasa* spp.), small mammals, small birds, and carrion (Brand et al. 1976, Parker et al. 1983, O'Donoghue et al. 1998, Aubry et al. 1999, Mowat et al. 1999). On rare occasions, lynx can kill both adult and juvenile white-tailed deer (*Odocoileius virginianus*), mule deer (*Odocoileius hemionus*), Dall sheep (*Ovis dalli*), red fox (*Vulpes vulpes),* and caribou (*Rangifer caribou*) (Stephenson et al. 1991, Fuller 2004, Poszig 2004). Of these food items, only red squirrels are a substantial alternate prey source when snowshoe hares are not abundant (Koehler 1990, Staples 1995, O'Donoghue et al. 1998, Aubry et al. 1999, Apps et al. 1999). At the southern extent of their range, lynx may exhibit a more generalist diet and use of habitat compared to more northerly-distributed lynx populations (Murray et al. 2008, Berg et al. 2012).

In Maine when hares were abundant, red squirrels appear to represent a relatively small proportion of a lynx winter diet. While backtracking lynx in a Maine study area, 89% of kills were snowshoe hare (n=25), 4% were red squirrels (n=1), and 7% were grouse species (n=2; MDIFW, unpublished data 1999-06).

Lynx hunt by actively walking, flushing, and chasing prey and by using resting/hunting beds to wait for prey to come close and then give chase (Saunders 1963). Lynx kill between 0.3-1.2 hares per day (Brand et al. 1976, O'Donoghue et al. 1998). Lynx will cache (hide and store their prey) snowshoe hare when hare populations and hunting success is high, but not when prey availability is low (Nellis and Keith 1968). During a 12-year study (1999-2010) of lynx in northern Maine, we documented lynx caching hares each winter (MDIFW, unpublished data).

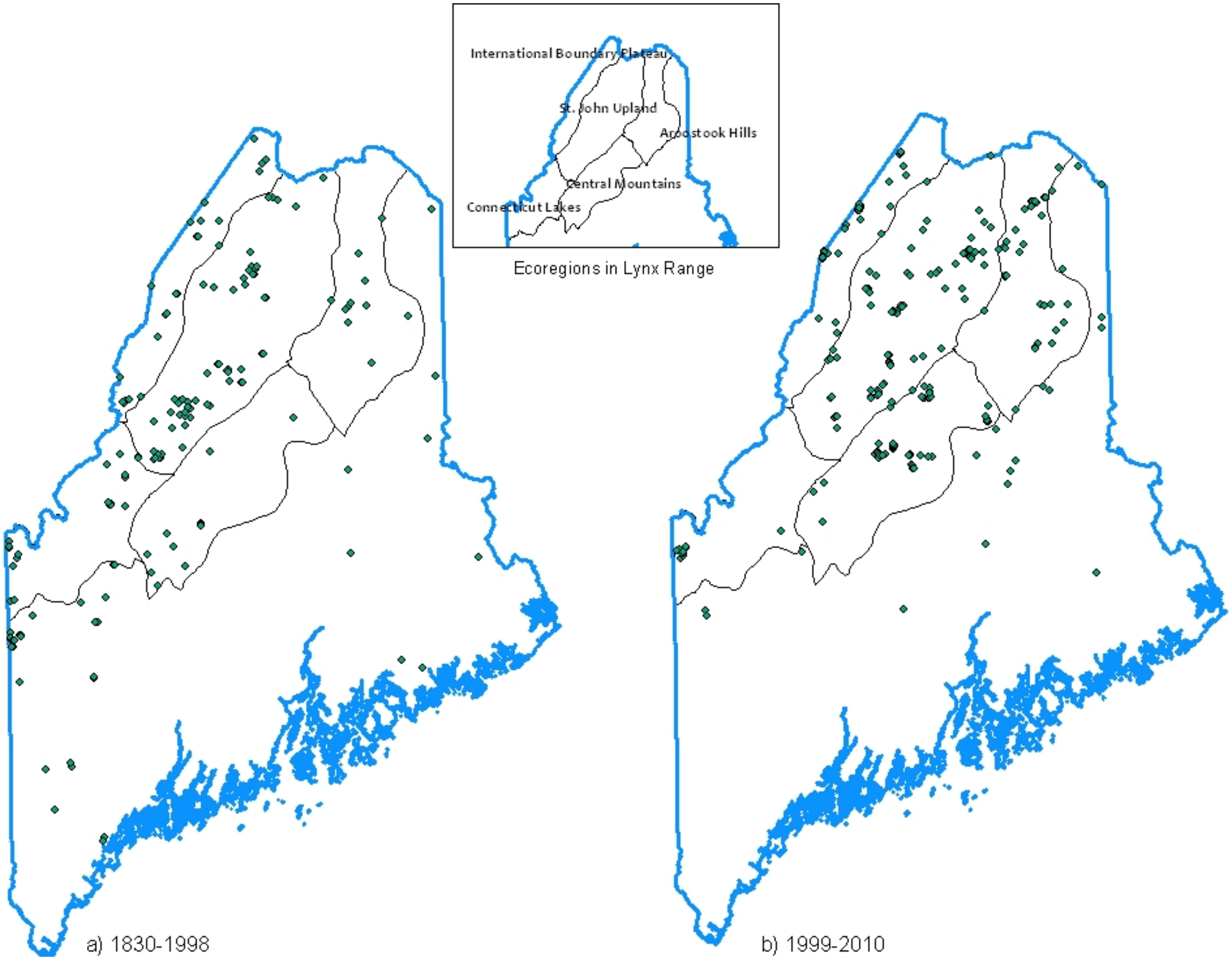
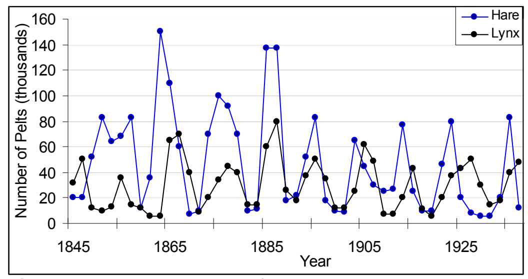



**Figure 1.3.** Observations of lynx from historical records (1830-1998) compiled by Hoving (a), and observations documented by MDIFW staff (not including lynx telemetry observations) between 1999-2010 (b) that identified 5 northern biophysical regions (inset) best represents both past (a) and current (b) lynx primary range in Maine.

During captive and field studies, individual lynx consumed between 170 and 200 snowshoe hares and a few small birds and mammals per year in Newfoundland (Saunders 1963). Despite the large number of hares killed by an individual lynx, only 9-26% of chases on snowshoe hare were successful (Nellis and Keith 1968, Brand et al. 1976, Parker et al. 1983). Parker et al. (1983) documented that hunting success was greater for lynx family groups primarily made up of a female with kittens but occasionally containing two adult animals.

Population Cycles

In the northern boreal forests of Alaska and Canada, around the start of each decade snowshoe hare populations reach high densities and then decline dramatically 8 to 11 years later (Elton and Nicholson 1942, Keith 1963, O'Donoghue et al. 1997, Slough and Mowat 1996). Several hypotheses to explain the snowshoe hare cycle include both hare-plant and hare-predator interactions. The hare-plant hypothesis proposes that the cycle is driven by changes in the nutritional quality and quantity of vegetation in response to hare browsing (Pease et al. 1979, Bryant 1981, Fox and Bryant 1984). However, several snowshoe hare populations have declined when food sources appeared to be sufficient (Keith et al. 1984, Krebs et al. 1986). The hare-predator hypothesis proposes that predators by themselves may be enough to drive the cycle (Krebs et al. 1992, O'Donoghue et al. 1997). Keith (1974, 1990) combined these two hypotheses and proposed that food shortages during a population peak in winter increases starvation rates and reduces reproductive output initiating the downturn in the hare cycle, while predation is then responsible for the continued decline and depression in hare numbers. Other studies have shown through experimental manipulation of food or predators that manipulation of just one of these factors fails to alter the numeric cycle in the hare population. Manipulation of both of these factors combined, however, does alter the cycle suggesting that a complex interaction among hares, plants, and predators may drive the population cycle (Krebs et al. 1995, Hodges et al. 1999).



Source: Hudson Bay Fur Company (1845-1937)

As a result of this hare population cycle, northern lynx populations also exhibit dramatic population fluctuations that are in delayed synchrony (1 to 2 years) with the snowshoe hare cycle (Elton and Nicholson 1942, Keith 1963, O'Donoghue et al. 1997). Over the course of a snowshoe hare cycle, lynx numbers may fluctuate 4-fold in central Canada (Keith et al. 1977) and up to 17-fold in northern Canada (Slough and Mowat 1996 and Poole 1994).

The decline or low in the lynx population is characterized by a decrease in productivity and kitten survival (Nellis et al. 1972, Brand and Keith 1979, Parker et al. 1983, Mowat et al. 1996) and an increase in mortality, emigration, and home-range size (Slough and Mowat 1996, Ward and Krebs 1985, Poole 1997). In northern populations where harvest of lynx is permitted, mortality from trapping can be additive to natural mortality when lynx populations are low. As a result when hare populations rebound, lynx populations can take more time to recover to former high densities (Brand and Keith 1979, Bailey et al. 1986, Poole 1994). Thus, harvest regulations for lynx are modified when hare populations are low (Bailey et al. 1986).

To date, in Maine and throughout the southern edge of their range, hare populations exist at lower densities than in the boreal forest and fluctuate at irregular intervals (Keith 1990, Hodges 2000, Scott 2009). Although these fluctuations do not follow a cyclic pattern, hare populations can fluctuation in synchrony across large geographic areas (Hodges 2000, Scott 2009). In northern Maine, the synchrony between two hare populations studied 34 miles apart (Scott 2009) was likely influenced by widespread habitat disturbance following an insect outbreak that created a more homogenous landscape of high quality habitat. In these stands, hare populations fluctuated from an average of 2.1 hares/2.5 acres to 1.0 hares/2.5 acres (2.5 acres = 1 ha; Table 1.1). In Canada and Alaska, hare densities ranged from 3 to 9 hares/2.5 acre during population peaks and <1.0 hare/2.5 acres during populations lows (Wolff 1980, Poole 1994, Slough and Mowat 1996, Krebs et al. 2002, Hodges et al. 2002).

**Table 1.1. Winter snowshoe hare densities (hares/2.5 acres) in Maine based on fecal pellet plots (Scott 2009).**

| | 2001-2006 | | | 2007-2009 | | |
|---|---|---|---|---|---|---|
| | Mean | SE | Average stand age | Mean | SE | Average stand age |
| Regenerating conifer clear cuts | 2.11 | 0.32 | 26 | 1.00 | 0.11 | 29 |
| Regenerating shelterwood/overstory removal | 0.92 | 0.05 | 10 | 0.76 | 0.1 | 13 |
| Regenerating mixedwood selective partial cut | 0.68 | 0.17 | 11 | 0.47 | 0.1 | 14 |
| Mature mixed forest (>40 years old) | | | | 0.23 | 0.01 | 39+ |
| Mature conifer forest (>40 years old) | | | | 0.21 | 0.05 | 39+ |

<u>Population Densities</u>

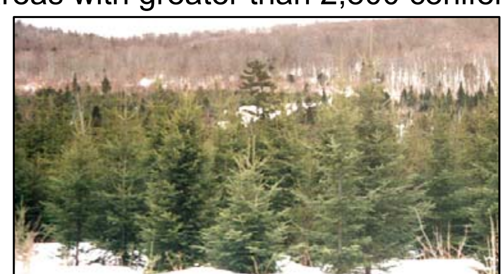
Several authors suggested that southern lynx populations would exist at densities similar to northern lynx populations when hare populations were low due to the patchy, transitional boreal forest found in southern lynx range (as summarized by Buskirk et al. 2000). In Maine, lynx abundances has fluctuated (Aldous and Mendall 1941, Hoving 2001), and until recently lynx densities likely existed at levels similar to northern populations during the cyclic low. Current lynx densities in Maine appear to be above historic levels and exceed densities reported for northern boreal populations at their cyclic low (Vashon et al. 2008a). Within the southern range, eastern lynx population densities (Parker et al. 1983, Vashon et al. 2008a) at least recently were also higher than those in the west (Koehler 1990, Apps et al. 1999). The more extensive and connected patches of spruce/fir forest often found on moist low elevation sites (e.g. spruce/fir flats) in the eastern U.S. likely provided higher quality habitat than spruce/fir forest of the western U.S. The recent abundance of young dense stands of softwood following an extensive disturbance event (i.e., spruce budworm outbreak) and salvage cutting in Maine mimicked large disturbance patterns observed in northern boreal forests that provide extensive areas of high quality habitat for snowshoe hares.

In northwestern Maine, when hare populations exceeded 2 hares/2.5 acres in budworm impacted spruce/fir stands, we estimated a minimum density of 4.5 adult lynx/39mi$^2$ (39mi$^2$=100 km$^2$) on our study site in 2003 (Vashon et al. 2008b). Based on unpublished demographic data from this study, we estimated a density of 5-9 kittens/39 mi$^2$, resulting in a total density of 9.2-13.0 lynx/39 mi$^2$. These densities were minimum estimates because it is likely that not all resident lynx were radiocollared and not all kittens were detected while backtracking (Vashon et al. 2008b). A model based on detections of lynx predicted similar lynx densities (3.0-6.0 lynx/39 mi$^2$) for areas with high probability of lynx occurrence, and in areas with lower probability of lynx occurrence, it predicted densities ranging between 0.4 and 2.0 lynx/39mi$^2$ (Simons 2009). We are currently estimating lynx densities when hares were less abundant in older regenerating conifer stands (1.0 hare/2.5 acre). Preliminary analyses suggest lynx densities have not changed significantly (David Mallett, University of Maine, personal communication).

Habitat Use

The most important factor determining habitat quality for Canada lynx is the abundance of snowshoe hare (as summarized by Aubry et al. 2000). Therefore, habitat that is ideal for snowshoe hare is also very important to Canada lynx. Throughout their range, snowshoe hares are highly associated with dense forest understories (Adams 1959, Brocke 1975, Wolff 1980, Wolfe et al. 1982, Litvaitis et al. 1985, Homyack et al. 2007) and appear to select dense understory habitats first for cover and second for food (Hodges 2000). Hares seek this dense understory for protection from predators, precipitation, and temperature extremes. Winter is the period of greatest stress for hares, thus dense cover takes on a greater importance during this time of year (Whittaker and Thomas 1983, Hodges 2000). In Maine, the forest stands that provide dense cover and are preferred by both snowshoe hare and lynx are regenerating sapling (15-35 years old) spruce-fir forest (Fuller et al. 2007, Vashon et al. 2008b). During a period (1999-2006) when hares exceeded 2 hares/2.5 acres in regenerating conifer sapling clearcuts, we studied lynx on a 400km$^2$ (156 mi$^2$) area in northern Maine where 25% of the forest was regenerating conifer sapling clearcuts and 42% of the forest supported >1 hare/2.5 acres (See Figure 2 in Vashon et al. 2008b).

At all spatial scales examined, both male and female lynx showed a strong preference for conifer and mixed conifer sapling forest (Fuller et al. 2007, Vashon et al. 2008b) that contained the highest winter snowshoe hare densities on our study area (Vashon et al 2008b). Although hare densities were greatest in areas with greater than 2,800 conifer stems (<3" DBH) per acre (7,000 conifer stems/ha; Fuller et al. 2004, Homyack et al. 2004, Robinson 2006), lynx avoided the densest stands (>5,600 conifer stems/acre or 14,000 conifer stems/ha; Fuller et al. 2007) that would be considered optimum for snowshoe hare (Litvaitis et al. 1985). Lynx encountered a similar number of hares in both moderately (2,800-4,450 stems/acre or 7,000-11,000 stems/ha) and



Regenerating conifer clearcuts provide ideal foraging habitat for Canada lynx in Maine.

densely stocked stands (>5,600 stems/acre) when hare numbers were relatively high, but were more successful hunting hares in less dense stands of young conifer (<5,000 stems/acre; Fuller et al. 2007). Habitat observations during telemetry flights of radiocollared lynx also showed a preference for moderately to densely stocked (>50% canopy closure) regenerating conifer or mixed conifer stands (5-25 ft tall or 1.5m to 7.5m; Vashon et al. 2005). Although most (94%) lynx locations occurred within a single habitat type, most of these (84%) were within 300 ft (90 m) of a different habitat type or feature, suggesting that edge habitats may be important to lynx (Vashon et al. 2005).

Adult female lynx need adequate habitat to give birth and raise their kittens. In Maine, forested stands with dense understories of conifer or deciduous trees or an abundance of fallen trees were used for denning (Organ et al. 2008). Den sites were often located on the edge of two stands of different ages or in dense regenerating conifer stands. These stands provide both optimal cover for kittens and access to prey. Older stands were more vulnerable to wind damage and provided down trees or root systems as cover. The increased number of fallen trees also opened the canopy to allow for woody-stem growth and resulted in dense cover to provide additional protection to kittens. Younger stands had high stem densities that are favored by snowshoe hare, and consequently, provide food for denning females. The close proximity of the two stand types enables the female to locate her den near a prey source, thus minimizing the time the female spends away from her kittens. In Maine, denning habitats do not appear to be a limiting resource (Organ et al. 2008).

Lynx used dense thickets (left) and depressions under downed logs or root systems (right) as “den sites” for giving birth to and raising their kittens.

Home Range

In an area where >40% of the forested habitat supported >1.0 hare/2.5 acres, lynx home ranges were small averaging 21 $mi^2$ (54 $km^2$) for males and 10 $mi^2$ (26 $km^2$) for females. Winter home ranges of males were only slightly smaller than summer ranges (17 $mi^2$ vs. 23 $mi^2$; 44 $km^2$ vs. 60 $km^2$). Conversely, female winter ranges were nearly 3 times larger than their summer ranges (15 $mi^2$ vs. 5 $mi^2$; 39 $km^2$ vs. 13 $km^2$). Although females were with kittens during both periods, the kittens were smaller and less mobile during the summer, which likely explains the smaller home-range size during this period (Vashon et al. 2008a).

Lynx, like many solitary carnivores, are less territorial when food is abundant. In Maine, each male shared a small portion (average 11%) of their range with at least 1 other male lynx. Female lynx had a lower tolerance for other female lynx, with only a few females (20%) sharing a portion of their range, and the amount of overlap was small (17%). However, every male shared a portion of his range with at one to three females, and every female shared most of her range with a male (Figure 2 in Vashon et al. 2008a).

In the northern boreal forest, lynx home-range size increases when hares decline below 1 hare/ha (Brand et al. 1976, Ward and Krebs 1985, Slough and Mowat 1996, Mowat et al. 2000), suggesting that hare densities above this level are needed to support lynx. In Maine when hares were abundant, male and female lynx home ranges were 2.5 and 2 times smaller, respectively, than the mean home-range size (58 $mi^2$ and 28 $mi^2$) reported for other southern lynx populations and were comparable to northern lynx populations (24 $mi^2$ and 12 $mi^2$) at the height of their population cycle (as summarized by Aubry et al. 2000). In the western United States, dense regenerating coniferous habitats that support high hare densities are more patchily distributed than in the east based on differences in topography, climatic conditions, soils, disturbance regimes, and forest successional pathways (Buskirk et al. 2000). Northern Maine's forests and perhaps other southeastern Canadian forests (Parker et al. 1983) likely provide more contiguous snowshoe hare habitat than the western U.S., and as a result lynx spatial use is more similar to northern lynx populations when hares are abundant (>1 hare/ha or 0.4 hare/acre).

<u>Reproduction and Reproductive Behavior</u>

Canada lynx breed in March, and kittens are born 60-70 days later in mid- to late-May. Female lynx can reproduce as yearlings, but usually only a small percentage of yearlings give birth to kittens, even when snowshoe hares are abundant (Mowat et al. 2000). Lynx select den sites in areas that have a large amount of horizontal structure and high visual obscurity (see Habitat Requirements). Without the presence of kittens, the actual den site is often not distinguishable from its natural surroundings. There is no excavation or alteration of the den site or the immediate surroundings. Lynx kittens may be located under a downed log, tip-up root system, or simple ground depression surrounded by dense vegetation or downed woody debris (MDIFW, unpublished data). The den is kept extremely clean with no feces or prey remains present at the site. At 8-10 weeks of age the kittens and the adult female begin to make larger movements away from the den site. Kittens remain with the adult female through the following winter before setting out on their own sometime in April/May prior to the adult female giving birth to a new litter.

Although kittens are typically born in May, during MDIFW's study in northwestern Maine, one female gave birth to a kitten in August. Radio-tracking in May and early June indicated that she had localized her activity to give birth. By mid-June before we could confirm the presence of kittens, she abandoned this area. We suspect the loss of her litter shortly after parturition induced ovulation and her receptivity to breeding again. To our knowledge, this is the first evidence of lynx producing two litters in one year.

In the boreal forest, litters generally average 4 kittens during cyclic highs for hares and decline to 1.0 to no kittens during hare lows (Poole 1994, Slough and Mowat 1996). In the Yukon, litters as large as 8 kittens were observed (Mowat and Slough 1998). In northwestern Maine when hares densities exceeded 2 hares/2.5 acres in regenerating clearcuts 18-35 years post-harvest (Scott 2009), most adult female lynx produced litters, and although litters averaged 3 kittens, litters of 4 or 5 kittens were also common (Vashon et al. 2005). Despite estimated hare densities of approximately 2 hares/2.5 acres, lynx productivity declined to 14% in 2006 (Table 1.2). From 2007-2009, hare densities declined to about 1 hare/2.5 acres within regenerating conifer clearcuts and remained at relatively low densities of <1 hare/2.5 acres from 2009-2011 (Harrison et al. *in press*). Correspondingly, only 2 of 15 female lynx (13%) were observed with kittens from 2007-2009. Despite that estimated hare densities remained below hares/2.5 acres in regenerating clearcuts during the winter of 2010 (Harrison et al. *in press*), all five adult female lynx that we were monitoring produced a litter of 2 to 3 healthy kittens (Table 1.2; MDIFW, unpublished data).

Table 1.2. Lynx mortality (≥1 years old) and productivity (litters/adult female) in a northern Maine study area and associated hare densities in regenerating conifer sapling clearcuts(CC), and shelterwood/overstory removals (SHW/OR).

| Year[a] | Total[b] | Dead | Mortality[c] | Adult Females | Females with kittens | CC[d] Hares/ 2.5 acres | SHW/OR[d] Hares/ 2.5 acres |
|---|---|---|---|---|---|---|---|
| 1999-00[e] | 6 | 3 | 50% | 1 | 100% | | |
| 2000-01 | 16 | 5 | 31% | 3 | 100% | | |
| 2001-02 | 19 | 2 | 11% | 4 | 100% | 2.22 | |
| 2002-03 | 19 | 4 | 21% | 9 | 100% | 1.80 | |
| 2003-04 | 24 | 5 | 21% | 7 | 86% | 1.85 | |
| 2004-05 | 23 | 5 | 22% | 9 | 78% | 1.79 | |
| 2005-06 | 33 | 4 | 12% | 5 | 80% | 2.29 | 0.87 |
| 2006-07 | 31 | 13 | 42% | 7 | 14% | 1.92 | 0.97 |
| 2007-08 | 18 | 1 | 6% | 7 | 29% | 1.19 | 0.65 |
| 2008-09 | 26 | 8 | 31% | 4 | 0% | 0.99 | 0.66 |
| 2009-10 | 25 | 9 | 36% | 4 | 0% | 0.80 | 0.64 |
| 2010-11[e] | 7 | 2 | 29% | 5 | 100% | 0.75 | 0.96 |
| 2011-12[e] | 1 | | n/a | 1 | 100% | 0.91 | 1.31 |

[a] Year is defined by birth pulse(i.e., May 1, 1999 to May 1, 2000).
[b] Total = number of lynx monitored (start of the year + new captures).
[c] Mortality of radiocollared lynx ≥1 year old is the inverse of Kaplain-Meier survival rates.
[d] Hare density (Scott 2009) and preliminary data (S. Olson, University of Maine).
[e] Sample size low (start or end of study (i.e., removing collars))

Throughout the southern edge of lynx range, lynx reproductive rates approached those of boreal lynx populations when hares were abundant. Similarly when hares populations were low, fewer lynx produced litters (Table 1.3). Studies in Montana and Colorado also observed fewer litters during the same period as Maine (John Squires, Rocky Mountain Research Station, personal communication; Shenk et al. 2008), suggesting some population synchrony across the southern range.

**Table 1.3. Lynx reproductive rates at the southern edge of their range when hares are abundant are are similar to northern lynx populations.**

| Location | Period | # Litters | Average litter size | Potential Litters | Productivity | Citation |
|---|---|---|---|---|---|---|
| ***Hares Abundant*** | | | | | | |
| Maine | 1999-05 | 34 | 2.74 | 38 | 89% | Vashon et al. 2005 |
| Minnesota | 2004-07 | 10 | 3.3 | 10 | 100% | Moen et al. 2008 |
| Montanna | 1999-06 | 57 | 2.3 & 3.2 | | | Squires et al. 2008 |
| Washington | 1986-87 | 2 | 2.25 | 2 | 100% | Koehler 1990 |
| Nova Scotia | 1977-80 | 25 | 3.6 | 37 | 68% | Parker et al. 1983 |
| Canada | | | >4.0 | | | Vashon et al. 2005 |
| ***Hares less abundant*** | | | | | | |
| Maine | 2006-10 | 8 | 2.25 | 27 | 30% | MDIFW unpub. data |
| Washington | 1980-83 | 0 | n/a | 12 | 0% | Brittell et al. 1989 |
| Colorado [a] | 2003-08 | 38 | 3.05 | 187 | 20% | Shenk et al. 2008 |

[a] Lynx were reintroduced in 1999 and litters were not produced until 2003

<u>Mortality</u>

Lynx have been documented to live as long as 15 years (Nava 1970); in Maine, to date one female and one male lynx lived 10 and 13 years, respectively (MDIFW, unpublished data). In Canada, when hares were abundant, lynx mortality rates were similar among 1 trapped (O'Donoghue et al. 2001) and 2 untrapped (i.e., trapping season closed for lynx, but furbearer trapping seasons remained open) lynx populations (Poole 1994, Slough and Mowat 1996). However when hares were scarce, a trapped lynx population in southwest Yukon experienced higher mortality rates (O'Donoghue et al. 2001). Where trapping seasons for lynx were closed, lynx had annual mortality rates of 8-11% and 0-22% during hare population peaks and 63%-75% and 0-60% during hare lows (Poole 1994, Slough and Mowat 1996). Adult mortality rates for southern untrapped lynx populations were similar to mortality rates for northern lynx populations at high hare densities (i.e., 0-22% mortality). In Maine, when hares were abundant (>2/2.5 acres), on average 20% of radiocollared lynx (≥1 year old) died each year. Between 2007 and 2010 when hares were scarcer (~1/2.5 acres), annual mortality rates averaged 29% and ranged from 6 to 42% (Table 1.2). Moen et al. (2008) and Squires and Laurion (2000) reported similar lynx mortality rates in Minnesota (13-25%) and Montana (33%).

Like elsewhere (Koehler 1990, Poole 1994, Slough and Mowat 1996, Squires and Laurion 2000, O'Donoghue et al. 2001), the primary sources of mortality for lynx in Maine were starvation and predation, accounting for nearly 68% of lynx deaths (MDIFW unpublished data; Table 1.4). Some starvation losses were likely associated with infestations of lungworm that may compromise respiration and the ability of lynx to chase and catch their prey (Dr. Jim Weber, University of Maine-pathologist, personal communication; see Disease section). Although Maine's carnivore community is diverse, it lacks the large carnivores of the west (wolves [*Canis lupus*], cougar [*Felis concolor*], and wolverine [*Gulo gulo*]) that have been observed to prey on lynx (Koehler 1990, Poole 1994, Slough and Mowat 1996, Squires and Laurion 2000, O'Donoghue et al. 2001). In Maine, 14 of 18 lynx that died from predation were killed by fisher (*Martes pennanti*) based on presence and location of pre-mortem puncture wounds found during necropsy and observations of fisher tracks, scat, caching behavior at the kill site. We weren't able to identify the predator for the other 4 predation losses, but we suspect one may have been killed by a coyote. We also suspect 9 other lynx were killed by fisher based on observations of fisher tracks and/or scat, caching behavior, and/or obvious kill site when we investigated the mortality, but were unable to confirm premortem puncture wounds because the carcass had been partially or completely consumed (McLellan et al. *in prep*). Despite the abundance of coyotes (*Canis latrans*) in northern Maine, coyotes do not appear to be an important source of mortality for lynx. Similarly, we have not documented lynx killing other lynx.

Table 1.4. Summary of lynx mortalities between 1999 and 2010 on a northern Maine study area.

| Cause of death[a] | No. of lynx |
|---|---|
| Predation | 18 |
| Suspected Predation | 9 |
| Starvation | 17 |
| Unknown | 8 |
| Legal Harvest in Canada | 7 |
| Illegal Harvest in Maine | 3 |
| Vehicles | 2 |
| Disease | 1 |

[a] Determined by investigating the deaths of tagged lynx.

Unlike other southern lynx populations (Moen et al. 2008, Shenk 2008), although 7 lynx were incidentally harvested in legal snares set for coyotes in Canada, human related causes of mortality in Maine were low (8%; MDIFW, unpublished data). Lynx have been fully protected from harvest in Maine since 1967, and the use of neck snares for coyote animal damage efforts in Maine has been illegal since 2003. However, hunting and trapping seasons remain open for bobcats and other furbearers (coyote, fox, marten, and fisher), and lynx are occasional caught in traps or shot by hunters. Because significant bobcat populations are in areas with few lynx (central, eastern and western Maine), the possibility of accidental shooting by bobcat hunters is lower. However, coyote, fox, marten, and fisher are common in northern Maine and trapping seasons are open for these species. Since 2000, 5 of 58 lynx caught in traps died as a direct result of accidental capture. These deaths occurred in "killer type" traps and not foot-hold traps. During the same period, 5 lynx were shot illegally, including one lynx shot by a hunter while in a trap (MDIFW, unpublished data; Table 2.3 in Management Section).

Although 27 lynx are known to have died when struck by vehicles (2 lynx/yr) in Maine between 2000 and 2011, only 1 radiocollared lynx was killed by a vehicle. A similar number of lynx were killed on unimproved logging roads with low traffic volumes and on paved roadways with higher traffic volumes and speeds (e.g., I-95, Routes 1, 2, 11, and 161). Although we have not yet determined the ages of all lynx struck and killed by vehicles, to date 5 were yearlings and 3 were 2 year-olds (MDIFW, unpublished data).

Kitten Survival

Lynx kittens remain with their mother for nearly a year (May to March). At the onset of the breeding season in March, the number of kittens observed traveling with their mother decreases indicating at least the temporary break-up of family groups (Saunders 1963, Brand et al. 1976, Parker et al. 1983, Poole 1995, Mowat et al. 1996).

Kitten survival rates observed in Maine were within the range reported for northern lynx populations, where most kittens survive their first year (Vashon et al. 2005). In the Northwest Territories and Yukon, between 50-90% and 66-83% of kittens survived their first year (Poole 1994, Mowat et al. 1996). Regardless of hare abundance on our northern Maine study area, nearly 80% of the kittens observed at the den were still traveling with their mother the following January and February (MDIFW, unpublished data; Table 1.5).

**Table 1.5**. Proportion of adult females traveling with at least one kitten in January and February and number of kittens that survived until at least February in northern Maine between 1999 and 2009.

| | June | | January and February | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Adult Females | | | | Kittens | | |
| Year | # litters | # kittens | No.[a] | No. with kits | Percent with kits | | Available[b] | Observed[c] | Survival |
| 1999-00 | 1 | 2 | 1 | 1 | 100% | | 2 | 2 | 100% |
| 2000-01 | 3 | 7 | 2 | 1 | 50% | | 5 | 2 | 40% |
| 2001-02 | 4 | 6 | 3 | 3 | 100% | | 5 | 5 | 100% |
| 2002-03 | 9 | 24 | 6 | 6 | 100% | | 17 | 14 | 82% |
| 2003-04 | 6 | 26 | 6 | 6 | 100% | | 26 | 18 | 69% |
| 2004-05 | 7 | 21 | 5 | 5 | 100% | | 13 | 11 | 85% |
| 2005-06 | 4 | 8 | 4 | 4 | 100% | | 8 | 7 | 88% |
| 2006-07 | 1 | 2 | 1 | 1 | 100% | | 2 | 2 | 100% |
| 2007-08 | 2 | 4 | 2 | 2 | 100% | | 4 | 3 | 75% |
| 2008-09 | 0 | 0 | -- | -- | -- | -- | -- | -- | -- |
| 2009-10 | 0 | 0 | -- | -- | -- | -- | -- | -- | -- |
| 2010-11 | 5 | 12 | 5 | 5 | 100% | | 12 | 11 | 92% |
| **1999-2011** | **42** | **112** | **30** | **29** | **97%** | | **82** | **64** | **78%** |

[a] Number of adult females alive in January and February

[b] Number of kittens observed and marked at den site minus kittens whose mother died

[c] Number of kittens observed traveling with their mother during telemetry flights and/or backtracking surveys

Dispersal and Long Distance Movements

Both juvenile and adult lynx can travel great distances, especially when prey populations are low (Ward and Krebs 1985, Slough and Mowat 1996, Poole 1997). In Montana, Brainerd et al. (1985) recorded a 616-km (383 mi) movement by an adult male. In the Yukon Territory, 17 lynx traveled distances of more than 100 km (62 mi), 11 traveled over 500 km (311 mi), and 2 traveled over 1,000 km (621 mi) (Slough and

Mowat 1996). In Northwest Territories, 37 of 60 radiocollared lynx dispersed. Yearlings and kittens made up the largest number of dispersing individuals, and both male and female lynx dispersed. During two winters following the decline in snowshoe hare numbers, adult dispersal was observed (Poole 1997).

In Maine between 1999 and 2010, at least 10 lynx (8M, 2F) dispersed into Canada, and 3 lynx made long distance movements within Maine that include a trip to Monroe and Palmyra (Figure 1.4). Most of these animals (80%) were adults that had established home ranges in Maine including an adult female that gave birth to 2 litters in Maine before moving to Canada. We lost radio contact with one lynx in Canada, and a lynx marked with ear tags as a kitten was struck by a vehicle in Quebec as a subadult. In addition, 8 lynx equipped with eartags or radiocollars in Maine were later incidentally captured and killed in neck snares set for coyotes in New Brunswick and Quebec. Straight-line distances from the study area and furthest relocation for these lynx ranged from 30 mi (49 km) to 249 mi (400 km; Figure 1.4).

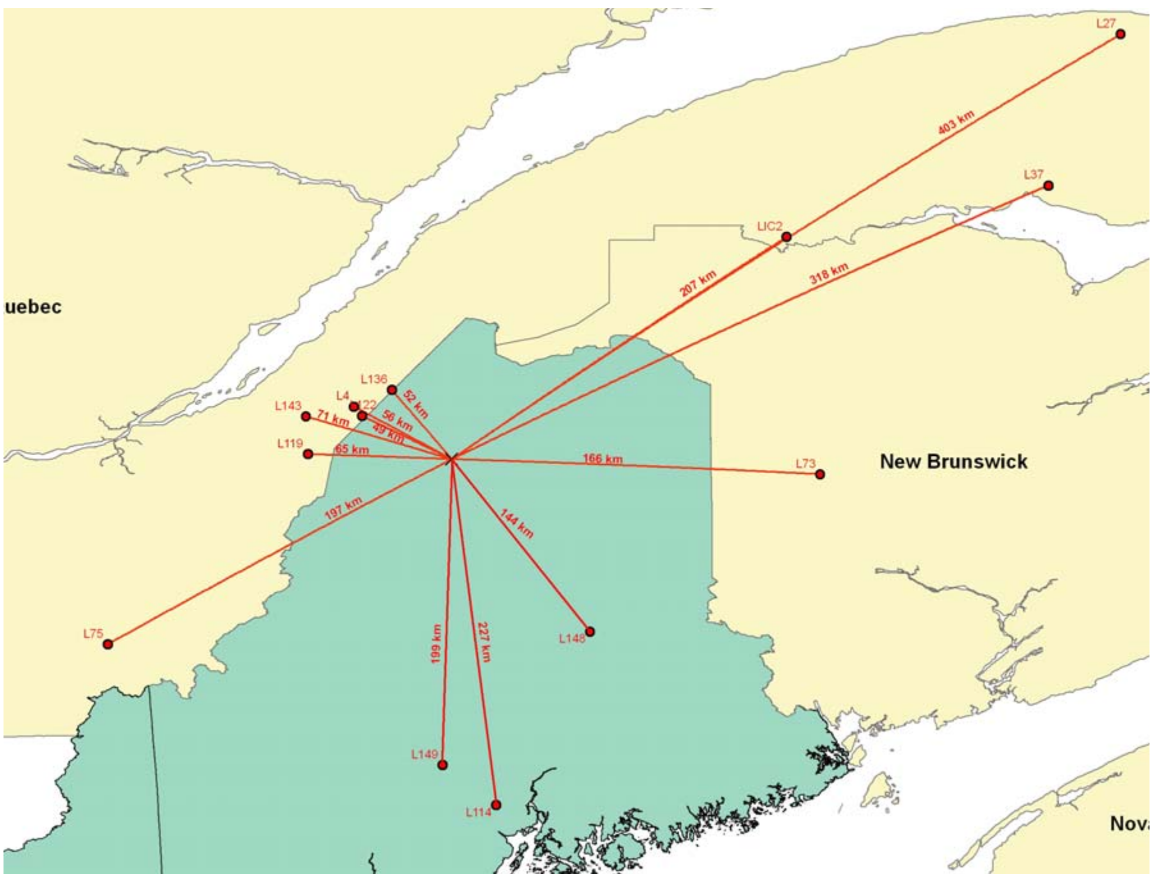



**Figure 1.4.** Movements of radiocollared lynx from the Maine study area. The longest straight-line movement was 249 miles (400 km; MDIFW, unpublished data).

<u>Social Interactions</u>

Male lynx are generally solitary animals except during the breeding season in early spring when a male will pair up with a female. Groups of lynx usually consist of a female and her kittens, although pairs of adults have been observed (MDIFW, unpublished data). Kittens remain with their mother for 10-11 months before separating. Hunting success increases with group size (Parker et al. 1983), and observations have suggested that family groups will hunt for prey cooperatively (Barash 1970; Parker et al. 1983; Jack McPhee, MDIFW telemetry pilot, personal communication). Male lynx appear to be tolerant of kittens during the breeding season. In Maine and southwest Yukon, an adult male has been observed with a female and her kittens in late spring (Jack McPhee, MDIFW telemetry pilot, personal communication; Mowat and Slough 1996). Although infanticide, where males kill unrelated or presumably unrelated juveniles, has been documented in some felids most notably African lions (*Panthera leo*), it is rare for lynx and bobcat (Anderson and Lovallo 2003).

Mowat and Slough (1996) suggest that female offspring will often remain in or near their mother's home range and interact occasionally with their mother up to several years after their initial separation. Although Poole (1995) did not know the genetic relationship of lynx in his study, he suggested females that shared their ranges were likely related. In Maine, we have not yet investigated the genetic relationship of lynx that shared their home ranges, but our observations also suggest greater tolerance among related individuals. During an aerial telemetry flight, we observed an adult female and her kittens in close proximity to 2 subadult lynx that we suspected were her kittens from the previous year (Jack McPhee, MDIFW telemetry pilot, personal communication). Interestingly, one of the subadults was a male.

Poole (1995) speculated that lynx maintain separate home ranges by passive scent-marking and not by direct, aggressive interactions. Lynx also communicate aggression with a low warning growl. In the Yukon, few fighting injuries were observed on a large sample of lynx captured (Mowat and Slough 1996), and in Maine, home range fidelity, lack of fighting injuries on study animals, and observations of scent-marking while backtracking lynx (MDIFW, unpublished data) provide further support of this hypothesis of passive territoriality. In addition to aggressive warning growls, vocalizations between male and female lynx during the mating period include a long wailing call, and family groups locate each other with a series of short barks. In Maine, we have heard all three calls with the only notable difference being that we have also heard adult males use the short bark during the mating period (MDIFW, unpublished data).

<u>Disease</u>

Disease in wild populations of Canada lynx has not been extensively studied. There are no known incidences of rabies virus in Canada lynx; however, a small number of bobcat cases have been documented. From 1960 to 2000, bobcats accounted for only 488 of 185,014 (<1%) documented rabies cases (Krebs et al. 2003). Although there is potential for lynx to be infected with the rabies virus, it is probably extremely rare. Another study collected 215 lynx samples from six areas in western North America (Montana-Alaska) and tested whether lynx were exposed to pathogens that included feline parvovirus (FPV), feline caronavirus, canine distemper virus, feline calicivirus, and feline herpesvirus (Biek et al. 2002). Exposure to FPV was detected in all areas sampled. Evidence for exposure to each of the other pathogens was found in at least one area, but no pathogen, including FPV, exceeded 8% of the total samples tested. A subset of samples was also tested for feline immunodeficiency virus, but all samples tested negative. The authors concluded that viral exposure to free-ranging wild lynx populations is relatively rare. Conversely, parasites in lynx may be more common. In Maine, we have documented lungworms *(Troglostongylus wilsoni)* in emaciated radiocollared lynx that died of presumed starvation (Jim Webber, personal communication, University of Maine; MDIFW unpublished data).

*Troglostongylus wilsoni* is a nematode that infects the lungs of lynx and bobcats (Sarmiento 1956, Van Zyll de Jong 1966, Kumar 1974, and Reichard 2004). Snails and slugs pick up the eggs of *T. wilsoni* from infected feces. The eggs lie dormant in the muscle of small mammals and birds that come in contact with infected snails and slugs. Lynx become infected when they consume infected prey. The eggs develop into larvae in the intestine of lynx and then enter the bloodstream and travel to the lungs. In the lung, the larvae mature into adult worms and reproduce. When infestations are high, the lynx will cough and swallow the eggs, the eggs are excreted, and the cycle is completed (McGuire 2009). In heavily infected animals, the worms infect the airway causing edema of the lung (Kumar 1974). Lynx with heavy infestations have difficulty breathing, which likely reduces their ability to capture prey, and thus succumb to starvation (Jim Webber, University of Maine, personal communication). Although lynx in Maine have died from lungworm infestations, we do not know how prevalent infestations are or what the dynamics of this disease event are (MDIFW, unpublished data).

Studies have also tested lynx exposure to parasites that include *Trichinella nativa* and *Toxoplasma gondii*. *T. nativa* is a common parasite (species of roundworm [Nematoda]) that infects carnivores and omnivores, including humans, and causes Trichinosis. These parasites are spread through the consumption of infected meat. Twenty-one percent of 1,065 lynx samples collected in Alaska from 1989-1993 contained *T. nativa*, and prevalence increased with the age of the lynx from 4% for kittens to 59% for adult lynx >5 yr in age (Zarnke et al. 1995). Overall prevalence of *T. nativa* did not differ among male and female lynx. *T. nativa* is rare in snowshoe hares, and the authors hypothesize that prevalence of this parasite would be higher during hare lows when lynx are more dependent on alternate prey sources.

*Toxoplasma gondii* is a protozoan parasite for which felids are the only known primary host species. A multitude of species, including humans, are known to act as secondary host. It can spread to lynx by ingestion of food or water contaminated with feces or by direct ingestion of infected tissues. Overall antibody prevalence of *T. gondii* in 255 lynx carcasses collected in interior Alaska was only 14% (Zarnke et al. 2001). In contrast, antibody prevalence in 131 samples of bobcats in Pennsylvania collected from 2000-2002 was 83% (Mucker et al. 2006). Zarnke et al. (2001) hypothesized that the relatively low incidence of this parasite in lynx can be explained by the low exposure potential of lynx populations to domesticated felids.

Limiting Factors

For wildlife populations to sustain themselves, new animals are needed to replace animals that die. Alternatively, populations can increase when the number of new animals entering the population exceeds mortality. Thus, conditions need to be adequate for juvenile animals to survive to adulthood (i.e., recruitment) and to support new animals moving in (i.e., immigration). We considered the following factors that may limit lynx populations in Maine: hunting and trapping, vehicle collisions, predation, disease (i.e., lungworm), prey abundance, competition for available prey, climate, and habitat.

Although hunting and trapping can limit wild populations, the USFWS concluded that the comparatively low numbers of lynx in the contiguous United States was not a result of overtrapping or hunting in the past, but occurred because lynx and their prey are naturally limited by marginal habitat, topography, and climate (USFWS 2000). More recently, lynx have been protected from hunting and trapping across their range. Despite the closure of trapping and hunting of lynx in Maine, some argue that accidental catches or shooting of lynx by trappers and hunters limits Maine's lynx, especially when their numbers are low. In 2009, a Federal Judge concluded that the incidental take of lynx by trappers in Maine is not limiting Maine's lynx population as evident by the ability of lynx to persist and even increase in the continued presence of trapping seasons for other common furbearers (Animal Welfare Institute v Martin 2009). A population model based on lynx population demographic data collected in Maine supports the Federal Court's ruling and shows a positive population growth rate even if 5 lynx accidentally caught in traps died each fall (Appendix VI), which currently exceeds our reported mortality level from trapping (see Table 2.3).

Although starvation, caused by lungworm infestations, and predation were the leading causes of mortality in a study of lynx in Maine's core lynx range (MDIFW, unpublished data), these losses did not appear to be limiting the population enough to prevent population growth. Even during the few years when lynx were not producing young in our study area, our ability to capture and monitor new animals suggested that recruitment/immigration may have offset these losses. Initial population models (Vortex) based on vital rates (recruitment exceeded mortality) from northern Maine show a stable to increasing population (Appendix VI). However, competition from fisher and other predators may limit lynx colonization of areas at the periphery of their range, where fisher densities are higher.

Most of Maine's lynx range is bisected by numerous unimproved and improved dirt roads for extracting wood. Between 2000 and 2011, at least fifteen lynx were struck on these roads (1 to 2 lynx/year) including a radiocollared lynx. At least another 11 lynx were stuck by vehicles on high-speed paved roads at the eastern and southern extent of lynx range in Maine, and an eartagged lynx from Maine was struck by a vehicle in Canada. Although roads do not appear to limit the core lynx population in Maine, high speed/traffic roads may limit lynx ability to colonize new areas. Future construction or improvements to existing roads that increase traffic volumes and speed (i.e., paved and maintained roads) in lynx range could result in increased vehicle collisions with lynx.

It has been hypothesized that roads and snowmobile trails may allow other predators (e.g., bobcats, coyotes, fisher) to increase in abundance or colonize areas where deep snows would otherwise inhibit their movement. Increased predator populations could increase lynx mortality rates by reducing prey numbers or by displacing or killing lynx (Buskirk et al. 2000). However, Kolbe et al. (2010) found that compacted snowmobile trails in Montana did not facilitate coyote movements, and snowshoe hares did not provide a large proportion of the coyotes' winter diet. In Maine's lynx range, most roads are not plowed in the winter, and snowmobile trails are more common near and between human settlements at the edge of lynx range. Thus, logging roads and snowmobile trails have likely not substantially increased the risk of mortality of lynx. However, the recent abundance of snowshoe hare in northern Maine has likely contributed to an abundance of marten, fisher, coyotes, hawks, and owls that compete with lynx for snowshoe hare. In addition, fishers appear to be an important source of mortality of adult lynx (Vashon et al. 2005, McLellan et al. *in prep*) based on telemetry studies in the core of lynx range (Tables 1.2, 1.4). We do not know the influence of increased predator populations on prey (Scott 2009) or lynx abundance in Maine.

Although the southern distribution of lynx in Maine is likely limited by snow depth and competition with more abundant carnivores (Hoving 2001 and Robinson 2006), the availability of snowshoe hare may be the factor that most likely limits lynx population growth. Both the ability of female lynx to successfully breed, produce, and raise their young, and dispersing lynx to find adequate areas to settle is determined by prey abundance. Recent studies of snowshoe hare in Maine's regenerating clearcuts (1.0 to 2.0 hares/ha) suggest snowshoe hares are at or above the implied densities (i.e., 0.5-1.0 hares/ha) needed to support lynx (Steury and Murray 2004). Since the landscape includes stands that support a variety of hare densities, landscape hare densities needed to support lynx would be lower than observed within the best stands (i.e. regenerating clear cuts). A recent habitat model for Maine suggest landscape hare densities (i.e. all forest stands) of 0.7 hares/ha is sufficient for lynx in Maine (Simons 2009). Predation, weather, and disease also influence landscape and stand level hare densities in Maine. Thus, a better understanding of the relationship between snowshoe hare abundance, forest stand age, forest composition, alternate prey (red squirrel, grouse, and small mammals), and extrinsic factors is needed to adequately assess future numbers of lynx in northern Maine forests (Murray et al. 2008).

Since snowshoe hare habitat is ephemeral, hare densities are expected to decline as regenerating spruce/fir sapling clearcuts mature. Over the last decade, we have been monitoring snowshoe hares in the same stands in Maine to determine when habitat conditions in budworm impacted stands no longer support adequate hare densities for lynx (Scott 2009). Starting in 2006, hare densities began declining but remained around 1.0 hare/ha. Forestry models suggested that these stands had not reached the self-thinning stage. Thus, the recent decline in hares was not influenced by age of regenerating stands (Scott 2009). Preliminary data from snowshoe hare monitoring in 2011 suggest hare densities have stabilized in older (23-38 year old) regenerating conifer clearcuts (Harrison et al. 2012).

Lynx at the southern edge of their range are part of a larger lynx population centered in Canada. Immigration of lynx from these areas may be needed to maintain lynx in southern areas where habitat and climatic conditions are less favorable. Although lynx are able to travel great distances, they are more susceptible to mortality when moving through less suitable areas. Thus, maintaining connected forested patches between source lynx populations may be needed to maintain lynx in Maine (Buskirk et al. 2000, Carroll 2005, Hoving et al. 2005). Travel corridors for lynx between Maine and Vermont appear to be sufficient, and human development does not currently pose a threat to lynx movements in the northeastern United States (Farrell 2012). However, the effect of a warmer climate on maintaining sufficient travel between populations of lynx is not clear.

Maine's lynx population is likely most limited by availability of prey and adequate snow depth. Climate change, forest disease, and forest management activities (influenced by forest ownership and wood markets) will likely have the greatest influence on lynx persistence in Maine. Maine's spruce and fir stands can regenerate easily and quickly following disease outbreaks and forest harvest, but often additional forest management activities to improve merchantable softwood volumes are desired. The principle methods employed in Maine are early herbicide application to reduce competition from fast growing hardwoods and shrubs and precommercial thinning to reduce crowding of regenerating softwoods stems (Olsen et al. 2012). If these activities maintain adequate conifer stem densities to provide adequate cover and browse for snowshoe hares, forest management can be beneficial to lynx by creating connected patches of mid-successional (saplings) spruce and fir. Conversely, forest management activities in spruce/fir stands that promote hardwood dominated mixed stands, shorten the cutting rotation period of spruce and fir (and hence the length of time the stand will be suitable for snowshoe hare), removes sapling spruce/fir trees, or fragments lynx habitat could be detrimental to lynx. Maintaining sufficient forage, travel, and denning habitat for lynx in northern and western Maine's spruce/fir forests and connectivity to source populations in Canada is essential to the persistence of lynx in Maine, especially if climate warms.

# MANAGEMENT

## Bounties

European settlers viewed lynx as vermin, and like many predators, lynx were subject to year-round open hunting and trapping that included a bounty to protect game species, principally deer, hares, and upland game birds from predation. Although early writings distinguished lynx from bobcats (Hoving 2001), bounty records did not distinguish the two (Hunt 1974). In Maine, the first bounty on wildcats was paid in 1832, and 210 wildcats were presented for bounty (Table 2.1). To claim a lynx or bobcat for bounty, the claimant was responsible for presenting the ears, nose, and tail of the wildcat to the warden in the district where the animal was killed. The claimant's and warden's signature, date, time, and location of kill were required on the certificate (Figure 2.1) that the warden mailed along with the tail to the Commissioner of Inland Fisheries and Game.

To the Commissioner of Inland Fisheries and Game:

I hereby certify that on the____day of_________ A. D., 19_____at_______________ in the state of Maine. I killed the bobcat, loupcervier, or Canada lynx, the skin of which I now exhibit to you, and I claim the bounty allowed by law for killing the same.

Dated at __________ this__________ day of______________ A.D.,19 _____

___________________________Claimant.

It is believed that the cat was killed at the time and place stated herein.
This ___________day of_____________ A.D.,19 _____

_______________________________________ Game Warden

**Figure 2.1.** Facsimile of a Maine bounty form to receive payment for the harvest of a wildcat. A claimant was required to complete a bounty certificate. However, the number of lynx bountied between 1832 and 1967 can not be determined from other wildcats.

During the 1960s, attitudes towards many predators began to shift, and bounties on several species were lifted. Because lynx were uncommon in Maine, not only was the bounty removed, but trapping and hunting seasons were also closed (Department of Inland Fisheries and Game, 1967-68 Revision; Table 2.2).

## State Management and Monitoring Efforts

In 1936 and again in 1939, the newly formed Maine Cooperative Wildlife Research Unit surveyed Maine Game Wardens to determine the status of Maine's big game and furbearing animals. Wardens reported lynx as rare in most districts and absent along the coast (Figure 2.2; Aldous and Mendall 1941). In 1977, while preparing a management plan for lynx, the Department surveyed game wardens again to document where and how common lynx were between 1950-1960 and 1960-1970. However, many Game Wardens had retired, and the survey was incomplete (MDIFW 1977). This management plan was initiated at the same time that the construction of

**Table 2.1.** Records of the wildcat bounty in Maine did not separate lynx from bobcat. Between 1832 and 1967, the number of wildcats (lynx and bobcats) presented for bounty ranged from 61 to 1,857 with bounty payments ranging from 1.00 to 20.00 dollars.

| Year | No. Wildcat (lynx and bobcats) | Bounty/cat | Annual Bounty Payment |
|---|---|---|---|
| 1832 | 210 | $1.00 | $210.00 |
| 1833 | 280 | $1.00 | $280.00 |
| 1834 | 101 | $1.00 | $101.00 |
| 1835-1908 | not available[1] | $2.00 | not available |
| 1909 | 61 | $2.00 | $122.00 |
| 1910 | 478 | $2.00 | $956.00 |
| 1911 | 529 | $2.00 | $1,058.00 |
| 1912 | 404 | $2.00 | $808.00 |
| 1913 | 405 | $3.00 | $1,072.00 |
| 1914 | 501 | $3.00 | $2,000.00 |
| 1915 | 497 | $4.00 | $1,988.00 |
| 1916 | 753 | $4.00 | $3,012.00 |
| 1917 | 567 | $4.00 | $2,268.00 |
| 1918 | 364 | $4.00 | $1,456.00 |
| 1919 | 860 | $10.00 | $8,000.00 |
| 1920 | 576 | $10.00 | $5,760.00 |
| 1921 | 303 | $10.00 | $3,030.00 |
| 1922 | 931 | $10.00 | $9,310.00 |
| 1923 | 991 | $10.00 | $9,910.00 |
| 1924 | 800 | $10.00 | $8,000.00 |
| 1925 | 829 | $10.00 | $8,290.00 |
| 1926 | 787 | $10.00 | $7,870.00 |
| 1927 | 661 | $10.00 | $6,610.00 |
| 1928 | 472 | $10.00 | $4,720.00 |
| 1929 | 683 | $10.00 | $6,830.00 |
| 1930 | 568 | $10.00 | $5,680.00 |
| 1931 | 635 | $10.00 | $6,350.00 |
| 1932 | 1,857 | $20.00 | $36,970.00 |
| 1933 | 1,139 | $10.00 | $12,050.00 |
| 1934 | 532 | $10.00 | $5,320.00 |
| 1935 | 900 | $10.00 | $9,000.00 |
| 1936 | 807 | $15.00 | $12,085.00 |
| 1937 | 695 | $15.00 | $10,425.00 |
| 1938 | 684 | $15.00 | $10,260.00 |
| 1939 | 617 | $15.00 | $9,255.00 |

**Table 2.1 (cont.)** Records of the wildcat bounty in Maine did not separate lynx from bobcat. Between 1832 and 1967, the number of wildcats (lynx and bobcats) presented for bounty ranged from 61 to 1,857 with bounty payments ranging from 1.00 to 20.00 dollars.

| Year | No. Wildcats (lynx and bobcat) | Bounty/cat | Annual Bounty Payment |
|---|---|---|---|
| 1940 | 505 | $15.00 | $7,575.00 |
| 1941 | 331 | $15.00 | $4,965.00 |
| 1942 | 367 | $15.00 | $5,505.00 |
| 1943 | 211 | $15.00 | $3,165.00 |
| 1944 | 302 | $15.00 | $4,530.00 |
| 1945 | 294 | $15.00 | $4,410.00 |
| 1946 | 377 | $15.00 | $5,655.00 |
| 1947 | 480 | $15.00 | $7,200.00 |
| 1948 | 514 | $15.00 | $7,710.00 |
| 1949 | 527 | $15.00 | $7,905.00 |
| 1950 | 549 | $15.00 | $8,235.00 |
| 1951 | 407 | $15.00 | $6,105.00 |
| 1952 | 438 | $15.00 | $6,570.00 |
| 1953 | 504 | $15.00 | $7,560.00 |
| 1954 | 762 | $15.00 | $11,430.00 |
| 1955 | 588 | $15.00 | $8,820.00 |
| 1956 | 810 | $15.00 | $12,150.00 |
| 1957 | 700 | $15.00 | $10,500.00 |
| 1958 | 633 | $15.00 | $9,495.00 |
| 1959 | 741 | $15.00 | $11,115.00 |
| 1960 | 844 | $15.00 | $12,660.00 |
| 1961 | 790 | $15.00 | $11,850.00 |
| 1962 | 831 | $15.00 | $12,465.00 |
| 1963 | 768 | $15.00 | $11,520.00 |
| 1964 | 1,119 | $15.00 | $16,785.00 |
| 1965 | 764 | $15.00 | $11,460.00 |
| 1966 | 642 | $15.00 | $9,630.00 |
| 1967 | 784 | $15.00 | $11,760.00 |

[1]Between 1835 and 1908, wildcat bounties were not separated from bear bounty payments.

**Table 2.2.** Summary of state and federal management actions for lynx in Maine 1832 to present.

| Year | Management Action |
|---|---|
| 1832 | Bounty on lynx and year round open season |
| 1939 | Survey of Game Wardens on abundance of game and furbearers |
| 1967 | Bounty on lynx repealed and season closed |
| 1977 | Survey of Game Wardens on distribution and abundance of lynx between1950-60 and 1960-1970 |
| 1977 | USFWS considered listing lynx as endangered species in Maine |
| 1977 | MDIFW drafted a management plan for lynx |
| 1987 | Proposed as State Threatened; not listed because status was deemed indeterminate (i.e., could not verify a breeding population) |
| 1991 | MDIFW annual trapper mailing provides information on distinguishing a lynx from a bobcat |
| 1991 | USFWS receives a petition to list the lynx as Endangered in Washington |
| 1992 | USFWS initiates a range-wide status review of lynx |
| 1994 | USFWS concludes listing of lynx is not warranted |
| 1995 | USFWS is sued over their decision that listing is not warranted |
| 1995-99 | MDIFW initiated winter snow-track surveys along Maine border |
| 1996 | MDIFW annual trapper mailing asks trappers for their assistance in reporting lynx sign and catches |
| 1997 | MDIFW designated lynx as Special Concern |
| 1997 | MDIFW annual trapper mailing includes lynx track descriptions |
| 1998 | MDIFW restricts use of neck snares for coyotes to protect lynx |
| 1998 | USFWS issues a proposed rule to list the lynx as Threatened |
| 1999 | MDIFW and USFWS initiates telemetry study in northern Maine |
| 1999 | MDIFW establishes a 24hr, 7 day a week phone number for trappers to report incidental captures of lynx and obtain assistance |
| 1999 | MDIFW establishes protocol for handling incidentally caught lynx |
| 2000 | USFWS lists Lynx as Threatened in Maine and 13 other northern states |
| 2003 | MDIFW eliminates neck snares as a legal harvest and ADC method for coyotes |
| 2002 | MDIFW develops databases to track past and current incidental takes of lynx and credible sightings of lynx, their track, or sign |
| 2003-08 | MDIFW initiated more extensive winter snow track surveys in northern and western Maine |
| 2003 | USFWS distributes a brochure to Avoid Incidental Take of Lynx by bobcat trappers and hunters in the United States |
| 2005 | USFWS drafted an interim Recovery Plan for lynx |
| 2005 | MDIFW adapts USFWS brochure for Maine and mails a copy to every licensed Maine trapper |
| 2006 | MDIFW considered lynx for state listing; remained Special Concern |

**Table 2.2 (continued).** Summary of state and federal management actions of lynx in Maine 1832 to present.

| Year | Management Action |
|---|---|
| 2006 | MDIFW's first submission of an Incidental Take Plan (ITP) to obtain a permit that allows a minimal level of accidental catches of lynx by licensed fur trappers that follow state trapping regulations. |
| 2007 | USFWS designated Critical Habitat (CH) on National Park Service lands in 5 states |
| 2007 | MDIFW restricts the use of conibears in WMD 1-11 to reduce incidental capture of lynx (www.maine.gov/ifw) |
| 2007 | MDIFW restricts the use of visible bait while trapping furbearers |
| 2007 | MDIFW settles a lawsuit with the Animal Protection Institute by committing to current conibear restrictions, implementing new size restrictions of foothold traps in northern Maine, develops a protocol for assessing and treating lynx caught in traps, and applies for a permit that allows a low level of incidental take of lynx |
| 2008 | USFWS proposed revising CH designation for lynx in ME, MN, MT, ID, WA, WY |
| 2008 | MDIFW requires trappers to immediately report the capture of lynx in traps |
| 2008 | MDIFW's second submission of an ITP to obtain a permit that allows a minimal level of accidental catches of lynx by licensed fur trappers that follow state trapping regulations. |
| 2008 | MDIFW increases outreach efforts on avoiding and reporting incidental capture of lynx by trappers |
| 2008 | MDIFW implements an emergency rule that clarifies trapping regulation for setting conibears in WMD 1-11 |
| 2009 | USFWS designated CH in Maine (100,000 $mi^2$) |
| 2009 | US Federal court denies AWI et al. request to close Maine's trapping season to protect lynx |
| 2010 | US Court of Appeals denies AWI et al. appeal & awards costs to the Defendants |
| 2011 | Federal register 90-day public comment period for MDIFW's ITP application and USFWS' environmental assessment of that application. |

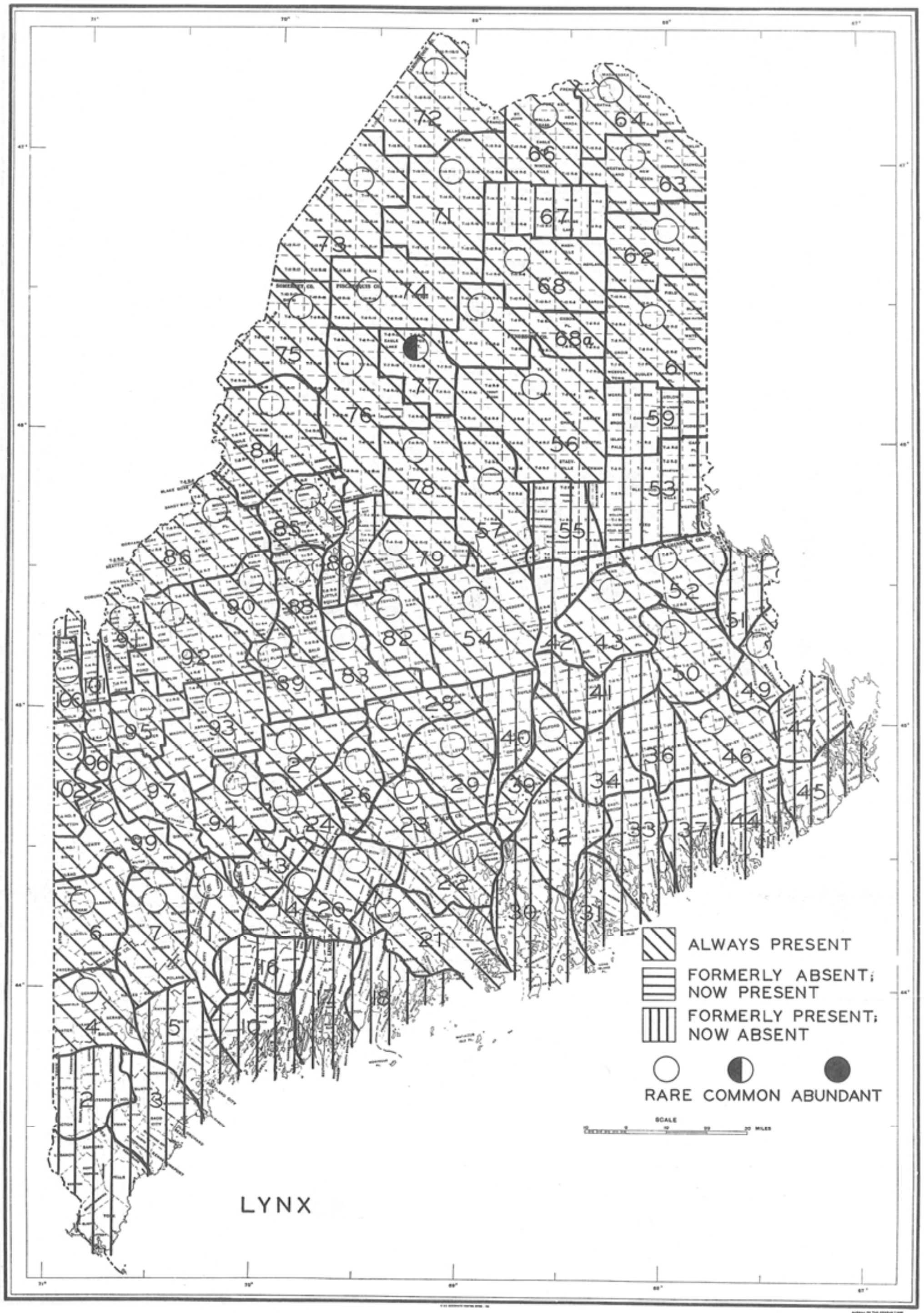



**Figure 2.2.** Lynx distribution in Maine based on surveys of game wardens (Aldous & Mendall 1941).

the Dickey-Lincoln Dam was being considered, and the State Supervisor for the USFWS in Maine expressed concern about the impacts of the dam on lynx. In a memorandum, the USFWS supervisor requested that Maine's lynx population be considered for protection as Endangered Species under the recently passed US Endangered Species Act (ESA). In his recommendation, he acknowledged that lynx were never numerous, were already protected from harvest, and efforts to increase lynx numbers were beyond the State's capabilities, but he expressed concern that the proposed project threatened local extirpation of lynx. Although lynx were not listed and a management plan for lynx was not finalized, the dam project was not approved.

In 1986, the Department recommended that lynx be protected as State Threatened during the state's first comprehensive review of Maine's rare mammals and birds. The Department's recommendation was successfully challenged on the basis that the Department could not confirm that a breeding population of lynx existed in the state. As a result, lynx were designated as a species of indeterminate status and not listed (MDIFW 1987). In 1997, the Department again considered protecting lynx under Maine's Endangered Species Act and designated lynx as a Species of Special Concern (MDIFW 1997). Although the status of Special Concern provides no additional protection, it identifies species that may be at risk of becoming threatened or endangered and directs monitoring and research efforts to address knowledge gaps.

Between 1995 and 1999, the Department initiated winter track surveys to document the status of lynx and other rare carnivores along the border of Maine and Quebec. Although most towns were only surveyed once during a single winter, lynx tracks were observed in several locations (Figure 2.3-left). In the late 1990s, the USFWS and a

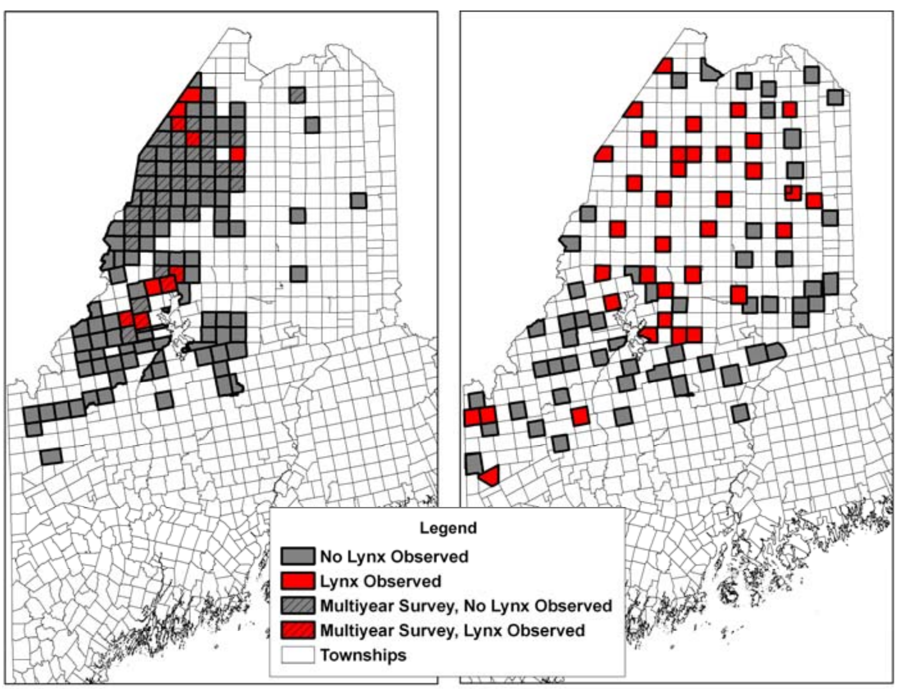



**Figure 2.3.** Townships where lynx snow-track surveys were conducted in Maine (1995-99 left and 2003-08 right).

graduate student at the University of Maine compiled credible historical observations of lynx in Maine (Joseph 1999, Hoving 2001). Since 2002, the Department maintains a database for verified lynx observations in Maine to identify areas where lynx are present and to aid federal review of development projects that may impact lynx. In 2003, the Department initiated more extensive snow-track surveys to document lynx distribution statewide as part of a Maine Natural Areas Program/MDIFW survey effort to document rare species and communities in Maine (i.e., ecoregional surveys; Vashon et al. 2003, 2007, and 2010). Although surveys were conducted only once each winter, lynx were found in many more northern locations (Figure 2.3-right).

In addition to these efforts, the Department, USFWS, and the University of Maine initiated several cooperative research efforts to document the status of lynx (Vashon et al. 2008 a, b; Organ et al. 2008; Fuller et al. 2007) and hare populations in Maine (i.e., Fuller 1999, Mullen 2003, Homyack 2000, Robinson 2006, Scott 2009) and develop models to predict past, current, and future habitat availability (Hoving 2001, Simons 2009). In 1999, the Department and USFWS initiated a telemetry study of lynx in northern Maine. The goal of this study was to determine if lynx observations in Maine represented a resident breeding population of lynx or dispersing individuals from neighboring Canadian populations and to identify factors that may limit lynx presence that included identifying lynx habitat use, mortality rates, cause of mortality, and influence of competition with other forest carnivores (fisher, coyotes, and bobcats). Although this study originated (January 1999) in Maine along the border of St. Pamphile, Quebec, the prevalence of lynx sign in 4 townships (T11 R12 Wels, T11 R11 Wels, T12 R12 Wels, and T12 R11 Wels) approximately 40 miles west of Ashland, ME, resulted in the study area being moved to this location in March of 1999. The results of this study have been summarized in the natural history section of this document and various scientific journals (Fuller et al. 2007, Organ et al. 2008, Vashon et al. 2008a, b).

In 2006, the Department reviewed whether lynx warranted protection under Maine's Endangered Species Act. Maine's lynx population did not meet state listing criteria for threatened or endangered because the population had increased over the previous 10 years, exceeded 500 individuals, and was not discrete or fragmented from other lynx populations (i.e., movement between the lynx population in Maine and eastern Canada; MDIFW 2006). Instead, lynx maintained their status as a Species of Special Concern (SSC), which is an internal, non-regulatory, classification used by MDIFW. To qualify as a SSC the species must meet criteria similar to that for endangered or threatened species, but the SSC classification has a lower threshold for qualification (MDIFW 2006 Listing Handbook).

<u>Federal Status</u>

In 1991, the USFWS received a petition from the National Audubon Society and 11 other organizations to list the Canada lynx in Washington State as endangered under the federal Endangered Species Act (ESA) and to designate critical habitat[1] for the

[1] Critical habitat is a specific geographic area(s) that is essential for the conservation of a threatened or endangered species that may require special management and protection; it may include an area that is not currently occupied by the species but needed for its recovery.

species. Although there was insufficient information to support the petition, the Service announced the need and their intent to commence in-depth range-wide status review for the lynx. In 1994, the USFWS determined that Canada lynx, in the contiguous United States, was *not* warranted for listing. Subsequently, Defenders of Wildlife and other environmental organizations sued the USFWS over this decision (Defenders of Wildlife v. U.S. Fish and Wildlife 1996). After several court decisions and settlements, in 1998 the USFWS proposed listing the contiguous US population of the Canada lynx as threatened (Appendix II).

On March 23, 2000, the USFWS listed lynx as threatened in 14 States (Figure 2.4) due to the lack of protection of lynx and lynx habitat on Federal land. Although the USFWS concluded that lynx populations in the Northeast, Great Lakes, Northern Rockies/Cascades, and Southern Rockies were isolated from each other by expanses of unsuitable habitats that limited or precluded lynx movements between regions, lynx were listed as a single distinct population segment (DPS) because none of the regions allegedly had significantly unique or unusual ecological settings. Although the USFWS has the authority to set a DPS' boundaries across international boundaries, Canada was not included in the DPS.

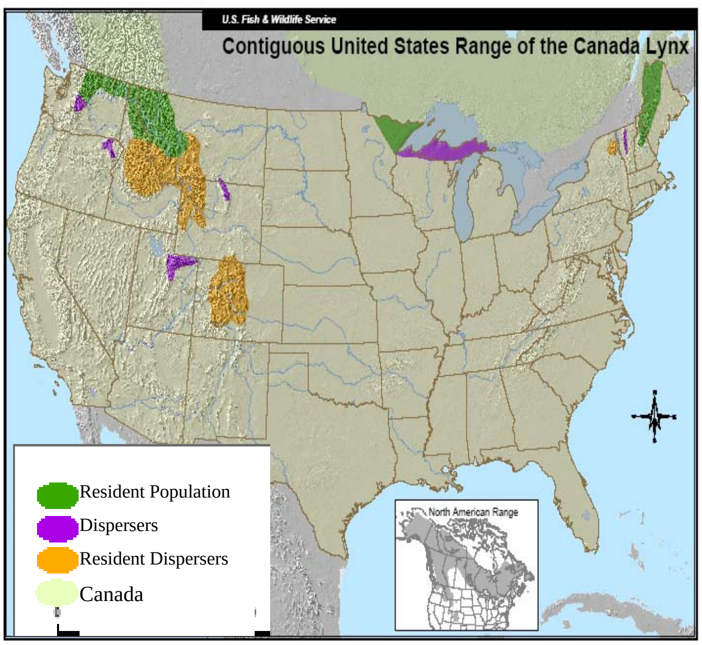



**Figure 2.4.** The 14 states where lynx are protected as Threatened Species by the federal Endangered Species Act.

Despite the USFWS conclusion that none of the areas in the DPS represented a unique ecological setting for lynx, the Northern Rockies/Cascades Region was deemed essential to the continued long-term existence of lynx in the contiguous United States. At the time of listing, this region supported the largest amount of lynx habitat and had the strongest evidence of a persistent resident lynx population (USDI 2000). In 2005, following a court order, a second status review, and public comment period to consider upgrading lynx to Endangered, the USFWS concluded that Endangered status was not warranted (USDI 2003).

The USFWS is charged with designating Critical Habitat and developing a recovery plan for species protected by the federal ESA. In 2005, the USFWS drafted a recovery outline for lynx. This lynx recovery outline serves as an interim strategy to guide recovery efforts and inform the Critical Habitat designation process for the contiguous United States until a recovery plan is completed. The goal of recovery is to address threats to lynx so that protection of this species is no longer necessary and delisting is warranted. In the draft guide, lynx may be considered recovered when conditions allow lynx populations to persist within each of the identified core areas (Figure 2.5; USFWS 2005). To date, a recovery plan for lynx has not been finalized.

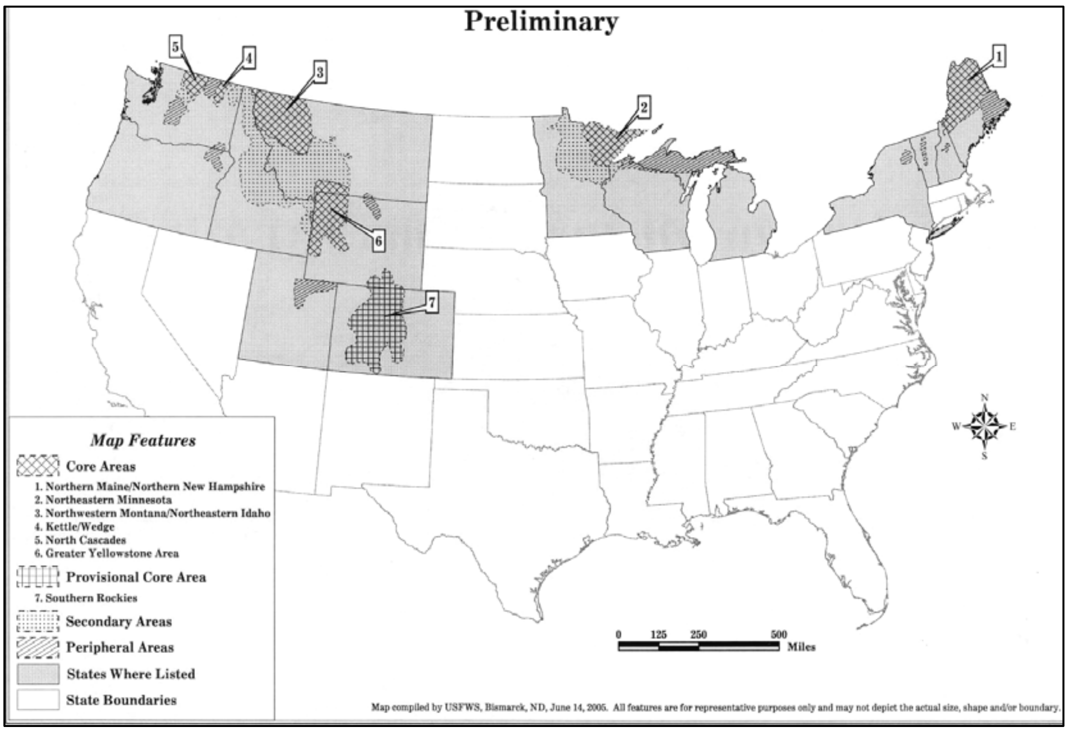



**Figure 2.5.** The USFWS has identified preliminary recovery areas including core areas essential for lynx recovery in Maine, Minnesota, Montana, Wyoming, Colorado, and Washington (USFWS 2005).

On November 9, 2005, the USFWS proposed 26,935 $mi^2$ of Critical Habitat for lynx in 4 states, including 10,633 $mi^2$ in portions of Aroostook, Franklin, Penobscot, Piscataquis and Somerset Counties in Maine. After receiving and reviewing public comments and management plans from landowners, the USFWS did not designate critical habitat for lynx in Maine because the benefits of not designating critical habitat for lynx (e.g., development of habitat management plans and support for research and conservation efforts by landowners) outweighed the benefits of including critical habitat (USFWS 2006).

In 2008, the USFWS proposed revising their Critical Habitat designation for Canada lynx after reviewing the conduct of the former Deputy Assistant Secretary of the Department of the Interior. On February 15th, 2009, the USFWS designated Critical Habitat on 39,000 $mi^2$ (101,010 $km^2$) in portions of Maine (9,500 $mi^2$; 24,598 $km^2$; Figure 2.6b), Minnesota, Montana, Idaho, Washington, and Wyoming (Figure 2.6a).

Approximately 10% of the proposed Critical Habitat for lynx in Maine was excluded from designation because the benefits of excluding outweighed the benefit of including these habitats. Landowners on this area had enrolled in the Natural Resources Conservation Service's Healthy Forest Reserve Program and had committed to developing and implementing forest management plans for lynx. Other private lands were included in the designation because their draft management plan did not provide a binding commitment to conserving lynx. Critical Habitat designation has limited impact on land management activities in Maine because most management actions on private lands do not require a federal permit or use federal funds. However, designation should increase awareness of habitat protection for lynx (USDI 2009).

Incidental Catch

Although hunting and trapping seasons for lynx are closed, lynx are sometimes caught in traps legally set for other furbearers or accidentally shot. Prior to 2000 when lynx were listed as federally threatened, Maine Wardens responded to around a dozen cases where hunters, trappers, or animal damage control (ADC) agents had caught or shot a lynx while trapping or hunting other furbearers or while setting neck snares to limit coyote predation in deer wintering areas (Table 2.3). During this period, Maine’s trapping laws required trappers and snarers to immediately release incidentally caught animals, and if the animal was found dead, they were required to report the incident to a Game Warden as soon as possible and surrender the animal. In 1998, MDIFW restricted coyote snaring activities around areas where lynx had been observed and closed the Round Pond deer yard to snaring due to the close proximity to a known concentration of lynx (i.e., MDIFW's lynx telemetry study area). In 2003, the Commissioner of MDIFW suspended the coyote snaring program in Maine under the advisement of the Attorney General following notification of intent to sue the Department over its snaring program. The plaintiffs alleged that the snaring program violated the federal ESA because lynx or bald eagles (*Haliaeetus leucocephalus*) had been caught and killed in snares set for coyotes. Following this notification, the Department began working with the USFWS on an Incidental Take Plan (ITP) for its coyote control program that would minimize and mitigate for the incidental take of lynx and bald eagles. This plan has not been finalized.

Under the federal ESA a “Take” is defined as harassing, harming, pursuing, hunting, shooting, wounding, killing, trapping, capturing or collecting any listed wildlife species. Since 2000, MDIFW and the USFWS have received and responded to 90 lynx takings in Maine that included the live release of 53 of 59 lynx captured in traps, the death of 6 lynx in traps, 4 deemed intentional and/or violated state or federal wildlife laws,

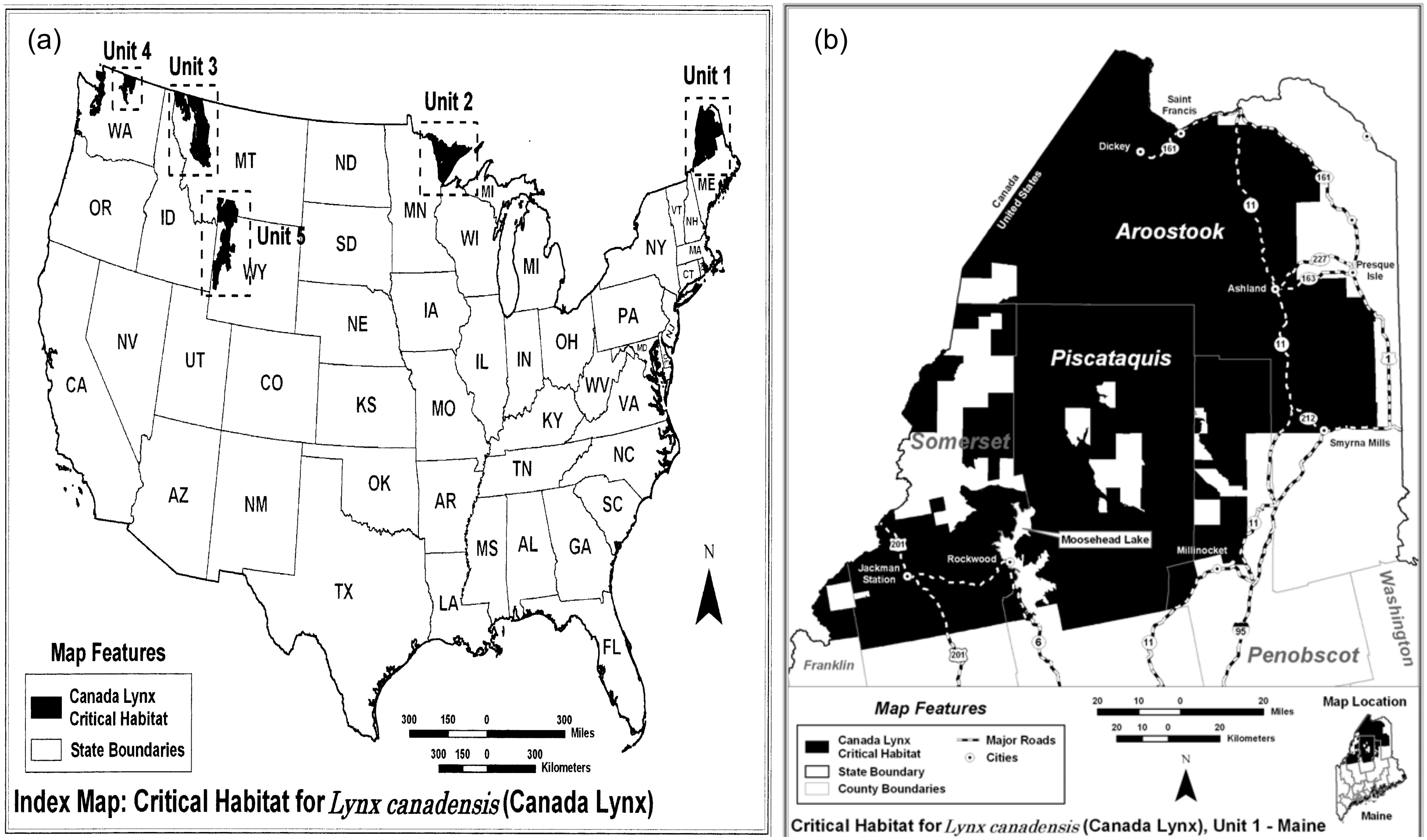



**Figure 2.6.** In 2009, the USFWS determined that 24% of Critical Habitat for lynx in the United States (a) occurs in northern Maine (b).

4 illegal shootings, and 27 lynx killed by vehicles (Table 2.3). To reduce the accidental catches of lynx by trappers, the Department increased its information and education efforts and placed additional restrictions on traps and trap setting requirements (Table 2.3).

**Table 2.3 Summary of illegal and incidental take of lynx in Maine.**

| | 1975-1999 | | 2000-11 | |
|---|---|---|---|---|
| Take | Alive | Dead | Alive | Dead |
| Incidental Trapping | 6 | 3 | 51 | 2[b] |
| Illegal Trapping[a] | | | 2 | 3 |
| Illegal shot in trap | | | | 1 |
| **Total Trapping** | **6** | **3** | **53** | **6** |
| | | | | |
| Illegal Shooting | | 2 | | 4 |
| Incidental Hunting | | 3 | | |
| Incidental Snares | | 1 | | |
| **Vehicles** | | | | **27** |

[a]Traps that were set in violation of Maine trapping laws (i.e. exposed bait, illegally placed).

[b] In 2008, regulations were changed to avoid future mortalities of lynx in traps. Since 2008, no lynx have died in legally set traps.

Each year prior to the opening of Maine's furbearer trapping season, the Department mails trappers (also available online) a booklet that relays new regulations and other important trapping considerations. Starting in 1991, this booklet included information to help trappers distinguish a lynx from a bobcat. In the mid 1990s, the Department requested trappers' assistance in reporting lynx sign and catches and provided information on how to distinguish lynx tracks. In 1999, the Department established a 24-hour, 7-day-a-week, phone line for trappers to report and request assistance with the release of incidentally trapped lynx (Figure 2.7). Since 1999, additional regulatory changes and education efforts to minimize take of lynx have occurred (Table 2.2 and Management-Lawsuits).

The accidental catch of lynx by trappers is considered a Take under the federal ESA unless the take is covered under a 4-D rule or by an Incidental Take Permit. Both the rule and permit allow a legal activity to occur that results in the incidental taking of a species listed under the federal ESA when a plan is designed and implemented that minimizes and mitigates any harm to the protected species. Shortly after lynx were listed, the USFWS began working with the effected states (Colorado, Maine, Minnesota, Montana, Washington, and Wyoming) to identify measures to minimize take of lynx in traps through a 4-D rule. However, a 4-D rule was not finalized because trapping regulations differed considerably among the 5 states, and an agreement on the measures needed to reduce accidental take of lynx in traps was not met (Lori Nordstrom, USFWS, personal communication).

## Incidental Lynx Captures

The Department of Inland Fisheries and Wildlife is conducting a study of lynx in Maine, and may be interested in placing radiocollars on any lynx trapped incidentally this fall.

If you accidentally trap a lynx during the 1999 trapping season, please notify a biologist or game warden immediately, before releasing the animal.

**For quickest response, phone 941-4466 during regular office hours (8 AM - 5 PM Monday-Friday) or 592-4734 at ANY TIME.**

You may also contact the nearest regional office at one of the numbers listed below.

Your assistance will help us to learn more about these rare cats.

---

MDIFW, in cooperation with the United States Fish and Wildlife Service and private landowners, began a lynx study in northwestern Maine this past winter. This study is being done in response to the proposed listing of lynx as a federally threatened species. To date, much of the information driving the proposed listing is coming from western states. We would like to ensure that if the lynx is listed as a threatened species, future conservation actions in Maine and other northeastern states are based upon the ecology of lynx in the region.

We are studying lynx by radiocollaring individuals and monitoring their movements, behavior, and habitat use. Our field crew is based at Clayton Lake. They are trapping lynx this fall, and will be working with houndsmen this winter to tree and capture additional lynx. Because of the rarity of lynx, additional individuals that are captured by trappers can supply valuable information to the study. We plan to mark all incidentally captured lynx with eartags, and most will be radiocollared. Please contact Craig McLaughlin, Wally Jakubas, or George Matula at 941-4466 for more information on lynx in Maine.

**Regional Offices -- Wildlife Division**

| | |
|---|---|
| Region A (Gray) | 657-2345 |
| Region B (Sidney) | 547-5318 |
| Region C (Machias) | 255-4715 |
| Region D (Strong) | 778-3324 |
| Region E (Greenville) | 695-3756 |
| Region F (Enfield) | 732-4132 |
| Region G (Ashland) | 435-3231 |

**Figure 2.7.** Notification to trappers of the establishment of a lynx hotline and ongoing lynx research in the Department's 1999 Trapper Information Booklet.

Thus in 2006, the Department submitted to the USFWS a draft Incidental Take Permit (ITP) application for Maine's trapping program. After review of the draft by the USFWS and rewrites by the Department, a revised draft ITP was submitted to the USFWS in August of 2008. This plan requested an IT permit for Maine's trapping program that would protect trappers, the Department, its agents, and licensees from liability under the ESA in the event a Canada lynx was incidentally trapped, as the result of otherwise lawful activities during Maine's trapping season. The USFWS reviewed MDIFW's application and has prepared an Environmental Assessment (EA) of the Department's application as required by law. A 90-day public comment period on the Department's ITP application and USFWS' EA closed on February 7, 2012. As of July 2012, the USFWS is responding to approximately 350 unique comment from the more than 6,000 comments received and preparing their findings before making a determination on our permit.

Lawsuits

Concurrent to MDIFW's preparation of an ITP, animal rights advocates sued the Department to prevent incidental take of lynx in Maine and to seek an injunction in Federal court to suspend the trapping seasons in northern Maine for other furbearing species. On April 18, 2006, the Department received a letter from the Animal Protection Institute (API) stating their intent to sue the Department for violating the US Endangered Species Act by allowing an activity that results in the incidental take of a listed species without an incidental take permit. Following hearings in the US District Court in Bangor, MDIFW and API reached an agreement on October 4, 2007, and a Consent Decree was signed by the court stipulating that the Department must restrict the type, size, and placement of traps; aid trappers with releasing incidentally captured lynx; assess incidentally captured lynx for injuries; and obtain an IT permit from the USFWS. The terms stated in the Consent Decree would remain in place until an IT permit was issued (Animal Protection Institute v. Martin 2007).

On August 11, 2008, the Animal Welfare Institute and the Wildlife Alliance of Maine (herein referred to as AWI) filed a lawsuit seeking a permanent injunction to prevent further incidental take of lynx in traps. Before this case was heard, a lynx was caught in a conibear trap and killed. The Court ordered MDIFW to "immediately take all action necessary to avoid the trapping of Canada lynx in conibear traps, including the promulgation of an emergency rule". MDIFW identified a gap in conibear trapping regulations, and on December 4, 2008, the Department adopted an emergency rule that clarified that conibear traps set in trees could not be set within 4 feet of any object that a lynx could climb to avoid future takes of lynx. On November 10, 2009, the U.S. District Court denied AWI's request for permanent injunctive relief because the plaintiffs had failed to prove that Maine's lynx population would suffer irreparable harm if the injunction was not granted (Animal Welfare Institute v Martin 2009). AWI appealed the District Court's decision to the First Circuit Court, in Boston. On October 20, 2010, the First Circuit Court affirmed the District Court's decision and required the AWI to cover all legal fees (Animal Welfare Institute v Martin 2010).

## HABITAT

<u>Overview</u>

Lynx are associated with boreal spruce and fir forest. Maine's forest is often referred to as the Acadian Forest that represents the transition between the northern boreal spruce and fir and southern temperate deciduous forests (Seymour and Hunter 1992). Maine has the highest proportion of forestland (>90%) and contains the greatest acreage of spruce/fir forest in the Lower-48 States. Of Maine's 17.7 million acres (7.2 million ha) of forestland, nearly 5.8 million acres (2.3 million ha, 33%) are classified as spruce/fir with 3.4 million acres (1.4 million ha, 59%) in the northern Maine counties of Aroostook, Penobscot, Piscataquis, and Somerset (Figure 3.1; McWilliams et al. 2005).

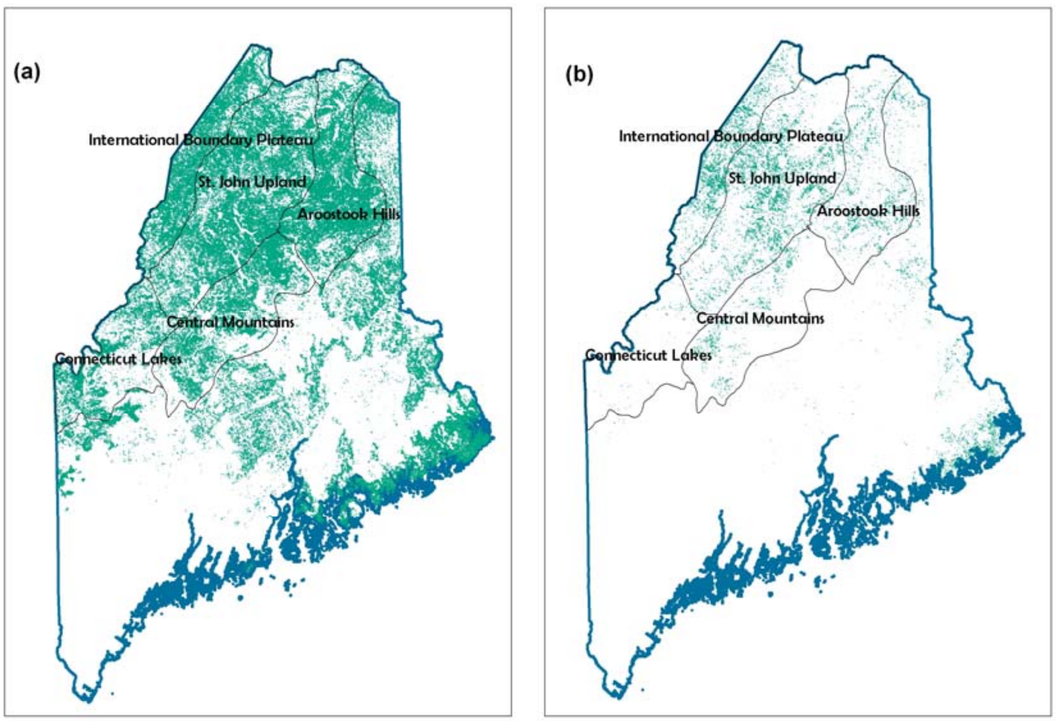



**Figure 3.1.** Distribution of spruce/fir forest type (a) and spruce/fir sapling forest (b) (>50% probability of occurrence) in Maine extrapolated from forest inventory data collected by the Maine Forest Service from 1999-2003 (McWilliams et al. 2005).

Several sources of data were available to quantify lynx habitat statewide: 1) Forest Inventory and Analysis (FIA), 2) landowner stand maps, 3) aerial photos, and 4) satellite imagery. FIA provides detailed (e.g., species, age class, stocking level) information on forest conditions from ground measurements at designated sample plots across the state that is then extrapolated and expanded to estimate statewide amounts and locations (i.e., probability of occurrence maps; e.g. Figure 3.1). Landowner stand maps provide spatially explicit detailed information of current and past forest conditions; however, classification systems are not standardized across landowners, and data are not always accessible. Satellite imagery provides information on both the location and amount of forest, but only general cover types (i.e., deciduous, coniferous, or mixed) for mature forest and broad classes for young forest (i.e., regeneration or scrub/shrub) have been identified statewide (i.e., 1993 and 2002 Maine Landsat imagery). Optimal foraging habitat for lynx (young conifer forest) was recently classified from satellite imagery for a portion of northern and western Maine that encompassed approximately half of Maine's current distribution of lynx (Figure 3.2; Simons 2009). Thus far, FIA is the only source of information that is available across the state over time. We used FIA to estimate past and current amounts of lynx habitat in northern Maine (entire lynx range) and compared our estimate with an independent estimate for a portion of northern Maine (~half of lynx range; Simons 2009).

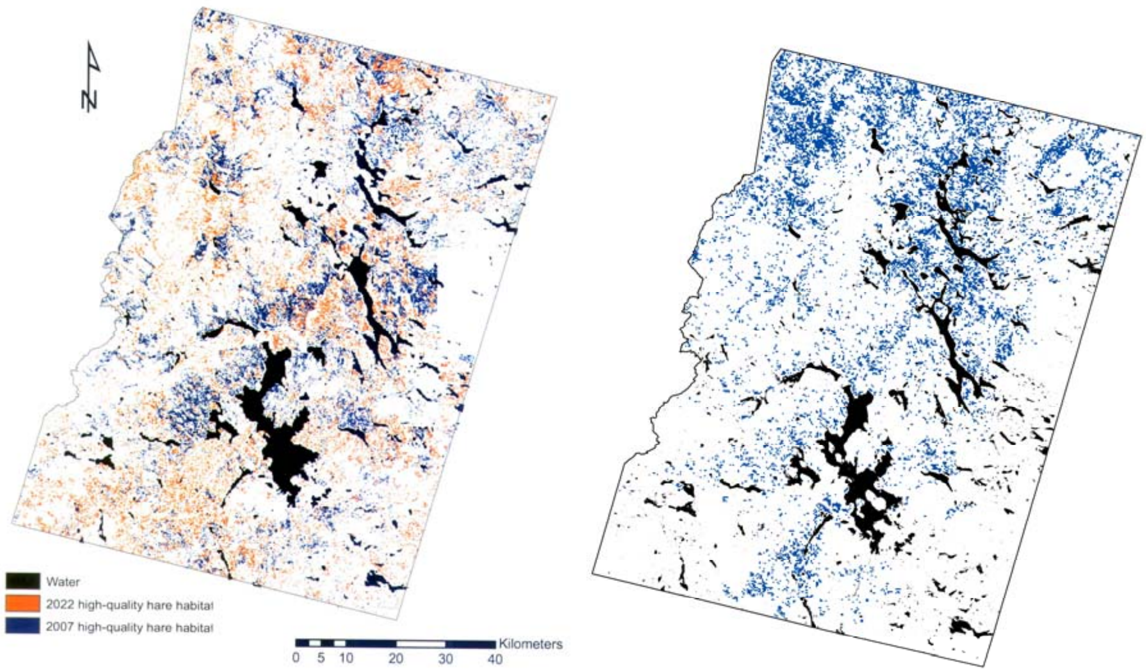



**Figure 3.2.** Lynx habitat from (left) satellite imagery (Simons 2009) and (right) FIA (>50% probability s/f sapling; McWilliams et al. 2005) produced similar patterns and estimates.

We estimated the amount of lynx habitat in Maine for the 5 northern biophysical regions (International Boundary Plateau, St. John Uplands, Aroostook Hills, Central Mountains, and Connecticut Lakes; McMahon 1990; Figure 3.1) that best define the past and current distribution of lynx in Maine where the average annual snow depth in northern (90 -103 inches) and western Maine (107-121 inches) exceeded other areas of the state (66 inches in central Maine and 58 inches in eastern Maine; NOAA climatology data). We used FIA data collected from 1972-2006 to estimate past and current amounts of lynx habitat. We identified ***potential lynx habitat*** as all conifer forest, because a matrix of different-aged conifer forest will provide current and future lynx habitat. We identified ***existing lynx habitat*** as the regenerating portion of the spruce/fir forest type dominated by sapling trees (Fuller et al. 2007; Vashon et al. 2008b). Not all of the spruce/fir sapling forest provides adequate snowshoe hare densities (i.e., sparsely stocked stands may not provide the cover for snowshoe hare) or lynx access to prey (i.e., very densely stocked stands may decrease lynx hunting success), therefore, we estimated **optimal**

**foraging habitat (OFH)** to be a subset of the spruce/fir seedling/sapling stand size class, using only those stands classified as moderately to well stocked (Table 3.1, Appendix III).

**Table 3.1 Hierarchy of lynx habitat conditions in northern Maine.**

| Lynx Habitat | Habitat Conditions |
|---|---|
| Potential | Conifer forest (FIA softwood forest types of all stand size and live stocking classes). |
| Existing | Spruce/fir forest type group (FIA MFTYP=120) and seedling/sapling stand size class (1.0-4.9 inches DBH). |
| Optimal Foraging | Spruce/fir forest type group, seedling/sapling stand size class 1.0-4.9 inches DBH,and a moderately (35-59%) to well (60-100%) all live stocking class. |

Quantifying the availability of OFH (i.e. 2,833-4,452 conifer saplings/acre) from FIA data was problematic because Fuller et al. (2007) and FIA used different criteria to identify seedling and sapling trees. Fuller et al. (2007) counted trees that were > 5 ft (1.5 meters) tall and ≤ 3 inches DBH to estimate the amount of saplings at vegetation plots, where FIA counted saplings between 1.0 and 4.9 inches DBH and seedlings <1.0 inch DBH. If we estimated OFH as a subset of FIA's saplings (1.0-3.0 inches DBH) with stem densities between 2,833 and 4,452 stems/acre (ca. 7,000 and 11,000/ha), we would underestimate the amount of OFH because it would not include trees < 1.0 inch DBH. Conversely, if we included the FIA seedling class (<1.0 inch DBH) and a subset of FIA's saplings (1.0-3.0 inches DBH), we would overestimate the amount of OFH, because short seedlings (<5 feet tall) would be included in the estimate. Thus, we estimated the minimum amount of OFH from FIA data based on the spruce/fir forest type group classed as seedling/sapling stand size (1-4.9 inches) with an all live stocking level classed as moderate (35-59%) or well (60-100%) to correspond and represent stands with a stem density between 2,833 to 4,452/acre (Appendix III).

<u>Past Habitat</u>

*Presettlement*

Before European settlement, northern Maine's forest was predominately old-growth (>100 years old and multilayered) mixed forest of spruce, fir, and northern hardwood trees (Lorimer 1977). Although pure stands of conifer and deciduous trees were less common, stand tables from the early 1900s (see Graves [1899] and Chittenden [1905]) described virgin hardwood lands and spruce flats (i.e., moist low elevation sites). Only 8% of Maine's presettlement forest was young (Lorimer 1977) with a greater proportion of young forest occurring in the spruce swamps and flats (14% seedling-sapling and small pole [1-30 years]) where natural disturbance was more frequent and severe than in mixed upland sites (5% seedling-sapling and small pole; Lorimer and White 2003).

Human disturbance did not play a large role in the structure of northern Maine's presettlement forest. The use of fire to improve croplands and hunting grounds by Native Americans was focused along river valleys and the coast (as cited by Lorimer and White 2003). Although large scale natural disturbance was relatively uncommon (Lorimer and White 2003), several large fires and blow downs (10,000-80,000 ha) were recorded in the presettlement forest of northern Maine (Lorimer 1977), creating some large isolated patches of early successional forest. More commonly, natural disturbances in Maine (forest fires, wind storms, and insect outbreaks) killed tree crowns rather than the entire stand (Lorimer 1977, Seymour et al. 2001, Trani et al. 2001; Lorimer and White 2003). This resulted in a forest dominated by an older multi-layered forest (Seymour et al. 2001).

*European Settlement*
By the 1600s, European settlers were clearing large areas of forestland for pasture and cropland across most of New England (DeGraaf and Miller 1996 as cited by Trani et al. 2001). In Maine, this activity was focused in southern and central portions of the state (Harper 1918). Northern Maine was settled later (1799-1825; Loring 1880) and had fewer human settlements and farms (Irland, unpublished report).

Insect outbreaks and commercial logging had the greatest influence on the structure and composition of northern Maine's post-settlement forest. Harvest of pine for shipbuilding (ca 1650) and spruce for the production of paper (late 1800s) provided a market for Maine's abundant large diameter white pine and spruce (Wilson 2005). By 1850, all forest types had been cut extensively (Wood 1935, Lorimer 1977), although most were classified as partial cuts that retained thin tree canopies and fostered growth of understory trees (Irland, unpublished report). The preferential harvest of valuable spruce through the late 1800s released a suppressed understory of balsam fir (as cited by Lorimer and White 2003). By the early 1900s, there was an abundance of mature balsam fir stands in northern Maine. Because balsam fir is highly susceptible to the spruce budworm (Seymour 1992), the abundance of mature balsam fir is believed to have triggered a major spruce budworm outbreak in Maine (as cited by Lorimer and White 2003) that killed 75% of the fir and 40% of the spruce between 1913 and 1919 (Coolidge 1963). As a result, northern Maine's spruce/fir forest was likely dominated by younger stands of spruce and fir through the mid-1900s.

The late 1920s market crash, WWI, and WWII led to decades of low demand for wood products allowing Maine's spruce and fir stands to grow back. By 1970, Maine's spruce and fir inventory (i.e., mature trees) reached a record high (Maine Forest Products Council 1995, McWilliams et al. 2005). Between 1975 and 1985, the abundance of over mature fir contributed to the largest recorded budworm outbreak in Maine (Irland et al. 1988). This insect outbreak coincided with an increased demand for wood, a shift to mechanized harvest equipment, and the expansion of pulp and saw mills (Irland 2005). As a result, large areas of spruce and fir were clearcut. This salvage harvesting removed >30% of the mature conifer forest between 1975 and 1988 (Simons 2009) and led to record levels of early successional spruce and fir forest by the mid-1990s (Trani et al. 2001).

In 1989, the Maine Legislature passed the Forest Practices Act (FPA) that restricts the size of clear cuts (<250 acres) and provides disincentives for clearcutting (e.g.

notification of harvest, separation zones between clearcuts, and harvest plans for larger clearcuts [21-250 acres]). However, the FPA allows a forest landowner to petition the Maine Forest Service to clearcut areas >250 acres when the harvest meets the intent of the FPA, puts undue hardship on the landowner, or otherwise provides a public benefit (Maine Forest Service 1999; Appendix II). However, landowners may be reluctant to cut Category 2 or 3 clearcuts or file for petitions to clearcut areas >250 acres because the process is laborious and petitions are open to public input.

Although the FPA may limit clearcutting and future amount of optimal snowshoe hare and lynx habitat in Maine, overstory removals may emulate clearcut conditions in conifer dominated stands and do not have size limitations under the FPA. Thus, overstory removals have the potential of creating high quality snowshoe hare and lynx habitat. An overstory removal is a forest harvest that removes the overstory component of the stand, leaving advanced regeneration of softwood or hardwood trees that are respectively greater than 3 or 5 feet tall and a minimum stocking of 450 trees/acre. Overstory removals often occur after natural or human disturbance (e.g. shelterwood harvest) that have partially removed the overstory, allowing young trees to regenerate in forest openings (Maine Forest Service 1999). Although the regeneration standards (> 450 stems/acre) before an overstory is removed are below the stem density needed to support snowshoe hares (~3,000 stems/acre), removal of a conifer overstory can foster growth of young trees that may reach stem densities capable of supporting hares and lynx.

*Forest Inventories (1959-2003)*

The United States Forest Service Northeastern Research Station (NERS) and Maine Forest Service (MFS) have been monitoring forest conditions periodically in Maine since 1959 as part of a national forest inventory that is compiled by periodically measuring forest conditions at survey plots across Maine. Between 1959 and 1995, the amount of timberland (i.e., forested and productive habitat capable of producing forest products) remained stable in New England (81%) and Maine (90%). During this period, most eastern states experienced a decline in early successional habitats and associated wildlife species (Litvaitis et al. 2001, Lormier et al 2001, Trani et al. 2001). In Maine, however, sapling inventories increased, and Maine had the greatest proportion of timberland in the seedling-sapling class (<5 in DBH) of any New England state (Trani et al. 2001).

In Maine, forest inventory data were collected in 1959, 1971, 1982, 1995, and 2003-06. Although we can not make direct comparisons of many forest conditions between inventories because NERS used different algorithms to classify the data at each inventory, we can make some broad comparisons on the availability of lynx habitat from FIA by comparing the change in volume (cubic feet) of growing stock trees (≥5 in DBH), and thereby infer that the lower abundance of spruce/fir sapling forest (<5 in DBH) occurred when spruce/fir growing stock volumes (trees ≥5” DBH) were greatest (Ken Laustsen, Maine Forest Service, personal communication). These data suggest that lynx habitat reached its lowest level in 1971 and peaked in 2003 (Figure 3.3).

NERS and MFS reanalyzed 1982 and 1995 inventories using the same algorithm used in 2003 to allow direct comparisons between 3 of 5 inventory periods (McWilliams et al. 2005). Following the 1975-85 budworm outbreak, most of northern Maine's conifer forest was cut. As a result, spruce and fir growing stock volumes did not change substantially between 1995 and 2003 (Figure 3.3). Conversely as the forest began to grow back, the amount of spruce/fir sapling trees (i.e. existing lynx habitat) increased during that same period from 0.5 to 1.3 million acres and estimates of OFH nearly doubled (Table 3.2). The greatest increase occurred in the 3 northern biophysical regions (i.e., International Boundary, St John Uplands, and Aroostook Hills; Table 3.2) that represent the core of the lynx range (Figure 3.4). In 2003, these regions contained the majority of existing habitat (76%) and OFH (77%). Although the Connecticut Lakes region did not contribute a significant amount of lynx habitat, it provided a greater proportion of lynx habitat in 1982 (Appendix III Table III.1).

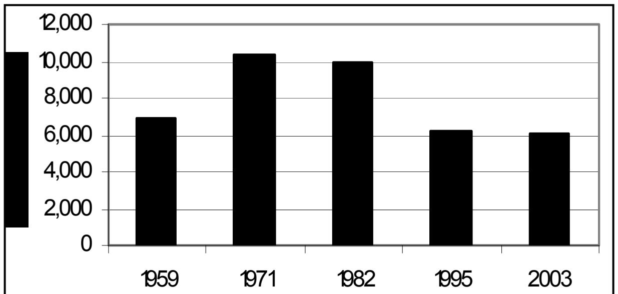



**Figure 3.3.** Comparison of spruce and fir growing stock volumes (>5" DBH) from Maine Forest Inventories 1959-2003.

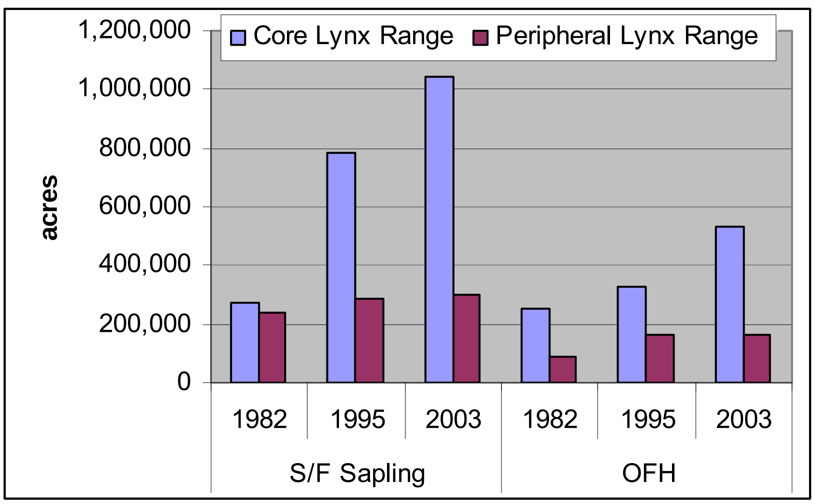



**Figure 3.4.** Change in acres of existing lynx habitat (spruce/fir sapling) and optimal foraging habitat between 1982 and 2003 Forest Inventories. Core range includes 3 northern biophysical regions and peripheral range includes 2 southern biophysical regions (see Figure 3.1).

**Table 3.2. Estimates of past lynx habitat (acres) by biophysical region and lynx range in Maine from 1982, 1995, and 2003.**

| | 1982 | | 1995 | | | | 2003 | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **Biophysical Region** | **Lynx Habitat[a]** | **OFH[c]** | **Lynx Habitat[a]** | **SE** | **OFH[c]** | **SE** | **Lynx Habitat[a]** | **SE** | **OFH[c]** | **SE** |
| International Boundary | 24,063 | 24,063 | 188,767 | 34,525 | 65,311 | 20,024 | 323,355 | 41,648 | 174,111 | 30,626 |
| St. John Uplands | 143,140 | 143,140 | 383,178 | 48,395 | 167,493 | 33,030 | 481,837 | 50,448 | 237,481 | 35,955 |
| Aroostook Hills | 102,681 | 82,145 | 212,379 | 35,871 | 96,853 | 24,920 | 235,319 | 35,063 | 123,458 | 38,186 |
| Central Mountains | 171,318 | 24,474 | 167,303 | 32,791 | 95,329 | 24,986 | 201,997 | 32,885 | 103,518 | 23,954 |
| Connecticut Lakes | 66,165 | 66,165 | 120,888 | 27,744 | 66,426 | 20,565 | 100,416 | 23,337 | 62,572 | 18,934 |
| **Lynx Range** | **507,367** | **339,987** | **1,072,515** | **81,645** | **491,412** | **56,215** | **1,342,924** | **84,469** | **701,140** | **67,979** |

[a] Lynx Habitat is defined as spruce/fir major forest type group and the seedling/sapling size class (1.0-4.9" dbh).

[b] Proportion of Habitat = the proportion of lynx habitat that the biophysical region contributes.

[c]OFH=optimal foraging habitat includes just the subset of seedling/saplings that are classified as moderately to well stocked.

Current Habitat

Although there is currently less spruce/fir forest in northern Maine than before the budworm period, the amount of existing habitat and OFH exceed pre-budworm estimates. Past FIA data, historical accounts, and an independent habitat model (Simons 2009) suggest that the amount of spruce/fir sapling forest in northern Maine reached record high levels in 2010. In 2010, 48% of the spruce/fir forest type in northern Maine was classified as lynx habitat (1.5 million acres) compared to 12% in 1982, and the amount of OFH more than doubled (Table 3.3).

**Table 3.3 Comparison of forest conditions (acres) in northern Maine during different forest inventory periods.**

| | 1982 | 1995 | 2003 | 2006 | 2010 |
|---|---|---|---|---|---|
| Forestland | 7,337,308 | 6,667,682 | 7,174,126 | 7,176,566 | 7,192,363 |
| Softwood forest types[a] | 4,004,458 | 2,886,053 | 2,995,507 | 3,046,167 | 3,056,352 |
| Spruce/fir seedling/sapling[b] | 507,367 | 1,072,515 | 1,342,924 | 1,398,898 | 1,461,313 |
| Moderately to well stocked s/f sapling[c] | 339,987 | 491,412 | 701,140 | 706,784 | 736,363 |

[a] Potential lynx habitat
[b] Existing lynx habitat
[c] Optimal foraging habitat

Although 2010 FIA data are available, a population estimate (see population section) and independent habitat model were based on habitat conditions in 2006 and 2007. Therefore, we summarized the distribution of lynx habitat in Maine based on 2006 FIA for ease of comparisons. In 2006, more than 75% of existing habitat and OFH occurred in the 3 northern most biophysical regions (Figure 3.1 inset). Within these biophysical regions, >40% of the forest is spruce/fir and nearly half of the spruce fir is classed as seedling/sapling forest (i.e., existing habitat). Despite being the smallest ecoregion, the International Boundary Plateau biophysical region (IBP) contains nearly 25% of existing habitat for lynx in Maine because the majority of the spruce/fir in the IBP was classified as lynx habitat (62%) and OFH (54%). Although the Connecticut Lakes biophysical region (CL) contributes to only 8% of Maine's existing habitat, the majority was classified as OFH (Table 3.4). The lack of suitable habitat in the CL has likely influenced the slow return of lynx to New Hampshire and Vermont.

Our estimate of 1.4 million acres of existing habitat throughout Maine's lynx range is proportionally similar to an estimate of between 635,000 and 1.1 million acres having a high probability (50-80%) of lynx occurrence in an area encompassing 4 million acres (55%) of Maine's current lynx range (Figure 3.5; Simons 2009-Chapter 2). An independent estimate of high quality hare habitat (HQHH; 467,000 acres), identified as conifer regenerating forest 16-35 years post harvest, was also proportionally similar to our estimate of OFH (Table 3.4; Simons 2009).

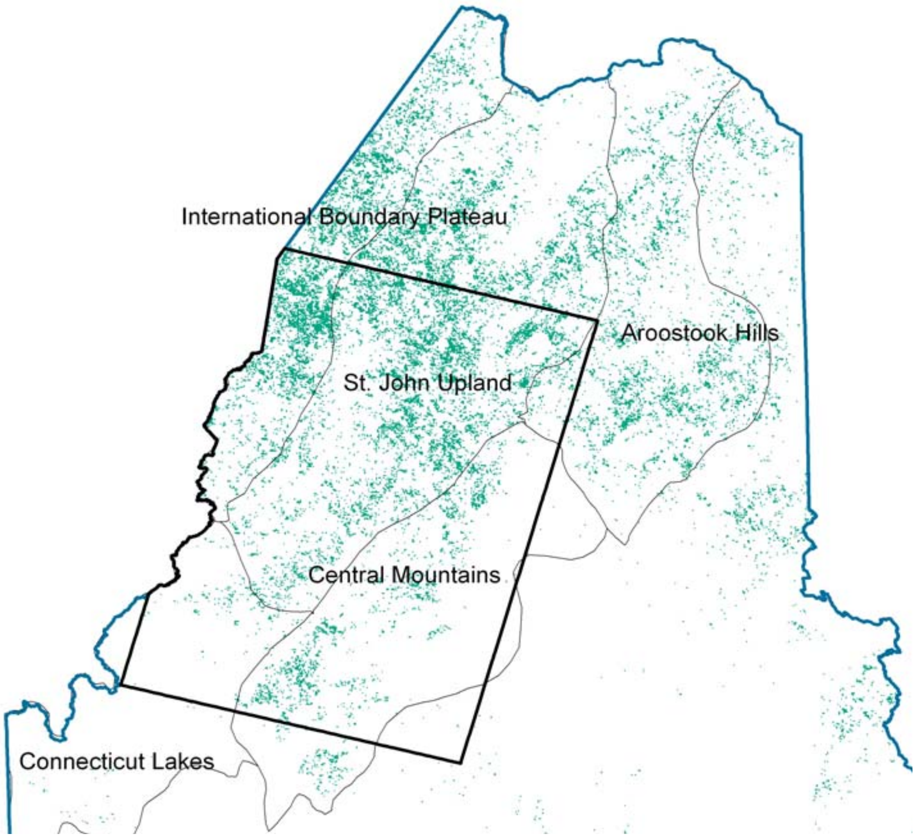



**Figure 3.5.** A model to estimate lynx habitat was developed for an area that encompassed about 55% of Maine's lynx range (Simons 2009).

**Table 3.4. Estimates of current lynx habitat (acres) in northern Maine from 2006 Maine Forest Inventory and Analysis by biophysical region.**

| | Lynx Habitat[a] | | | | Optimal Foraging Habitat (OFH)[c] | | | Potential Habitat[d] | | | Total Forest |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Biophysical Region** | **Acres** | **SE** | **Proportion** | **Contribution[b]** | **Acres** | **SE** | **Proportion** | **Acres** | **SE** | **Proportion** | **Acres** |
| International Boundary | 330,906 | 42,488 | 62% | 24% | 179,071 | 31,373 | 54% | 532,005 | 53,626 | 52% | 1,013,493 |
| St. John Uplands | 459,970 | 48,619 | 48% | 33% | 199,909 | 33,065 | 49% | 1,007,675 | 70,638 | 43% | 2,313,951 |
| Aroostook Hills | 269,384 | 37,848 | 36% | 19% | 155,600 | 29,159 | 52% | 705,008 | 60,631 | 46% | 1,431,279 |
| Central Mountains | 231,712 | 35,637 | 43% | 17% | 102,573 | 23,828 | 51% | 512,928 | 51,293 | 36% | 1,307,975 |
| Connecticut Lakes | 106,926 | 23,716 | 36% | 8% | 69,631 | 19,831 | 62% | 288,551 | 38,752 | 25% | 1,109,868 |
| **Lynx Range** | 1,398,898 | 86,221 | 46% | 100% | 706,784 | 62,361 | 52% | 3,046,167 | 125,197 | 41% | 7,176,566 |

[a]Lynx Habitat is defined as spruce/fir major forest type and the seedling/sapling size class (1.0-4.9" dbh).

[b] Contribution of habitat = the proportion of lynx habitat that the biophysical region contributes to rangewide estimate.

[c]Optimal foraging habitat (OFH) includes the subset of seedling/saplings that are classified as moderately to well stocked.

[d]Potential Habitat is all softwood forest types of all stand size and all live stocking classes.

Future Habitat
Past timber harvest and insect outbreaks have played the greatest role in the composition and structure of northern Maine's forests that provided ideal habitat conditions for lynx during the last decade. Young forests are ephemeral, changing with forest succession and growth, and depend on repeated disturbance (i.e., fire, storm, disease, timber harvest; Trani et al. 2001). Change in landownership, passage of the Maine's Forest Practices Act (FPA) that provides disincentives for clearcutting, and the legacy of salvage harvesting following the budworm outbreak will influence future habitat conditions. Forest harvest has shifted from softwood dominated to hardwood dominated forested stands (Jin and Sader 2006) and from clearcutting to partial harvesting techniques (i.e., residual basal area of trees >30 $ft^2$/acre) resulting in an increase in the acres of forest harvested annually (McWilliams et al. 2005). To date, these partial harvested stands have not provided the understory conditions to support high hare densities like the older (>15 yrs post harvest) and larger conifer dominated clearcut (Scott 2009).

There is one model to estimate future amounts of HQHH based on timber harvesting patterns since the 1970s (Simons 2009). It was assumed that areas that were previously conifer or mixed forest that were clearcut or received a heavy partial cut (i.e., residual basal area < 30 $ft^2$/acre) would produce future HQHH 16 to 35 years post harvest (Simons 2009). The model indicated that the amount of HQHH (0.5 million acres) in the study area peaked in 2009 and remained relatively stable through 2022 (Simons 2009). Although, the model predicted a decline in HQHH as budworm stands matured in the northern portion of the study area, this decline was offset by increases in HQHH in the southern half of the study area. The model also predicts future HQHH will occur in smaller more isolated patches due to recent partial harvesting activity, but the total amount of HQHH in northern Maine is not expected to decline until after 2022.

To help guide future (after 2007) forest management for lynx, a model was developed to predict how changes in future habitat supply could be influenced by different forest management regimes including: 1) no forest harvest, 2) maintain current harvest trends (FPA), 3) increase maximum allowable clearcuts size (from 250 to 500 acres), and 4) increase the area that is clearcut harvested (currently 4%; Simons 2009). The model, on a portion (9%) of the prior study area, indicated that lynx habitat should remain stable through 2012, but should begin to decline steadily through 2032 regardless of forest management activities. However, 2032 habitat amounts would remain at or above 1995 estimates (see Figure 4.3 Simons 2009). The projected decline in lynx habitat after 2012 should occur as a large number of trees regenerated from the spruce budworm era of the 1980s reach the age where they no longer provide good habitat for snowshoe hare (i.e., >35 years post harvest). The scenario that resulted in the least severe decline of lynx habitat (-12%) and an increase in the amount of habitat after 2027 allowed the acreage harvested by clearcut or shelterwood to increase to a level that achieved maximum sustained yield (Simons 2009). Interestingly, increasing the size of individual clearcuts from 250 to 500 acres did not increase the overall future amount of lynx habitat. Another forestry model suggests conifer sapling forest will continue to increase through 2010-2012 and then begin a steady decline through 2032-2040 as spruce and fir grow into merchantable trees (Gadzik et al. 1998).

Although lynx habitat trends may not be reversed immediately given past forest management, it was suggested that there may be some opportunities to create lynx habitat by clearcutting parcels that were previously partially harvested (Simons 2009). There is also an opportunity to guide forest management activities to create lynx habitat when Maine's spruce/fir forest that was impacted by budworm approaches merchantable size. Although the FPA permits large clearcuts that benefit wildlife (Appendix V), which may provide an opportunity to once again clearcut Maine's spruce/fir flats, landowners may be reluctant to clearcut these areas because of past public opposition to large clearcuts (Simons 2009). Partial harvests in Maine's spruce/fir flats that foster well-stocked understories of conifers (e.g., shelterwood and overstory removals) may support hare densities sufficient to maintain lynx. While it may be desirable to mimic past high levels of lynx habitat, the harvest of spruce and fir that created these conditions was not sustainable. Future sustainable harvest of spruce and fir that promotes large patches of moderate to dense spruce/fir regeneration in clearcuts or understories of partially harvested stands can provide more stable habitat conditions for lynx and other wildlife.

It is important to point out that most models (e.g. Simons 2009) do not incorporate extrinsic factors that may also influence future habitat conditions. State regulations, timber markets, future budworm outbreaks, and forest ownership patterns will influence future levels of early successional conifer forest in northern Maine (McWilliams et al. 2005). Budworm outbreaks develop and gain momentum in the northeastern United States when there is a large proportion of mature and over-mature balsam fir in the forest. Another spruce budworm outbreak is anticipated around 2020. While the exact timing, length and magnitude of the next budworm event in Maine is uncertain, it is probable that the budworm will return in numbers large enough to significantly impact the spruce/fir resource (Sewall 2011). Although landowners may be reluctant to clearcut and herbicide large areas, this disease event has the potential to create favorable habitat conditions for lynx and snowshoe hare sometime after 2035.

On a longer time scale, global warming may result in a net loss of conifer forest in Maine, as conifers are replaced by more temperate southern deciduous forest. Climate models for Maine during the 21$^{st}$ Century trend towards warmer and wetter conditions during all four seasons, with the greatest increase occurring in northern Maine. Over the next 100 years, northern Maine could see an 8% increase in winter temperature and a 16% increase in winter precipitation, with more winter precipitation in the form of rain (Jacobson et al. 2009). These changes will not only affect future snow levels, but will likely influence habitat suitability for individual trees species; balsam fir could become scarce, red spruce may decline especially in interior sections, and red maple could become more abundant (Jagels et al. 2009). Because mature trees are more tolerant to environmental stress, change in forest composition can be slow in existing forest. Conversely, young trees (seedling and saplings) are more susceptible to stress and disturbance (Logan and Gottschalk 2007 as cited by Jacobson et al. 2009). Forest management can play a critical role in Maine’s response to global warming by slowing down or speeding up changes in forest composition by enhancing retention of critical species or facilitating the introduction of new species (Jagels et al. 2009).

# POPULATION

Overview

Although MDIFW evaluated the status of Maine's lynx population when lynx were considered for state listing in 1997 and again in 2006, this is the first formal assessment of Maine's lynx population. Earlier evaluations determined if lynx were below target population levels and warranted additional state protection. This assessment and concurrent models developed by researchers at the University of Maine are the first formal assessment of the amount of available lynx habitat that coincides with lynx population demographic data to formally estimate past and current numbers of lynx in Maine.

For this assessment, we estimated past (1995) and current lynx numbers (2003 and 2006) based on the proportion of habitat (forest and spruce/fir sapling forest) occupied by lynx. We estimated occupied habitat from winter snow track surveys at two different time periods (1995-98 and 2003-08) and estimated the number of lynx in occupied areas based on the size and amount of habitat in a lynx homerange. The estimate based on the size of the homerange assumes all habitat in a lynx homerange is used, where the estimate derived from the acres of habitat in a lynx homerange assumes that lynx only use spruce/fir sapling forest. The first method is likely a conservative estimate and the second a liberal estimate. Therefore, we provide the midpoint between the two estimates here and provide more detailed information on the methods and assumptions used to estimate Maine's lynx population in Appendix IV.

Past Populations

It is likely that lynx have been present in Maine for at least 2,000 years, and their numbers have fluctuated considerably over that period. Early written accounts did not always distinguish bobcats from lynx (Hoving 2001); thus, the relative abundance of lynx in Maine can only be inferred by the availability of habitat. Prior to European settlement, lynx likely existed at low densities in understory patches created by openings in the forest canopy and at locally higher densities in the relatively uncommon large patches of young forest created by fires, wind, and other natural disturbance.

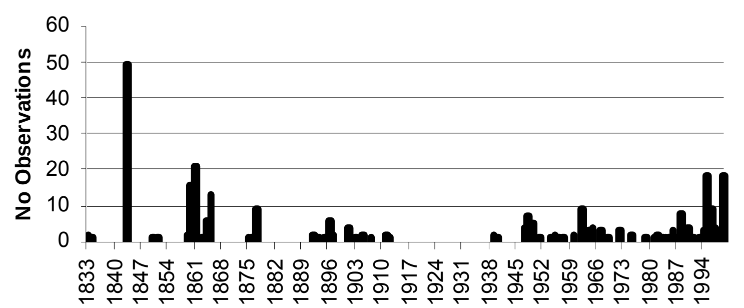
After European settlement, lynx populations likely increased when the harvest of spruce provided early successional habitat in the understory of partially harvested stands. However, lynx populations likely did not flourish until the late-1800s, mid-1900s, and early-2000s following budworm outbreaks (e.g., late 1870s, 1913-19, and 1975-85) that provided more extensive areas of regenerating spruce and fir 15-40 years later (e.g. 1885-1910, 1934-59, and 2000-2025).

Hoving (2001) compiled the most comprehensive historical account of lynx in Maine. Prior to 1939, these observations were based largely on written accounts of lynx from museum records, journals, and periodicals (e.g., Field and Stream magazine). After 1939, lynx observations were also documented from interviews of trappers, biologists, and game wardens (R.Joseph, USFWS, personal communication) and winter snow track surveys conducted by MDIFW (1994-1998). Despite a bounty on wildcats (1832-

1967), no figures on the number of lynx taken annually were available because lynx were not distinguished from bobcats (Aldous and Mendall 1941, MDIFW 1978).

By the mid to late 1800s, written accounts suggested that lynx were common in Maine especially in the burnt lands (Audubon and Bachman 1852 and Thoreau 1893 as cited in Hoving 2001) and were likely most abundant between 1865 -1873 when fur buyers bought between 100 and 200 lynx each year (Hardy 1870 and Stephen 1873 as cited by Hoving 2001). Although Hoving (2001) did not link historical observations to insect outbreaks or fires, his compilation of historical accounts suggest lynx were rare immediately following a minor and two major budworm outbreaks (late 1870s, 1913-1919 and 1975-85, respectively) and were more common 30 years later (Figure 4.1). Following the 1919 budworm outbreak, Allen (1923 as cited by Hoving 2001) wrote that lynx were formerly common, but now much depleted. Lynx remained rare throughout northern and central Maine into the early 1930s (Aldous and Mendall 1941). By the 1950s, lynx were reported as common in western Aroostook County. In modern times, Maine's lynx populations likely reached their lowest level in the 1970s when Maine's spruce fir forest was predominately mature trees (>40 years old). During that period, lynx were reported as common in only 1 warden district in Aroostook County and were thought to number less than 100 individuals statewide (MDIFW 1978). During the 1980s, sapling stands of spruce and fir were still uncommon. Potential lynx densities and populations in the southern half of lynx range were estimated by the amount of high quality hare habitat from satellite imagery in simulated non-overlapping circular ranges centered on lynx track observations that estimated a density of between 0.6 and 1.1 lynx/100km$^2$ or 82-164 lynx on a study area in northern Maine in 1988 (about 55% of lynx range; Simons 2009). As habitat conditions improved during the 1990s, track surveys suggested that 18-29% of survey areas were occupied by lynx. In 1995, Maine's lynx population likely numbered between 240 and 320 lynx.

**Figure 4.1** Historical Lynx Observations (n=281; Hoving 2001)




A recent review of historic species' accounts suggested that the lynx population in northern Maine is "recently re-established". These accounts suggest that: "In the early to mid-1800s, Canada lynx occurred across the Moosehead Plateau of northern and western Maine. In the 1900s, the bobcat replaced the lynx in northern Maine, but since the late 1990s, bobcat populations have retreated to central and southern Maine whereas lynx populations have rebounded across the northwestern part of the state" (Krohn and Hoving 2010: 33, 35).

Current Populations

Maine's lynx population grew more rapidly after 1995 in response to record high amounts of optimal foraging habitat. During 2003-08 winter track surveys, we observed lynx in 50% and 83% of the survey areas modeled as having a low and high probability of lynx occurrence, respectively (Appendix IV). Although 2010 FIA data are available, lynx demographic data have not been completely analyzed for this period, and additional surveys are needed to update estimates of occupied habitat. Thus, current population estimates were based on 2003 and 2006 FIA data, occupancy rates from 2003-08 winter track surveys, and 2003 lynx home range estimates. By 2006, we estimated between 750 and 1,000 adult lynx in northern and western Maine (Table 4.1).

**Table 4.1. Estimated adult lynx population size and acres of regenerating spruce/fir forest in 5 biophysical regions in northern Maine.**

| | Population estimate | | S/F Sapling (acres) | |
|---|---|---|---|---|
| | Minimum | Maximum | Average | SE |
| 1982 | | | 507,367 | |
| 1995 | 244 | 319 | 1,072,515 | 81,645 |
| 2003 | 769 | 1,041 | 1,342,924 | 84,469 |
| 2006 | 781 | 1,057 | 1,398,898 | 86,221 |

An independent estimate of between 2.6-4.0 lynx/100km$^2$ or 242-365 lynx in the southern half of lynx range in 2004 was generated from simulated non-overlapping ranges centered on lynx track observations (Simons 2009). Interestingly, that study found a similar proportion of lynx habitat in simulated ranges as we observed in real ranges used to generate our population estimates (Method 2 Appendix IV). The difference between estimates is likely attributed to the use of simulated non-overlapping ranges (i.e. 1 lynx/range in Simons [2009]) and real range estimates where a male range overlapped a female's range (i.e. 2 lynx/range; Appendix IV).

MDIFW winter track surveys, demographic data from telemetry studies (Appendix VI), an independent population model (Simons 2009), and a variety of indices (accidental catches by trappers, vehicle strikes, and sightings) indicate that Maine's population was growing rapidly. Systematic snow-track surveys found lynx tracks in more than 80% of the towns with a high probability of lynx occurrence and 50% of the survey areas with a low probability of lynx occurrence, suggesting that by 2006 lynx were approaching carrying capacity. We estimated the carrying capacity (i.e., all habitat occupied) of the habitat in northern and western could support between 1,100 and 1,800 adult lynx.

Recent observations of lynx in eastern Maine and New Hampshire, lower hare densities in regenerating clearcuts (Scott 2009), and lower lynx reproductive rates on our northern study area could indicate a declining population. However the continued presence and abundance of lynx in northern Maine, including our study area, and observations of lynx with kittens outside our study area further suggest that this was not the case (Figure 4.2). In 2010, lynx reproductive and recruitment rates recovered at our study site (see Table 1.1 and 1.5) possibly in response to increased hare densities in stands regenerating after shelterwood harvest/overstory removals (see Table 1.2). Overall, during the past decade the studied population of lynx in northern Maine was increasing and excess individuals were available to disperse into other areas (Appendix VI).

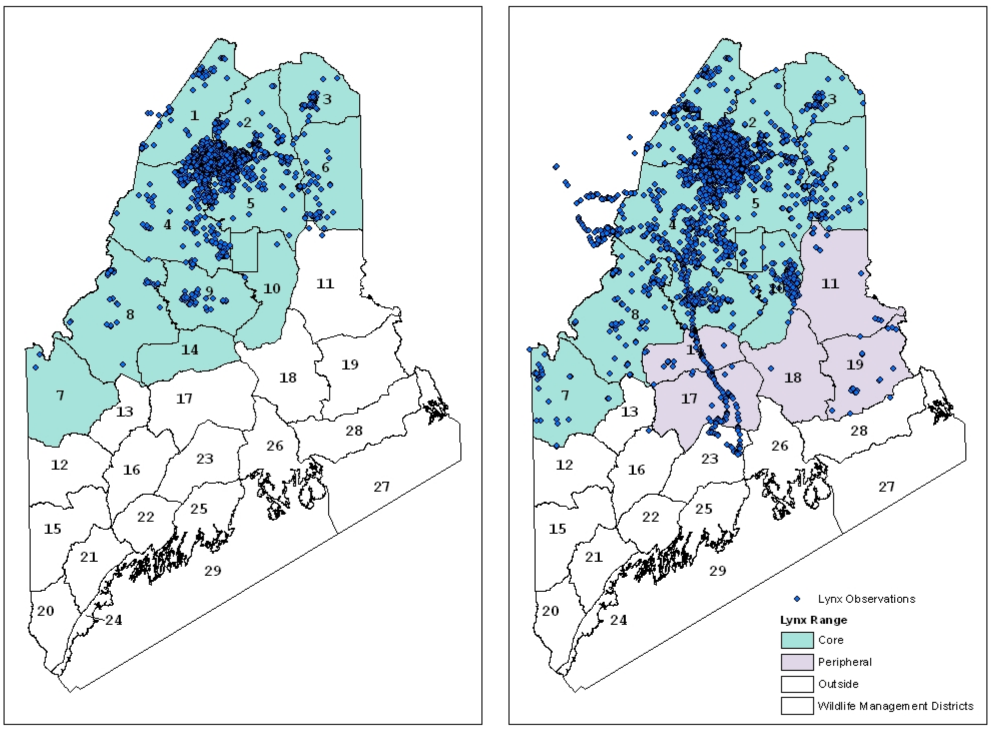



**Figure 4.2.** Lynx observations 2000-2005 (left) and lynx observations 2000-2011 (right).

<u>Future Populations</u>

We anticipate a decline in Maine's lynx population when extensive areas of regenerating spruce/fir stands mature and no longer provide optimal cover for snowshoe hares. Although forests continue to be harvested in Maine, there isn't sufficient early succesional spruce and fir to replace midsuccessional spruce/fir sapling stands (40%) when they transition to late-successional forest (e.g., pole/small sawlogs). By 2032, a model suggests that lynx densities may decline to 1 lynx / 24,711 acres or approximately 130 lynx in half of Maine's current lynx range due to the legacy of past forest harvest and disease events (Simons 2009). Although this density is lower than current densities, it exceeds 1988 lynx densities, where 78% of that study area supported less than 1 lynx / 24,711 acres (Simons 2009). Assuming landscape lynx densities are similar in the core lynx range, Maine's lynx population in 2032 could number 300 adults.

However, most models do not include other extrinsic factors (e.g. budworm outbreak, climate change, timber markets) that will influence future lynx numbers. Climate change is expected to have the greatest impact on wildlife species that occur at the southern edge of their range. Lynx are associated with areas of deep snow (Hoving et al. 2005) and an abundance of young conifer (spruce/fir) where lynx have a competitive advantage over other common forest predators (i.e., bobcat, fisher, coyotes) and their prey, snowshoe hare, are abundant. It is uncertain how climate change will impact future lynx populations, but if projections are accurate, we can expect lynx populations to recede northward and populations to decline substantially over the next 100 years. A decline in Maine could still leave lynx reasonably widespread or common in Canada (Hunter et al. 2009). Maintaining connected undeveloped land, such as Maine's working forest that may continue to support moderate to dense young conifer and abundant hare populations, likely offers the best chance of retaining lynx in Maine.

# USE AND DEMAND

Past Use and Demand

Stemming from general anti-predator attitudes, Canada lynx were traditionally viewed as a vermin, as early references to lynx as a catamount or “evil devil” demonstrate (Williamson 1832), but they were also a valuable furbearing animal. Manly Hardy, a naturalist and fur buyer from Brewer, Maine during the 1800s, wrote that Canada lynx and many other fur-bearing animals were trapped and hunted as part of the fur and hide business (Hardy 1907a). From the 1600s through the early 1900s, the “fall fur hunt” was a common activity throughout North America. Although primarily targeting furbearing animals, fall fur hunts also took big game animals both for the meat and hide that could be used in camp and later sold at market (Krohn 2005). Early commercial hunting or trapping referred to as “long-hunts” involved traveling great distances by horse to shoot and trap game and obtain furs, hides, and meat through trade with Native Americans for later sale at markets. Long hunts were most common in eastern North America through the 1700s, and continued in the West well into the 1800s (Holden 2000). Fall fur hunts avoided the hardships of trapping through the ice and traveling in deep snow (Worthy et al. 1987); although, some trapping expeditions continued through the winter when furbearer pelts became prime (Barker and Danforth 1882). Records of fall/winter fur-hunts in Maine and New Brunswick from the mid- to late-1800s show an animal community more characteristic of a boreal versus a temperate ecosystem, with lynx, moose, and caribou being fairly common and widely distributed in northern Maine and eastern Canada. However, by the late 1800s, all three of these species were less abundant in Maine (Krohn and Hoving 2010) as well as neighboring New Brunswick (see Parker 2004).

Because lynx were not distinguished from bobcat, the number of lynx taken annually is not available from bounty records (Aldous and Mendall 1939). During the 60 years when there was a bounty on all wildcats in Maine, 39,205 wildcats were bountied, and bounty payments totaled over $468,000. During this period, the annual number of wildcats killed for bounty greatly exceeded modern trapping and hunting harvest rates for bobcat (mean = 260 bobcats / yr from 1976 to 2010). Prior to 1920, bounty payments ranged between 1 and 4 dollars per wildcat and increased to 10 to 20 dollars per cat between 1920 and 1967 (see Table 2.1). Because lynx pelts were more valuable than bobcat pelts, demand for lynx was likely higher than bobcats. In years when fur prices were low, bounty payments provided added incentives to harvest wildcats. Not only were their economic incentives for hunting and trapping wildcats, it was also an enjoyable pursuit for outdoor enthusiasts.

Although bounty records do not provide insight into the value and use of lynx in particular, Hardy (1897) reported buying up to 200 lynx annually when lynx were abundant (e.g. 1865 and several years later) with most of the fur coming from Maine. The higher pelt price for lynx indicated that lynx were a highly sought fur (Aldous and Mendall 1941). Use and demand for lynx during the mid and late 1900s was likely low given the relative rarity of lynx and the closing of trapping and hunting seasons for lynx (MDIFW 1978).

## Current Use and Demand

Maine residents and visitors are very interested in lynx, not only because Maine is one of the few places in the United States where lynx occur, but also due to the impact that lynx conservation efforts have had on other recreational pursuits or land use practices. Despite conflicts between lynx conservation efforts and use of other natural resources, consumptive and non-consumptive users have demonstrated a shared interest in lynx conservation in Maine. Landowners, forest products industry, conservation groups, and private citizens have provided financial support for lynx and snowshoe hare research efforts in Maine. The Maine Trappers Association has cooperated with MDIFW to reduce the incidental take of lynx in traps, and many landowners are including lynx in their forest management plans.

### *Nonconsumptive Use*

Nonconsumptive uses of lynx include opportunities to view lynx or their sign (e.g., tracks in winter). At this time, there are no specific surveys indicating the percentage of people who enjoy seeing lynx in Maine. Although personal sighting reports from outdoor photographers, loggers, fishermen, trappers, and hunters are fairly common, in general, people are not very successful viewing lynx because of the dense forested habitat in which lynx live. To overcome the difficulty of seeing a live lynx, several conservation groups travel to northern Maine each winter in the hopes of observing lynx tracks and sign.

### *Consumptive Use*

For more than 4 decades, lynx have been protected from harvest with the closing of hunting and trapping seasons for lynx and elimination of a bounty for all wildcats. Thus, lynx have no direct consumptive values to the people of Maine. Efforts to minimize "take" (i.e., trap, capture, harass, kill, shoot, harm) of lynx have influenced the consumptive use of other abundant fur-bearing animals by restricting legal methods of harvest.

### *Nuisance Control*

In other parts of the United States, lynx have raided chicken coops and killed poultry and other small livestock (Ron Moen, Minnesota, personal communication and Kim Royar, Vermont Fish and Wildlife, personal communication). In Maine, we have only recently received complaints of lynx killing or harassing poultry and have not received any complaint of lynx killing other livestock or pets. The low level of complaints involving lynx is likely influenced by low human densities and abundance of natural prey in areas where lynx occur. Since lynx rarely prey on large game, lynx have not directly influenced large game populations. However, the presence of lynx in northern Maine has restricted coyote control efforts aimed at addressing localized predation of white-tailed deer during winter. Thus lynx have indirectly influenced Maine's animal damage control (ADC) efforts.

Use and Demand Projections

Because the majority of Maine’s lynx occur in remote areas with low human densities, only a small segment of the public seek opportunities to view lynx or their tracks.  Most lynx are likely observed by people pursuing other outdoor activities or working in the woods.  Although such encounters provide added enjoyment, it is unlikely to increase lynx viewings.  Opportunities to view lynx or their sign are likely to decline when the abundance of high quality mid-successional forest (i.e., sapling) transitions to pole or sawlogs.

Lynx protection as a federally Threatened Species may continue to impact the harvesting of other animals through efforts to minimize the incidental take of lynx.  Such minimization measures may include modifications to Maine's trapping regulations and ADC protocols.  However not all impacts will necessarily be negative.  For example, lynx habitat conservations efforts may provide allowances for forest management activities that are currently restricted (e.g., larger clearcuts).

## SUMMARY AND CONCLUSION

Canada lynx are found at northern latitudes in areas where snow levels are deep and prey densities are high. The boreal spruce/fir forest of northern Canada and Alaska supports the largest population of lynx in North America. Lynx also occur in northern portions of the contiguous United States, but are less common. Historically lynx occupied 14 northern tier states. In the Northeast, this includes parts of Maine, New Hampshire, Vermont, and New York. Currently, Maine has the only resident breeding population, although lynx may be colonizing northern New Hampshire and Vermont.

Lynx subsist largely on one prey item, the snowshoe hare. In the boreal forest of Canada and Alaska, hare numbers fluctuate or are cyclic. A variety of factors, including habitat quality and predator abundance, may cause cyclic changes in snowshoe hare abundance. In most areas, hares are common at the beginning of the decade and remain abundant for several years. Often hare numbers will decline for 4 to 6 years before they reach their low and increase again. The cycle is repeated every eight to ten years. Changes in lynx densities tend to mimic changes in hare numbers; however, lynx densities tend to lag changes in hare numbers by a year or two.

In the contiguous United States, snowshoe hares are less abundant and may exhibit irregular fluctuations in density. There have been periods when hare and lynx were more common in northern Maine that often followed natural or human disturbances that altered the composition and structure of Maine's spruce/fir forest. The most recent disturbance event occurred in the 1970s and 1980s when most of northern Maine's spruce and fir was defoliated by the spruce budworm. Extensive areas were subsequently cut and cleared of trees. Fifteen years later (ca 1995) these areas grew back into dense thickets of regenerating spruce and fir sapling trees that provided an abundance of ideal cover for snowshoe hare. Lynx numbers increased, and by 2006, the number of lynx in northern and western Maine's spruce/fir forest reached an historic high of between 750 and 1,000 adults.

A current habitat model indicates that lynx populations have stabilized. This model was based on occupancy data collected when the population was increasing and when lynx were likely colonizing the best habitat. Recent observations of lynx, including evidence of kittens in eastern and western Maine and in New Hampshire, suggest that lynx populations may still be expanding. Regardless, we anticipate a decline in the amount of habitat when the budworm stands mature. The cutting of diseased spruce and fir in the 1980s was not sustainable; thus, there are not enough younger stands to replace current stands as they mature. Although we anticipate less sapling spruce/fir forest and fewer lynx in the future, projected amounts still exceed pre-budworm estimates. Sustainable forest management that provides an even distribution of young, mid-aged, and older spruce/fir forest could provide a stable supply of habitat allowing lynx populations to persist, but lynx numbers would likely be lower than 2006 estimates.

Current habitat models suggest the recent shift from clearcutting to partial harvesting may not benefit lynx, as these stands support relatively low snowshoe hare densities.

However, these harvests occurred in a variety of stands (softwood, hardwood, mixed stands) that tend to be smaller, more isolated, and younger than the regenerating softwood clearcuts that support high hare and lynx densities. Recently, hare densities have increased (>1 hare/ha) in some partially harvested stands (SHW/OR). Although the Maine Forest Practices Act of 1989 (FPA) favors partial harvesting and smaller clearcuts, the composition and configuration of current partially harvested stands is an artifact of the budworm outbreak. When budworm impacted stands reach merchantable size, partial harvests could provide sufficient habitat for lynx if managed to produce well-stocked understories of conifers. Although forest managers may be reluctant to clearcut large areas, the FPA allows larger clearcuts to improve or create wildlife habitat when prescribed and justified by a certified wildlife professional (Appendix V).

Low snow levels and habitat loss pose the greatest risks to Maine's lynx population. If the prediction of a warming climate with more winter precipitation in the form of rain occurs, lynx may be restricted to extreme northern sections of Maine, and spruce/fir may also decline and recede northward. Management of Maine's "spruce/fir flats" that maintains northern forest conditions and connectivity between neighboring lynx populations in Canada may allow lynx to persist in Maine. Commercial harvest of Maine's spruce and fir forest will likely continue, but new markets that favor shorter rotations and use sapling trees will likely reduce the quantity and quality of future lynx habitat, and changes in forest landownership could lead to more land development. Forest management activities that do not promote conditions to support lynx and hares may be offset by future tree-disease outbreaks. Since 1999, conservation easements have protected 2 million acres (28%) of northern Maine's working forest from development, and additional easements have been proposed as mitigation for development.

Lynx were listed as federally Threatened in Maine in 2000. It was not known at the time that lynx numbers were increasing in Maine. The results of a recent 12-year field study in northwestern Maine demonstrated a productive source population of lynx (Appendix VI) that appears to be expanding into other areas of northern New England and Maine. Lynx can not be delisted without a federal recovery plan. Because lynx were listed as a single distinct population segment by the US Fish and Wildlife Service, when recovery objectives are established, lynx must meet recovery objectives in all the states where they are currently protected. Establishing recovery objectives for a species at the edge of their range, whose numbers naturally fluctuate and may be affected by warmer climates is especially challenging. This assessment and the development of management goals and objectives for lynx in Maine may help inform Federal recovery planning efforts.

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## Appendix I. Current Trapping Regulations to Minimize Incidental Capture of lynx in traps.

**Rule 09-137 DEPARTMENT OF INLAND FISHERIES AND WILDLIFE**

**Chapter 4: HUNTING AND TRAPPING**

G. Open Seasons for the Hunting and Trapping of Furbearing Animals

2. Statewide Regular Trapping Season: Bobcat, coyote, fisher, fox, marten, mink, muskrat*, opossum, otter, raccoon, red squirrel, skunk, weasel: The Sunday preceding the first day of the open firearm season on deer through December 31.

   Any lynx caught incidentally, whether dead or alive, during any trapping season must be reported to a game warden or biologist of the Department as soon as possible and prior to removing the animal from the trap, unless a Department official can not be reached in time to prevent injury to the lynx. Any lynx released under this provision before reporting to the Department must also be reported to the Department within 24 hours from the time it was discovered.

J. Size of Traps

Animals may be trapped with any common ordinary steel trap except that in Wildlife Management Districts 1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 14, 18 and 19 no foothold trap (also known as a leghold trap) maybe used that has an inside jaw spread of more than 5 3/8 inches, except that a foothold trap with an inside jaw spread of more than 5 3/8 inches may be used if it is set so as to be fully or partially covered by water at all times. Inside jaw spread is the distance, with the trap in the set position, from the inside center of one jaw (at the dog) to the inside center of the opposite jaw when measured directly across the center of the pan and perpendicular to the base plate. Every foothold trap used in Wildlife Management Districts 1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 14, 18 and 19 that is not set so as to be fully or partially covered by water at all times must be equipped with at least one chain swivel. Killer-type traps with a jaw spread not to exceed 5 inches may be used, except as limited by paragraph K; or killer-type traps with a jaw spread not to exceed 8 inches may be used if set completely under water or at least four feet above ground level or snow.

It shall be lawful to trap furbearing animals with a common cage type live trap, except that in Wildlife Management Districts 1, 2, 3, 4, 5, 6, 8, 9, 10, 11, 14, 18 and 19, no cage trap which has an opening of more than 13 inches in width or more than 13 inches in height may be used unless the cage trap is being used (1) for wildlife research and survey activities; (2) for the removal of animals that are causing damage to property; or (3) to capture bear. Furbearing animals may also be trapped with so-called colony traps having outside dimensions no greater than 7 inches high by 7 inches wide by 40 inches long, only if set so as to remain completely under water at all times.

K. Location of and Preparation for Traps

Steel foothold or killer-type traps must not be set within 50 yards of bait that is visible from above. Bait may be used for trapping if it is completely covered to prevent it from being seen from above, and it must be covered in such a way as to withstand wind action and other normal environmental conditions. Bait is defined as animal matter including meat, skin, bones, feathers, hair or any other solid substance that used to be part of an animal. This includes live or dead fish. For the purposes of this paragraph, bait does not include animal droppings (scat), urine or animals, dead or alive, held in a trap as the result of lawful trapping activity.

No person may set, place, or tend any killer-type trap in Wildlife Management Districts 1 – 11, 14, 18 and 19 unless set completely underwater or at least 4 feet above the ground or snow level except that killer-type traps with an inside jaw spread not to exceed 5 inches may also be used under the following conditions:

(1) when set so as to be partially covered by water at all times, or

(2) when set under overhanging stream banks, or

(3) when used at blind sets as defined below.

For purposes of this paragraph, a blind set is defined as any set designed to catch a wild animal, without the use of bait, lure or visible attractor, by intercepting the animal as it moves naturally through its habitat. Bait, lure and visible attractor do not include animal droppings (scat) or urine.

All killer-type traps in Wildlife Management Districts 1 – 11, 14, 18 and 19 that rely on the rule requiring such traps to be set at least 4 feet above the ground or snow level must be at least 4 feet away from any bank and must be affixed to a pole or tree that is no greater than 4 inches in diameter at 4 feet above the ground or snow level. If a pole is used, the pole must be a natural section of tree, with or without bark, the sides of which have not been sawed, planed or otherwise altered to create a flat surface. The pole or tree to which the trap is affixed must be at an angle of 45° or greater to the ground the entire distance from the ground to the trap. The area within 4 feet of the trap in all directions must be free of trees, poles or other objects greater than 4 inches in diameter and must be free of all trees or poles that are slanted at an angle of less than 45° to the ground at any point between the ground and the height of the trap. The purpose of this rule is to ensure that killer-type traps are not placed in the vicinity of objects that make it easier for lynx to access the trap.

**Appendix II. The Chronology of Events that Led to Listing the Canada Lynx as a Federally Threatened Species in 14 States including Maine (Source: www.fws.gov/mountain-prairie/species/mammals/lynx).**

**August 22, 1991**: A petition to list the "North American" (Canada) lynx in the North Cascades ecosystem of Washington as an endangered species and to designate critical habitat was received by the Fish and Wildlife Service (Service) from the National Audubon Society and 11 other organizations.

**October 6, 1992:** The Service published a notice of a 90-day finding (57 FR 46007) indicating that the petition to list the "North American" (Canada) lynx in the North Cascades did not provide substantial information. Region 1 (Portland Regional Office) had the lead on the petition because the petitioned area was confined to that Region. Region 6 (Denver Regional Office) had the national lead for the lynx.

**Late 1992 or 1993:** The Greater Ecosystem Alliance and other organizations sued the Service over the negative 90-day finding announced on October 6, 1992.

**April 28, 1993:** A settlement agreement was reached whereby the Service agreed to reevaluate the negative 90-day finding announced on October 6, 1992, in light of new information that was submitted by the petitioners.

**July 9, 1993:** The Service published a notice (58 FR 36924) indicating that the negative 90-day finding had been revisited by Region 1, but that there still was not substantial information to support the petitioned action. However, the Service announced in the notice that it believed that sufficient evidence existed to indicate that an in-depth rangewide status review for the lynx should be conducted and that the Service intended to commence this status review.

**November 30, 1993:** A second settlement agreement was reached. The Service agreed to complete and publish the results of a status review throughout the lower 48 States by November 14 1994.

**February 2, 1994:** The Service published a notice (59 FR 4887) indicating that it was soliciting information for a rangewide status review. The Service indicated that it would complete and publish its finding no later than November 15 1994. Region 6 was given the lead.

**April 27, 1994:** A petition to list the "North American" (Canada) lynx in the contiguous United States and to emergency list the southern Rocky Mountain population was received from the Biodiversity Legal Foundation and four individuals.

**August 26, 1994:** The Service published a notice (59 FR 44123) indicating that the Service's administrative 90-day finding found that the petition received April 27, 1994, presented substantial information indicating the requested action for the contiguous

United States population may be warranted, but there was not substantial information to indicate that an emergency listing of a southern Rocky Mountain population was warranted.

**December 27, 1994:** The Service published a notice (59 FR 66507) indicating that the Service's 12-month finding was that listing the Canada lynx in the contiguous United States was not warranted. The finding represented the Service's administrative finding as a result of the status review agreed to in the April 28, 1993, lawsuit settlement and the administrative 12-month finding for the petition received April 27, 1994.

**January 30, 1996:** The Defenders Of Wildlife and 14 other organizations and individuals sued the Service in the U.S. District Court, District of Columbia, over the not warranted petition finding that was announced in the Federal Register on December 27, 1994.

**March 27, 1997:** The court issued an opinion and order setting aside the not warranted finding and remanded it back to the Service for further consideration. The Service was ordered to publish a 12-month on the status of the lynx within 60 days.

**May 27, 1997:** The Service published a 12-month petition finding (62 FR 28653) that the Canada lynx population in the contiguous United States was warranted for listing under the Endangered Species Act but precluded by actions on other species of higher taxonomic status. This warranted but precluded finding automatically elevated the Canada lynx to candidate species status.

**September 15, 1997** Defenders of Wildlife et al. filed suit against the Service in the U.S. District Court, District of Columbia, arguing that the Service violated the Endangered Species Act in finding that listing the Canada lynx population in the contiguous United States was warranted but precluded (published in the Federal Register May 27, 1997).

**December 22, 1997:** The court denied the plaintiffs' Motion to Enforce Judgement against the Service's May 1997 finding that listing the Canada lynx population in the contiguous United States was warranted but precluded. At the same time, the court set an expedited schedule and hearing date (March 18, 1998) for the lawsuit filed in September 1997.

**February 11, 1998:** The Service and the Plaintiffs reached a settlement that calls for the Service to publish a proposed rule to list the Canada lynx in the contiguous United States by June 30, 1998. The settlement has been submitted to the U.S. District Court, District of Columbia for approval.

**June 30, 1998:** The Service issues a proposed rule to list the contiguous United States population of the Canada lynx as threatened. Critical habitat was not proposed.

**July 8, 1998:** Proposed rule is published in the Federal Register

**July 8, 1999:** Notice of 6-month extension of final listing decision published in Federal Register.

**March 24, 2000:** Final rule listing the contiguous United States population of the Canada lynx as threatened published in the Federal Register.

## Appendix III. Methods to summarize potential lynx, existing lynx, and optimal foraging habitat (OFH) using Forest Inventory & Analysis (FIA) data

By Kenneth M. Laustsen, Biometrician,
Maine Forest Service, Department of Conservation
22 State House Station, Augusta, ME

Background

We developed and tested an analytical approach in an attempt to correlate periodic FIA data to other data and research efforts conducted by MDIFW and the University of Maine. Statewide FIA data has been collected under a variety of sampling designs, intensities, and variables starting with the first periodic inventory in 1958; followed by inventories in 1972, 1982, and 1995. In 1999, the periodic inventory was converted to an annualized inventory. In-house Maine Forest Service data files for 1982 and SAS (Version 9.1) were used for data processing and statistical analysis of this single inventory period. The online USDA Forest Service FIA website named EVALIDator (http://apps.fs.fed.us/Evalidator/tmattribute.jsp) was used to generate all other desired habitat estimates for 1995, 2003, 2006, and 2010 and their associated standard errors.

Analysis focused on five biophysical regions (Aroostook Hills, Connecticut Lakes, International Boundary Plateau, Maine Central Mountains, and St. John Uplands). This delineation was preferred by MDIFW because

- Biophysical regions have a better spatial scale than either Wildlife Management Districts (WMD's) or individual counties;
- Known lynx occurrences and observations matched well to biophysical region boundaries; and
- Some ancillary IF&W data had already been summarized by biophysical regions.

NERS and FIA Spatial Data Services provided a plot listing, using plot level GPS coordinates, to link each FIA plot and measurement to a unique biophysical region for the 1995 periodic. The 1995 biophysical region assignment was then used to backcast just those plots to their previous and earlier measurement in 1982.

Potential lynx habitat was assumed to include a matrix of

- Any softwood forest type,
- Any stand size class, and
- Any all live stocking class.

Existing lynx habitat is further characterized by research efforts as

- Spruce-Fir stands
- Regenerating sapling size class

Optimal foraging habitat (OFH) is then further characterized by research efforts as

- Conifer with 7,000 to 11,000 stems per hectare (2,833 to 4,452 stems per acre) that are a minimum 1 ½ meters (≥ 5 feet) in height and ≤ 3.0" DBH.

Process

Melding FIA attributes to the characterizations of current and preferred lynx habitat (OFH) consisted of the following -

- Spruce-fir stands - FIA assigns a forest type to each plot/condition. Using a computer algorithm, tallied trees are assigned a stocking value based on species, DBH, and crown position. Stocking values are then processed through another computer algorithm that uses individual or groupings of stocking values to assign a forest type. This mathematical method works purely on the basis of the forest composition at the time of each plot's measurement. If the composition undergoes a change due to natural succession, natural disturbance (fire, wind, insect, or disease), or harvesting; then at the next measurement it is possible that the same plot area will be assigned a different forest type. These transitions in forest type can have unintended consequences when viewed temporally. But for this analysis the process of a point-in-time forest type assignment based on a purely composition served our purpose. The major forest type group (MFTYP) labeled spruce/fir (MFTYP = 120) was chosen as the best match.

- Regenerating saplings– in FIA terminology this matches up with a stand size class category of Seedling/sapling. This FIA classification process is based on stocking of all live trees (1.0"+ DBH). A computer algorithm calculates the stocking value of each tallied tree, then totals up the stocking value within defined DBH ranges and assigns a stand size class. For the seedling/sapling stand size class, the plurality of tree stocking values are tallied and measured for trees that are 1.0 – 4.9" DBH.

    - Existing lynx habitat now could be characterized by the following attributes within FIA
        - FIA Major Forest Type Group (MFTYP) = 120 (Spruce-Fir)
        - Stand size class = Seedling/sapling (1.0 – 4.9 " DBH)

- Between 7,000 and 11,000 s/f sapling stems/ha – in FIA the term "stocking" describes the degree of occupancy of the land by trees relative to the growth potential utilized by the site. It is expressed as a percent of the "normal" value referenced in various yield tables and stocking guides. In FIA, when the all live stocking of trees ≥1" DBH is classed as moderately stocked, the stocking range (occupancy) is 35 to 59%. Whereas a FIA well-stocked class has stocking values in the range of 60 – 100%. Both the FIA classes of moderately and well stocked could be used to further qualify optimal foraging habitat for lynx in Maine.

- The final criteria defining a qualified conifer stem (≥ 5 feet in height and ≤ 3" DBH) created two problems within the FIA database.

    - FIA counts a subsample of seedlings on plots to estimate the number of seedlings/acre, and these sampling methods varied by inventory period.

- Under the seedling sampling methodd, the qualified FIA seedling stem counts provide no indication of which stems were actually meeting the desired 1 ½ meter (5 feet) minimum height requirement.
- The inclusion of all tallied seedlings would either include those that did not meet the minimum height requirement, or then in later stand development stages exclude plots that had many seedlings meeting the minimum height requirement.

A suitable method or metric within the FIA data, which could be linked to this final criterion, remains undeveloped despite several analytical processing attempts.

As a surrogate, the following FIA attributes that provided the best correspondence and match to the research criteria for Optimal foraging habitat for lynx (OFH) could now be characterized, using
- FIA Major Forest Type Group (MFTYP) = 120 (Spruce-Fir)
- Stand size class = Seedling/sapling (1.0-4.9 inches)
- All live stocking being in the Moderately (35 – 59%) and the Well (60 – 100%) stocked classes.

Table III.1. Summary analysis of lynx habitat based on three habitat criteria for Forest Inventory Analysis (FIA) 1982, 1995, 2003, 2006, and 2010 by biophysical region.

| | | | Potential Lynx Habitat | | Existing Lynx Habitat | Optimal Foraging Habitat (OFH) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Biophysical Region | Year | Total Timberland | All FIA Softwood Major Forest Types (MFTYP) | Just Spruce/Fir MFTYP | Seedling/Sapling stand size class (STDSZCL) in Spruce/Fir MFTYP | Moderate & Fully stocked classes within S/F MFTYP & Seedling/Sapling STDSZCL | Spruce/fir MFTYP (%) of Total Timberland | Seedling/sapling STDSZCL (%) of Total Spruce/Fir MFTYP | Moderately & Well stocked (%) of seedling/sapling STDSZCL | Proportion of habitat |
| International Boundary | 1982 | 673,768 | 409,074 | 409,074 | 24,063 | 24,063 | 61% | 6% | 100% | 5% |
| St John | 1982 | 2,805,538 | 1,746,303 | 1,746,303 | 143,140 | 143,140 | 62% | 8% | 100% | 28% |
| Aroostook Hills | 1982 | 1,355,396 | 698,235 | 698,235 | 102,681 | 82,145 | 52% | 15% | 80% | 20% |
| Central Mtn | 1982 | 1,443,966 | 709,746 | 660,798 | 171,318 | 24,474 | 46% | 26% | 14% | 34% |
| CT Lakes | 1982 | 1,058,640 | 441,100 | 441,100 | 66,165 | 66,165 | 42% | 15% | 100% | 13% |
| Total | 1982 | 7,337,308 | 4,004,458 | 3,955,510 | 507,367 | 339,987 | 54% | 13% | 67% | 100% |
| International Boundary | 1995 | 796,897 | 445,786 | 445,786 | 188,767 | 65,311 | 56% | 42% | 35% | 18% |
| St John | 1995 | 2,185,876 | 956,598 | 950,280 | 383,178 | 167,493 | 43% | 40% | 44% | 36% |
| Aroostook Hills | 1995 | 1,372,131 | 598,664 | 585,496 | 212,379 | 96,853 | 43% | 36% | 46% | 20% |
| Central Mtn | 1995 | 1,330,044 | 515,664 | 495,046 | 167,303 | 95,329 | 37% | 34% | 57% | 16% |
| CT Lakes | 1995 | 982,734 | 369,341 | 362,837 | 120,888 | 66,426 | 37% | 33% | 55% | 11% |
| Total | 1995 | 6,667,682 | 2,886,053 | 2,839,445 | 1,072,515 | 491,412 | 43% | 38% | 46% | 100% |
| International Boundary | 2003 | 1,003,937 | 525,253 | 525,253 | 323,355 | 174,111 | 52% | 62% | 54% | 24% |
| St John | 2003 | 2,339,908 | 1,022,591 | 1,003,937 | 481,837 | 237,481 | 43% | 48% | 49% | 36% |
| Aroostook Hills | 2003 | 1,414,824 | 680,628 | 656,798 | 235,319 | 123,458 | 46% | 36% | 52% | 18% |
| Central Mtn | 2003 | 1,303,512 | 485,528 | 465,088 | 201,997 | 103,518 | 36% | 43% | 51% | 15% |
| CT Lakes | 2003 | 1,111,945 | 281,507 | 278,845 | 100,416 | 62,572 | 25% | 36% | 62% | 7% |
| Total | 2003 | 7,174,126 | 2,995,507 | 2,929,921 | 1,342,924 | 701,140 | 41% | 46% | 52% | 100% |
| International Boundary | 2006 | 1,013,493 | 532,005 | 532,005 | 330,906 | 179,071 | 52% | 62% | 54% | 24% |
| St John | 2006 | 2,313,951 | 1,007,675 | 987,951 | 459,970 | 199,909 | 43% | 47% | 43% | 33% |
| Aroostook Hills | 2006 | 1,431,279 | 705,008 | 692,148 | 269,384 | 155,600 | 48% | 39% | 58% | 19% |
| Central Mtn | 2006 | 1,307,975 | 512,928 | 493,170 | 231,712 | 102,573 | 38% | 47% | 44% | 17% |
| CT Lakes | 2006 | 1,109,868 | 288,551 | 284,780 | 106,926 | 69,631 | 26% | 38% | 65% | 8% |
| Total | 2006 | 7,176,566 | 3,046,167 | 2,990,054 | 1,398,898 | 706,784 | 42% | 47% | 51% | 100% |
| International Boundary | 2010 | 1,013,943 | 572,222 | 572,222 | 313,210 | 170,820 | 56% | 55% | 55% | 21% |
| St John | 2010 | 2,294,251 | 956,925 | 951,134 | 509,986 | 221,080 | 41% | 54% | 43% | 35% |
| Aroostook Hills | 2010 | 1,419,009 | 675,622 | 664,040 | 283,404 | 158,028 | 47% | 43% | 56% | 19% |
| Central Mtn | 2010 | 1,347,565 | 536,415 | 516,244 | 231,459 | 112,743 | 38% | 45% | 49% | 16% |
| CT Lakes | 2010 | 1,117,595 | 315,168 | 311,287 | 123,254 | 73,692 | 28% | 40% | 60% | 8% |
| Total | 2010 | 7,192,363 | 3,056,352 | 3,014,927 | 1,461,313 | 736,363 | 42% | 48% | 50% | 100% |

**Appendix IV. Descriptions of methods used to estimate lynx population numbers in 5 biophysical regions of northern and western Maine.**

Overview:
We used telemetry and track survey data collected in Maine to estimate how many lynx occupied northern Maine's forest in 1995, 2003 and 2006. We used two methods to derive our population estimate. One method was based on the acres of forested habitat and the other was based on the amount of lynx habitat (spruce/fir sapling forest) in a lynx homerange. The first method, derived from the amount of habitat in lynx homerange provides a liberal estimate, because it assumes all forest is of value to a lynx. However, a lynx homerange is based on where a lynx spends most of its time. Radiotelemetry locations obtained over a year are used to identify concentrations of activity (85% fixed kernel homerange; Vashon et al. 2008a), thus the homerange provides a good estimate of area used by lynx. The second method, derived from acres of habitat in a lynx homerange provides a conservative estimate because it assumes only spruce/fir sapling forest is of value to a lynx. Approximately, 30% of a lynx homerange contains spruce/fir sapling forest, thus the second method assumes the remaining 70% of their homerange is of no value to lynx. The best approximate estimate is likely between these two methods. We describe both approaches below and the assumptions that influence these estimates.

For both methods, the first step was to estimate the amount of occupied habitat in lynx range in Maine (northern and western Maine). For the first method, we estimated the amount of occupied habitat on approximately 7 million acres of forested habitat in Maine's lynx range and the second method, we estimated the amount of occupied habitat on approximately 1.5 million acres of spruce/fir sapling forest in Maine's lynx range.

We estimated the proportion of habitat occupied by lynx based on the proportion of survey areas (~100km$^2$) where lynx tracks were detected. Track surveys conducted between 1995 and 1998 were stratified based on the acres of young forest (i.e., >2,000 acres 29% with lynx and <2,000 acres 18% with lynx). We stratified surveys conducted between 2003 and 2008 by the probability of lynx occurrence (low vs. moderate/high) from an early habitat model (Hoving 2001). We observed lynx tracks in 50% of the survey areas that were modeled to have a low probability of lynx occurrence and observed lynx tracks in 83% of the survey areas projected to have a moderate to high probability of occurrence (Figures IV). Unfortunately, we were unable to estimate the proportion of lynx range with a high and low probability of lynx occurrence, because the layer to generate those proportions was no longer available (Erin Simons, University of Maine, personal communication).

Assumptions: Occupied Habitat:

1. Our minimum estimate of occupied habitat assumes all 5 northern biophysical regions had a low probability of lynx occurrence. Thus our minimum estimate of occupied habitat is conservative.
2. Our maximum estimate of occupied habitat assumes all 5 northern biophysical regions had moderate or high probability of lynx occurrence. Thus our maximum estimate of occupied habitat is liberal.
3. Each survey area was surveyed once. We assume that survey areas where a lynx track was not observed during the survey were not occupied.
4. We assume that each lynx track observed was correctly identified. To reduce misidentification, we conducted most track surveys when snow-tracking conditions were ideal and we ranked track quality. We only included high quality tracks in our estimate of occupied survey areas.

To estimate the amount of habitat a lynx uses, we mapped the home range (Vashon et al. 2008a) and measured the amount of conifer sapling forest in the home range of a male and female lynx (Tables IV 1 and 2). We then estimated the number of lynx that share the same area from telemetry data. Although male lynx did not share the same area, each radiocollared male lynx shared a portion of its range (avg. 65%) with 1 to 3 female lynx (Vashon et al. 2008a) and each female lynx shared her entire range with one male. Thus, our estimate was based on an adult female sharing the same area with an adult male lynx.

*Assumptions: Homerange estimator:*

1. The 85% fixed kernel home range estimate is the best approximation of the area of concentrated use by radiocollared lynx in Maine.
2. The number of telemetry relocations (50-100 relocations/animal/year) was sufficient to estimate lynx use of an area.
3. The sample of radiocollared lynx (11M:13F) is representative of the population of lynx in Maine.

Assumptions: Amount of habitat in homerange:

1. The habitat configuration on MDIFW's lynx study area is representative of habitat configuration in lynx range (i.e across all 5 biophysical regions).
2. Method 1: assumes all forest is of value to a lynx.
3. Method 2: assumes only spruce/fir sapling forest is of value to lynx.

Although we did not estimate the number of kittens in Maine's population, each adult female has the potential to give birth to a litter of 1 to 5 kittens each year. From a 12-year telemetry study in Maine, between 30 and 89% of female lynx had 2 to 3 kittens and 78% of the kittens survived their first year.

To assess the validity of our population estimates, we compared these to population estimates derived from lynx density estimates from a habitat model that encompassed the southern half of lynx current geographic range (Simons 2009). Simon's approach was similar to our second method, where between 575 and 825 adult lynx were estimated.

*Calculations:* Method 1: All forested habitat in home range

**Table IV.1. Parameters used to estimate lynx numbers in 2006 using method 1.**

| Variable | Min | Max | Avg | SE | N |
|---|---|---|---|---|---|
| Surveys areas with lynx | 50%[a] | 83%[b] | | | |
| Acres forested habitat (FIA) lynx range[c] | 6,998,124 | 7,355,008 | 7,176,566 | 178,442 | |
| Male home range (acres)[c,d] | 10,443 | 13,557 | 12,000 | 1,557 | 11 |
| Female home range (acres)[c,d] | 5,369 | 7,321 | 6,345 | 976 | 13 |

[a] Percent of survey areas (low lynx probability) with lynx tracks.
[b] Percent of survey areas (high/moderate lynx probability) with lynx tracks.
[c] Minimum and maximum were calculated form estimates of standard errors (SE).
[d] Homerange size estimated as the 85% fixed kernel (Vashon et al. 2008a).

Step 1: Estimate Occupied habitat

Acres of forested habitat in lynx range X % survey areas with lynx

Minimum occupied habitat = 6,998,124 acres X 50% = 3,499,062 acres
Maximum occupied habitat = 7,355,008 acres X 83% = 6,129,174 acres

Step 2: Estimate the number of lynx in occupied area

Minimum # males = min. occupied habitat/ minimum male home range
Minimum # males = 3,499,062 acres/10,443 acres = 335 male home ranges

Minimum # females = min. occupied habitat/ minimum female home range
Minimum # females = 3,499,062 acres/5,369 acres = 652 female home ranges

**Minimum # lynx = 335 + 652 = 987 adult lynx**

Maximum # males = max. occupied habitat/ maximum male homerange
Maximum # males = 6,129,174 acres /13,557 acres = 452 male homeranges

Maximum # females = max. occupied habitat/ maximum female homerange
Maximum # females = 6, 129,174 acres /7,321 acres = 837 female homeranges

**Maximum # lynx = 452 + 837 =1,289 adult lynx**

Calculations Method 2: Acres of lynx habitat (s/f sapling) in homerange.

**Table IV.2. Parameters used to estimate lynx numbers in 2006 using method 2.**

| Variable | Min | Max | Avg | SE | N |
|---|---|---|---|---|---|
| Surveys areas with lynx | 50%[a] | 83%[b] | | | |
| Acres spruce/fir (FIA) lynx range[c] | 1,312,677 | 1,485,119 | 1,398,898 | 86,221 | |
| Acres of spruce/fir sapling in male homerange (acres)[c,d] | 3,031 | 4,189 | 3,610 | 579 | 11 |
| Acres of spruce/fir sapling in female homerange (acres)[c,d] | 1,829 | 2,339 | 2,084 | 255 | 13 |

[a] Percent of survey areas (low lynx probability) with lynx tracks.
[b] Percent of survey areas (high/moderate lynx probability) with lynx tracks.
[c] Minimum and maximum were calculated form estimates of standard errors (SE).
[d] Homerange size estimated as the 85% fixed kernel (Vashon et al. 2008a).

Step 1: Estimate Occupied habitat

Acres of existing lynx habitat within lynx range X % survey areas with lynx

Minimum occupied habitat = 1,312,667 acres X 50% = 656,339 acres
Maximum occupied habitat = 1,485,119 acres X 83% = 1,237,599 acres

Step 2: Estimate the number of lynx in occupied area

Occupied habitat/Minimum acres habitat in lynx homerange

Minimum number of male lynx = 656,339 acres/ 2,938 acres = 217 males
Minimum number of male lynx = 656,339 acres/1,736 acres = 359 females
**Minimum number of lynx = 217 male + 359 females = 575 adult lynx**

Maximum number of male lynx = 1,237,599 acres/ 4,282 acres = 295 males
Maximum number of female lynx = 1,237,599 acres/2,432 acres = 529 females
**Maximum # lynx = 295 males + 529 female ranges = 825 adult lynx**

Population estimates reported in assessment:
For both methods used to estimate Maine's lynx population, we assumed Maine's lynx range had either a high or low probability of lynx occurrence because the proportion of low or high probability of lynx occurrence was not available. Thus, the minimum population estimate for each method was biased low and conversely the maximum estimate was biased high. Method 1 assumes all forested habitat is of value to lynx, conversely method assumes only spruce/fir sapling forests are used by lynx. Since method 1 likely overestimates and method 2 likely overestimates the number of lynx in northern and western Maine, we reported the minimum and maximum number of lynx in Maine based on the averaged of the minimum estimates and maximum estimates respectively.

*For example*:
Minimum: (987 + 575) /2 = 781 adult lynx Maximum: (1289+825)/2=1,057 lynx

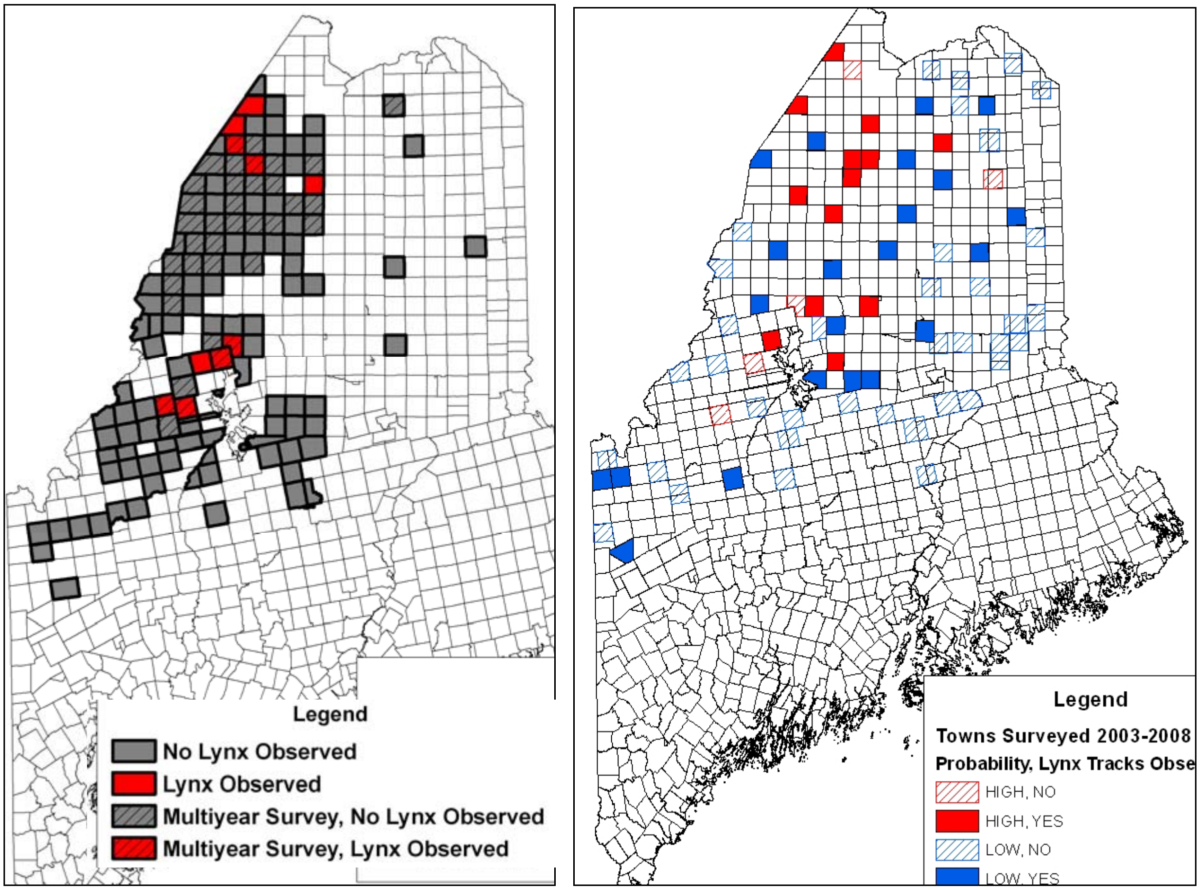



**Figure IV.** Areas where MDIFW conducted winter snow track surveys to detect lynx presence in northern and western Maine (1995 to 1998 (left) and 2003 to 2008 (right) used to estimate lynx occupancy of past and current lynx habitat in Maine.

**Appendix V. Maine Forest Practice Act - clearcutting standards (Maine Forest Service 1999).**

A **clear cut** is defined as a timber harvest on a forested site greater than 5 acres in size with a residual basal area of acceptable growing stock trees over 4.5 inches dbh of less than 30 square feet per acre. Unless after harvesting the site has a well distributed stand of softwood trees > 3 feet in height or hardwood trees > 5 feet in height.

**The maximum size of clear cut** is 250 acres. However a forest landowner can petition for permission to clear cut areas greater than 250 acres if it provides undue hardship on the landowner, meets the intent of the FPA, or the public interest is otherwise served.

All clear cuts must have a **separation zone;** the size and amount of trees in the separation zone are defined by the size of the clearcut. Smaller clear cuts have smaller separation zones and have lower forested area requirements.

**Category 1 clear cuts** are between 5 and 20 acres and have at least 250 foot separation zone between clear cuts. **Separation zones** must have a basal area greater than 30 $ft^2$/acre of acceptable growing stock trees that are well distributed in the zone or contain at least 450 trees/acre of softwood or hardwood trees that are greater 3 or 5 feet tall, respectively.

**Category 2 clear cuts** are between 21 and 75 acres.
**Category 3 clear cuts** are between 76 and 250 acres.

**Category 2 and 3 clear cuts** must have a **harvest plan** that provides the justification for larger clear cuts. **Separation zones** must be equal or larger than the clear cut, contain at least 60 square feet basal area per acre of trees 1 inch DBH or larger that are well distributed in the zone. A minimum of 40 square feet basal area per acre must be comprised of acceptable growing stock trees and a minimum of 40 square feet basal area per acre must be comprised of trees 4.5" DBH or larger; *or* the separation zone contains at least 300 trees/acre of at least 10 foot tall softwood or 20 foot tall hardwood trees that are well distributed in the separation zone.

For all clear cuts, a separation zone must be maintained until the regenerating clear cut contains at least 300 trees/acre of at least 10 or 20 feet tall softwood or hardwood trees respectively or at least 10 years have elapsed since the date the harvest was completed.

The Maine FPA allows the creation of category 2 and 3 clear cuts (i.e. 21-250 acres) for among other things the improvement or creation of wildlife habitat as prescribed and justified by a certified wildlife professional. Trees that are salvaged harvested after they are damaged by wind are not considered a clear cut as long as only the damaged trees are harvested.

See Maine Forest Service (1999) for definition of terms, list of exemptions, minimum elements of harvest plan, and regeneration standards.

**Appendix VI. Summary of inputs used to assess lynx population growth rates and the influence of minor annual trapping related mortality on lynx.**

We used VORTEX 9.99 software to calculate the growth rate of Maine's lynx population and to simulate lynx population dynamics from lynx demographic data collected in Maine between 1999 and 2010. The purpose of the simulation was to 1) update the inputs used in the population model presented in Maine's 2008 Incidental Take Plan (Plan), and 2) to determine if Maine's lynx population would continue to increase despite minor losses that might result from the incidental capture of lynx in traps set for other furbearing animals. We considered the effects of incidental trapping over the 15-year time frame of the Incidental Take Permit (ITP).

We collected data on lynx vital rates during a period when snowshoe hare populations fluctuated from >2 hares/ha to >1.0 hare/ha in northern Maine's regenerating conifer clearcuts (Scott 2010). Data collected from this period suggests that Maine's lynx population reached a historic high due to the abundance of young conifer forests that supported high prey densities. When hares declined, lynx reproductive rates also declined.

Vortex allows users to consider the influence of small isolated populations on population growth rates. For our simulations, we selected no inbreeding depression because DNA analysis indicated that Maine's lynx are not isolated from lynx populations in northeastern Canada. We also have direct observations of 12 lynx monitored in Maine moving between Maine and Quebec or New Brunswick.

Since environmental variability can influence various vital rates, Vortex allows for concordance between female reproductive rates and adult survival (e.g., a stressful winter can reduce survival and production of kittens). In Maine, a major source of mortality is predation of lynx. Predation can be independent of environmental variability; thus, we did not select concordance between female reproductive rates and adult survival for our model and simulations. However, Vortex did simulate concordance in survival rates among age-sex classes.

Although female lynx can breed (March) as 1 year olds and produce their first litter (May) at age 2 (Parker 1980), we set the first age of reproduction at age 3 since most lynx produce their first litter at 3. Setting the first age of reproduction at 3 should produce a conservative estimate of population growth. Male lynx can breed at 2 years of age. To date, the oldest female lynx that produced a litter in Maine was 13 and the sex ratio of kittens from all litters was 50% male and 50% female (n=35 litters).

Lynx are considered polygynous breeders (i.e., male lynx will mate with several female lynx). Although most female lynx produce 1 litter a year, we observed the birth of a late litter shortly after the loss of an earlier litter one summer.

Between 1999 and 2010, when hares populations fluctuated between 1 and 2 hares/ha, 65% of the adult female lynx produced litters (range = 0-100%, σ = 42; n=66) of 1-5 kittens each year ( $\overline{X} = 2.64$; σ = 1.21; n =111), where σ = standard deviation. The high variability associate with this vital rate was influenced by years with very good productivity and years with very poor productivity. Thus, we also ran simulations where the σ =10, which may better reflect true variability. For our simulations, we provided mortality rates for 3 age classes; kittens (<1 year old), juveniles (1 and 2 year olds), and adults (3 years and older). We had good estimates of adult (21%, σ = 17) and kitten mortality rates (18%; σ = 23) in Maine from a 12-year telemetry study. However, our sample size of juvenile lynx was small. Therefore, we used our knowledge of carnivore and felid ecology to estimate juvenile lynx mortality rates. We assumed that male and female juvenile mortality rates were twice and 1 ½ times our observed adult lynx mortality rates (21%), respectively, since male juveniles experience higher mortality rates because they often disperse greater distances than female juveniles (Breitenmoser et al. 1993). Among felids, female offspring often do not disperse and remain near their mother's range (Breitenmoser et al. 1993).

Maine's lynx assessment estimated between 600 and 1,200 lynx in WMD 1-10 and 14 and a carrying capacity between 1,100 and 1,800 lynx. For our simulations, we set our initial population at 600 lynx and Maine's carrying capacity at 1,350 lynx. We ran our simulations for 15 years, since our permit request spans a 15 year period.

Based on population vital rates observed in Maine when hare populations fluctuated, Vortex calculated a slightly increasing population growth rate (r = 0.0505) without the loss of any animals from harvest (Figure VI. 1; Output I).

To test the assumption that Maine's lynx population size would continue to increase even if lynx mortalities resulted from incidental trapping (or other causes), the USFWS requested that we run our simulations using a level of lethal take that was higher than maximum lethal take requested in our Plan. Maine's Plan requested that trappers in Maine's trapping program be allowed to incidentally kill up to 5 lynx (adults and juveniles) over the 15-year time frame of the ITP. We used a rate of lethal incidental take that was 15 times greater than the maximum rate of lethal take requested in our Plan. Specifically, we ran our simulations to determine the influence of the loss of 5 lynx (2 adult females, 1 adult male, and 1 yearling male and female) each fall during the 15-year permit period. Use of this high level of lethal take, does not imply that either agency believes that this level of lethal take has or will occur. Even at 15x the rate of lethal incidental take requested in our Plan, our simulations indicated that Maine's lynx population could maintain a positive growth rate (r = 0.0323) (Figure IV.1; Output II).

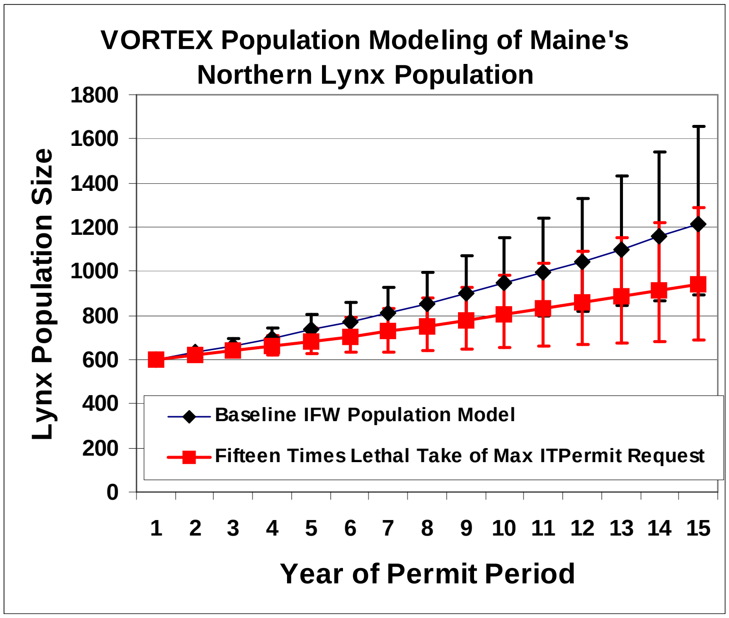
**Table VI.1. Lynx reproductive rates observed for radiocollared lynx in Maine between 1999 and 2010 used in Vortex to estimate population growth rates and affect of the lethal take of 5 lynx incidentally captured by trappers in Maine.**

| | Female | Male |
|---|---|---|
| Age of first reproduction | 3 | 2 |
| Maximum breeding age | 13 | |
| Sex ratio at birth | 50 | 50 |
| Percent of adults that breed | 65 | 100 |
| Percentage of breeding females that produce 1 litter | 100 | |
| | Average | SD |
| Litter size | 2.64 | 1.21 |

**Table VI.2. Lynx mortality rates observed for radiocollared lynx in Maine between 1999 and 2010 used in Vortex to estimate population growth rates and affect of the lethal take of 5 lynx incidentally captured by trappers in Maine.**

| | Females | | Males | |
|---|---|---|---|---|
| | Average | SD | Average | SD |
| Litter size | 2.64 | 1.21 | | |
| Mortality 0-1 | 18% | 23 | 18% | 23 |
| Mortality 1-2 | 32% | 20 | 42% | 20 |
| Mortality 2+ | 21% | 17 | 21% | 17 |

**Figure VI.1. Depiction of the intrinsic rate of increase of Maine's lynx population when (1) no lethal take occurs and (2) at 15 times the level of lethal take requested in Maine's Incidental Take Plan. Values were obtained from a VORTEX population model and the most recent demographic data on lynx in Maine.**




This model applies VORTEX mean overal r-values (intrinsic rates of increase) along with mean overall SEs of those r-values. The error bars are ~95%CIs. The starting population size is set to equal 600.

This model assumes no density-dependence and compounding uncertainty in future expectations. This model is deterministic using mean values from 1,500 stochastic model runs of ***a density-dependent model, which affects the mean r-values if those model populations approach a level where growth rate becomes affected by denisty-dependent model paramters.***

## Output 1: Results of Base run with no take of lynx in 15 year permit period

VORTEX 9.99 -- simulation of population dynamics

Base Run - 0 take
Thu Dec 22 13:58:29 2011

1 population(s) simulated for 15 years, 100 iterations
Each simulation year is 365 days duration.

Extinction is defined as no animals of one or both sexes.

No inbreeding depression

EV in mortality will be concordant among age-sex classes
but independent from EV in reproduction.

First age of reproduction for females: 3 for males: 2
Maximum breeding age (senescence): 13
Sex ratio at birth (percent males): 50

Population 1: Population 1

Polygynous mating;
% of adult males in the breeding pool = 100

% adult females breeding = 65
EV in % adult females breeding: SD = 42

Distribution of number of separately sired broods produced by a female in a year ...
0.00 percent of females produce 0 broods (litters, clutches) in an average year
100.00 percent of females produce 1 broods (litters, clutches) in an average year

Of those females producing progeny, ...
Mean number of progeny per breeding female per year = 2.64
SD in number of progeny = 1.21

% mortality of females between ages 0 and 1 = 18
EV in % mortality: SD = 23
% mortality of females between ages 1 and 2 = 32
EV in % mortality: SD = 20
% mortality of females between ages 2 and 3 = 21
EV in % mortality: SD = 17
% mortality of adult females (3<=age<=13) = 21
EV in % mortality: SD = 17
% mortality of males between ages 0 and 1 = 18
EV in % mortality: SD = 23
% mortality of males between ages 1 and 2 = 42
EV in % mortality: SD = 20
% mortality of adult males (2<=age<=13) = 21
EV in % mortality: SD = 17

EVs may be adjusted to closest values possible for binomial distribution.

Initial size of Population 1: 600
(set to reflect stable age distribution)

| Age 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 99 | 53 | 38 | 27 | 20 | 14 | 10 | 8 | 5 | 4 | 3 | 2 | 1 | 284 | Males |
| 99 | 62 | 45 | 32 | 23 | 16 | 12 | 9 | 6 | 5 | 3 | 2 | 2 | 316 | Females |

Carrying capacity = 1350
EV in Carrying capacity = 10

Deterministic projections assume no stochastic fluctuations, no inbreeding depression, no limitation of mates, no harvest, and no supplementation.

Scenario: Base Run - 0 take

Population 1: Population 1

Deterministic population growth rate:

r = 0.092
lambda = 1.096
R0 = 1.665
Generation time for:
females = 5.56
males = 4.66

Stable age distribution:

| Age class | females | males |
|---|---|---|
| 0 | 0.153 | 0.153 |
| 1 | 0.115 | 0.115 |
| 2 | 0.071 | 0.061 |
| 3 | 0.051 | 0.044 |
| 4 | 0.037 | 0.032 |
| 5 | 0.027 | 0.023 |
| 6 | 0.019 | 0.016 |
| 7 | 0.014 | 0.012 |
| 8 | 0.010 | 0.009 |
| 9 | 0.007 | 0.006 |
| 10 | 0.005 | 0.004 |
| 11 | 0.004 | 0.003 |
| 12 | 0.003 | 0.002 |
| 13 | 0.002 | 0.002 |

Ratio of adult (>= 2) males to adult (>= 3) females: 1.193

Initial population size, N = 600
Initial carrying capacity, K = 1350

## Results from VORTEX 9.99 simulations completed Thu Dec 22 13:58:29 2011

Project: LynxITP-expandedRuns
Scenario: **Base Run - 0 take**

Population 1: Population 1
Year 1
N[Extinct] = 0, P[E] = 0.000
N[Surviving] = 100, P[S] = 1.000
Mean size (all populations) = 670.62 ( 22.84 SE; 228.44 SD)
Means across extant populations only:
Population size = 670.62 ( 22.84 SE; 228.44 SD)
Expected heterozygosity = 0.999 ( 0.000 SE; 0.000 SD)
Observed heterozygosity = 1.000 ( 0.000 SE; 0.000 SD)
Number of extant alleles = 917.81 ( 19.32 SE; 193.19 SD)

Year 2
N[Extinct] = 0, P[E] = 0.000
N[Surviving] = 100, P[S] = 1.000
Mean size (all populations) = 696.83 ( 32.18 SE; 321.84 SD)
Means across extant populations only:
Population size = 696.83 ( 32.18 SE; 321.84 SD)
Expected heterozygosity = 0.998 ( 0.000 SE; 0.001 SD)
Observed heterozygosity = 1.000 ( 0.000 SE; 0.000 SD)
Number of extant alleles = 774.43 ( 21.05 SE; 210.53 SD)

Year 3
N[Extinct] = 0, P[E] = 0.000
N[Surviving] = 100, P[S] = 1.000
Mean size (all populations) = 738.24 ( 35.91 SE; 359.15 SD)
Means across extant populations only:
Population size = 738.24 ( 35.91 SE; 359.15 SD)
Expected heterozygosity = 0.998 ( 0.000 SE; 0.001 SD)
Observed heterozygosity = 1.000 ( 0.000 SE; 0.000 SD)
Number of extant alleles = 675.36 ( 20.88 SE; 208.82 SD)

Year 4
N[Extinct] = 0, P[E] = 0.000
N[Surviving] = 100, P[S] = 1.000
Mean size (all populations) = 764.67 ( 39.52 SE; 395.17 SD)
Means across extant populations only:
Population size = 764.67 ( 39.52 SE; 395.17 SD)
Expected heterozygosity = 0.997 ( 0.000 SE; 0.001 SD)
Observed heterozygosity = 1.000 ( 0.000 SE; 0.001 SD)
Number of extant alleles = 601.22 ( 20.10 SE; 201.04 SD)

Year 5
N[Extinct] = 0, P[E] = 0.000
N[Surviving] = 100, P[S] = 1.000
Mean size (all populations) = 772.06 ( 39.64 SE; 396.35 SD)
Means across extant populations only:
Population size = 772.06 ( 39.64 SE; 396.35 SD)
Expected heterozygosity = 0.997 ( 0.000 SE; 0.002 SD)
Observed heterozygosity = 1.000 ( 0.000 SE; 0.001 SD)
Number of extant alleles = 544.57 ( 18.84 SE; 188.39 SD)

Year 6
N[Extinct] = 0, P[E] = 0.000
N[Surviving] = 100, P[S] = 1.000
Mean size (all populations) = 783.24 ( 42.58 SE; 425.83 SD)
Means across extant populations only:
Population size = 783.24 ( 42.58 SE; 425.83 SD)
Expected heterozygosity = 0.996 ( 0.000 SE; 0.002 SD)
Observed heterozygosity = 0.999 ( 0.000 SE; 0.002 SD)
Number of extant alleles = 493.11 ( 18.51 SE; 185.07 SD)

Year 7
N[Extinct] = 0, P[E] = 0.000
N[Surviving] = 100, P[S] = 1.000
Mean size (all populations) = 752.85 ( 41.96 SE; 419.56 SD)
Means across extant populations only:
Population size = 752.85 ( 41.96 SE; 419.56 SD)
Expected heterozygosity = 0.996 ( 0.000 SE; 0.002 SD)
Observed heterozygosity = 0.999 ( 0.000 SE; 0.002 SD)
Number of extant alleles = 450.87 ( 17.38 SE; 173.84 SD)

Year 8
N[Extinct] = 0, P[E] = 0.000
N[Surviving] = 100, P[S] = 1.000
Mean size (all populations) = 799.98 ( 43.56 SE; 435.59 SD)
Means across extant populations only:
Population size = 799.98 ( 43.56 SE; 435.59 SD)
Expected heterozygosity = 0.996 ( 0.000 SE; 0.002 SD)
Observed heterozygosity = 0.999 ( 0.000 SE; 0.002 SD)
Number of extant alleles = 421.61 ( 16.77 SE; 167.65 SD)

Year 9
N[Extinct] = 0, P[E] = 0.000
N[Surviving] = 100, P[S] = 1.000
Mean size (all populations) = 815.76 ( 43.09 SE; 430.92 SD)
Means across extant populations only:
Population size = 815.76 ( 43.09 SE; 430.92 SD)
Expected heterozygosity = 0.995 ( 0.000 SE; 0.003 SD)
Observed heterozygosity = 0.998 ( 0.000 SE; 0.003 SD)
Number of extant alleles = 394.72 ( 15.90 SE; 159.01 SD)

Year 10
N[Extinct] = 0, P[E] = 0.000
N[Surviving] = 100, P[S] = 1.000
Mean size (all populations) = 832.17 ( 43.04 SE; 430.43 SD)
Means across extant populations only:
Population size = 832.17 ( 43.04 SE; 430.43 SD)
Expected heterozygosity = 0.995 ( 0.000 SE; 0.004 SD)
Observed heterozygosity = 0.998 ( 0.000 SE; 0.002 SD)
Number of extant alleles = 370.05 ( 15.29 SE; 152.87 SD)

Year 11
N[Extinct] = 0, P[E] = 0.000
N[Surviving] = 100, P[S] = 1.000
Mean size (all populations) = 863.60 ( 44.11 SE; 441.12 SD)
Means across extant populations only:
Population size = 863.60 ( 44.11 SE; 441.12 SD)

Expected heterozygosity = 0.994 ( 0.000 SE; 0.004 SD)
Observed heterozygosity = 0.997 ( 0.000 SE; 0.003 SD)
Number of extant alleles = 350.81 ( 14.55 SE; 145.47 SD)

Year 12
N[Extinct] = 0, P[E] = 0.000
N[Surviving] = 100, P[S] = 1.000
Mean size (all populations) = 832.85 ( 40.17 SE; 401.69 SD)
Means across extant populations only:
Population size = 832.85 ( 40.17 SE; 401.69 SD)
Expected heterozygosity = 0.994 ( 0.000 SE; 0.005 SD)
Observed heterozygosity = 0.997 ( 0.000 SE; 0.003 SD)
Number of extant alleles = 331.59 ( 13.51 SE; 135.12 SD)

Year 13
N[Extinct] = 0, P[E] = 0.000
N[Surviving] = 100, P[S] = 1.000
Mean size (all populations) = 864.53 ( 43.49 SE; 434.85 SD)
Means across extant populations only:
Population size = 864.53 ( 43.49 SE; 434.85 SD)
Expected heterozygosity = 0.993 ( 0.001 SE; 0.005 SD)
Observed heterozygosity = 0.997 ( 0.000 SE; 0.003 SD)
Number of extant alleles = 315.43 ( 12.81 SE; 128.09 SD)

Year 14
N[Extinct] = 0, P[E] = 0.000
N[Surviving] = 100, P[S] = 1.000
Mean size (all populations) = 849.68 ( 43.40 SE; 433.99 SD)
Means across extant populations only:
Population size = 849.68 ( 43.40 SE; 433.99 SD)
Expected heterozygosity = 0.993 ( 0.001 SE; 0.006 SD)
Observed heterozygosity = 0.996 ( 0.000 SE; 0.003 SD)
Number of extant alleles = 298.51 ( 12.02 SE; 120.21 SD)

Year 15
N[Extinct] = 0, P[E] = 0.000
N[Surviving] = 100, P[S] = 1.000
Mean size (all populations) = 845.08 ( 42.75 SE; 427.50 SD)
Means across extant populations only:
Population size = 845.08 ( 42.75 SE; 427.50 SD)
Expected heterozygosity = 0.992 ( 0.001 SE; 0.006 SD)
Observed heterozygosity = 0.996 ( 0.000 SE; 0.004 SD)
Number of extant alleles = 284.14 ( 11.51 SE; 115.14 SD)

In 100 simulations of Population 1 for 15 years: 0 went extinct and 100 survived.

This gives a probability of extinction of 0.0000 (0.0000 SE), or a probability of success of 1.0000 (0.0000 SE).

Means across all populations (extant and extinct) ...
Mean final population was 845.08 (42.75 SE; 427.50 SD)

| Age 1 | 2 | Adults | Total | |
|---|---|---|---|---|
| 132.08 | | 269.92 | 402.00 | Males |
| 131.31 | 82.64 | 229.13 | 443.08 | Females |

Across all years, prior to carrying capacity truncation,
mean growth rate (r) was 0.0505 (0.0110 SE; 0.4273 SD)

Final expected heterozygosity was 0.9922 ( 0.0006 SE; 0.0062 SD)
Final observed heterozygosity was 0.9956 ( 0.0004 SE; 0.0040 SD)
Final number of alleles was 284.14 ( 11.51 SE; 115.14 SD)
**************************************************************************

**Output 2: Simulate the affect of lethal take of 5 lynx each year for the 15 year permit period.**

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VORTEX 9.99 -- simulation of population dynamics

MaxTakeUnderITP_10SDonK
Thu Dec 22 14:07:49 2011

1 population(s) simulated for 15 years, 100 iterations
Each simulation year is 365 days duration.

Extinction is defined as no animals of one or both sexes.

No inbreeding depression

EV in mortality will be concordant among age-sex classes
but independent from EV in reproduction.

First age of reproduction for females: 3   for males: 2
Maximum breeding age (senescence): 13
Sex ratio at birth (percent males): 50

Population 1: Population 1

Polygynous mating;
% of adult males in the breeding pool = 100

% adult females breeding = 65
EV in % adult females breeding: SD = 42

Distribution of number of separately sired broods produced by a female in a year ...
0.00 percent of females produce 0 broods (litters, clutches) in an average year
100.00 percent of females produce 1 broods (litters, clutches) in an average year

Of those females producing progeny, ...
Mean number of progeny per breeding female per year = 2.64
SD in number of progeny = 1.21

% mortality of females between ages 0 and 1 = 18
EV in % mortality: SD = 23
% mortality of females between ages 1 and 2 = 32
EV in % mortality: SD = 20
% mortality of females between ages 2 and 3 = 21
EV in % mortality: SD = 17
% mortality of adult females (3<=age<=13) = 21
EV in % mortality: SD = 17
% mortality of males between ages 0 and 1 = 18
EV in % mortality: SD = 23
% mortality of males between ages 1 and 2 = 42
EV in % mortality: SD = 20
% mortality of adult males (2<=age<=13) = 21
EV in % mortality: SD = 17

EVs may be adjusted to closest values possible for binomial distribution.

Initial size of Population 1: 600
(set to reflect stable age distribution)

| Age | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | Total | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 99 | 53 | 38 | 27 | 20 | 14 | 10 | 8 | 5 | 4 | 3 | 2 | 1 | 284 | Males |
| | 99 | 62 | 45 | 32 | 23 | 16 | 12 | 9 | 6 | 5 | 3 | 2 | 2 | 316 | Females |

Carrying capacity = 1350
EV in Carrying capacity = 10

Animals harvested from Population 1, year 1 to year 15 at 1 year intervals:
females 1 years old: 1
female adults (3 <= age <= 13): 2
males 1 years old: 1
male adults (2 <= age <= 13): 1

Deterministic projections assume no stochastic fluctuations, no inbreeding depression, no limitation of mates, no harvest, and no supplementation.

Scenario: MaxTakeUnderITP_10SDonK

Population 1: Population 1

Deterministic population growth rate:

r = 0.092
lambda = 1.096
R0 = 1.665
Generation time for:
females = 5.56
males = 4.66

Stable age distribution:

| Age class | females | males |
|---|---|---|
| 0 | 0.153 | 0.153 |
| 1 | 0.115 | 0.115 |
| 2 | 0.071 | 0.061 |
| 3 | 0.051 | 0.044 |
| 4 | 0.037 | 0.032 |
| 5 | 0.027 | 0.023 |
| 6 | 0.019 | 0.016 |
| 7 | 0.014 | 0.012 |
| 8 | 0.010 | 0.009 |
| 9 | 0.007 | 0.006 |
| 10 | 0.005 | 0.004 |
| 11 | 0.004 | 0.003 |
| 12 | 0.003 | 0.002 |
| 13 | 0.002 | 0.002 |

Ratio of adult (>= 2) males to adult (>= 3) females: 1.193

Initial population size, N = 600
Initial carrying capacity, K = 1350

**Results from VORTEX 9.99 simulations completed Thu Dec 22 14:07:49 2011**

Project: LynxITP-expandedRuns
Scenario: **MaxTakeUnderITP_10SDonK**

Population 1: Population 1

Year 1
N[Extinct] = 0, P[E] = 0.000
N[Surviving] = 100, P[S] = 1.000
Mean size (all populations) = 670.27 ( 22.46 SE; 224.59 SD)
Means across extant populations only:
Population size = 670.27 ( 22.46 SE; 224.59 SD)
Expected heterozygosity = 0.999 ( 0.000 SE; 0.000 SD)
Observed heterozygosity = 1.000 ( 0.000 SE; 0.000 SD)
Number of extant alleles = 953.35 ( 16.40 SE; 163.99 SD)

Year 2
N[Extinct] = 0, P[E] = 0.000
N[Surviving] = 100, P[S] = 1.000
Mean size (all populations) = 752.59 ( 33.56 SE; 335.62 SD)
Means across extant populations only:
Population size = 752.59 ( 33.56 SE; 335.62 SD)
Expected heterozygosity = 0.998 ( 0.000 SE; 0.001 SD)
Observed heterozygosity = 1.000 ( 0.000 SE; 0.000 SD)
Number of extant alleles = 823.23 ( 20.56 SE; 205.64 SD)

Year 3
N[Extinct] = 0, P[E] = 0.000
N[Surviving] = 100, P[S] = 1.000
Mean size (all populations) = 774.95 ( 38.50 SE; 384.98 SD)
Means across extant populations only:
Population size = 774.95 ( 38.50 SE; 384.98 SD)
Expected heterozygosity = 0.998 ( 0.000 SE; 0.001 SD)
Observed heterozygosity = 1.000 ( 0.000 SE; 0.000 SD)
Number of extant alleles = 713.35 ( 21.70 SE; 217.04 SD)

Year 4
N[Extinct] = 0, P[E] = 0.000
N[Surviving] = 100, P[S] = 1.000
Mean size (all populations) = 787.10 ( 41.93 SE; 419.34 SD)
Means across extant populations only:
Population size = 787.10 ( 41.93 SE; 419.34 SD)
Expected heterozygosity = 0.997 ( 0.000 SE; 0.001 SD)
Observed heterozygosity = 1.000 ( 0.000 SE; 0.000 SD)
Number of extant alleles = 634.72 ( 21.21 SE; 212.07 SD)

Year 5
N[Extinct] = 0, P[E] = 0.000
N[Surviving] = 100, P[S] = 1.000
Mean size (all populations) = 772.63 ( 40.82 SE; 408.25 SD)
Means across extant populations only:
Population size = 772.63 ( 40.82 SE; 408.25 SD)
Expected heterozygosity = 0.997 ( 0.000 SE; 0.002 SD)
Observed heterozygosity = 1.000 ( 0.000 SE; 0.001 SD)
Number of extant alleles = 568.94 ( 20.02 SE; 200.16 SD)

Year 6
N[Extinct] = 0, P[E] = 0.000
N[Surviving] = 100, P[S] = 1.000
Mean size (all populations) = 787.69 ( 39.75 SE; 397.49 SD)
Means across extant populations only:
Population size = 787.69 ( 39.75 SE; 397.49 SD)
Expected heterozygosity = 0.997 ( 0.000 SE; 0.002 SD)
Observed heterozygosity = 0.999 ( 0.000 SE; 0.001 SD)
Number of extant alleles = 515.62 ( 18.53 SE; 185.28 SD)

Year 7
N[Extinct] = 0, P[E] = 0.000
N[Surviving] = 100, P[S] = 1.000
Mean size (all populations) = 778.43 ( 40.80 SE; 408.00 SD)
Means across extant populations only:
Population size = 778.43 ( 40.80 SE; 408.00 SD)
Expected heterozygosity = 0.996 ( 0.000 SE; 0.003 SD)
Observed heterozygosity = 0.999 ( 0.000 SE; 0.002 SD)
Number of extant alleles = 466.79 ( 17.50 SE; 175.00 SD)

Year 8
N[Extinct] = 0, P[E] = 0.000
N[Surviving] = 100, P[S] = 1.000
Mean size (all populations) = 759.70 ( 43.07 SE; 430.73 SD)
Means across extant populations only:
Population size = 759.70 ( 43.07 SE; 430.73 SD)
Expected heterozygosity = 0.995 ( 0.000 SE; 0.003 SD)
Observed heterozygosity = 0.999 ( 0.000 SE; 0.003 SD)
Number of extant alleles = 429.80 ( 16.81 SE; 168.06 SD)

Year 9
N[Extinct] = 0, P[E] = 0.000
N[Surviving] = 100, P[S] = 1.000
Mean size (all populations) = 739.95 ( 42.78 SE; 427.76 SD)
Means across extant populations only:
Population size = 739.95 ( 42.78 SE; 427.76 SD)
Expected heterozygosity = 0.995 ( 0.000 SE; 0.004 SD)
Observed heterozygosity = 0.998 ( 0.000 SE; 0.004 SD)
Number of extant alleles = 396.67 ( 15.96 SE; 159.59 SD)

Year 10
N[Extinct] = 0, P[E] = 0.000
N[Surviving] = 100, P[S] = 1.000
Mean size (all populations) = 782.91 ( 45.06 SE; 450.61 SD)
Means across extant populations only:
Population size = 782.91 ( 45.06 SE; 450.61 SD)
Expected heterozygosity = 0.994 ( 0.000 SE; 0.004 SD)
Observed heterozygosity = 0.997 ( 0.000 SE; 0.005 SD)
Number of extant alleles = 370.38 ( 15.26 SE; 152.55 SD)

Year 11
N[Extinct] = 0, P[E] = 0.000
N[Surviving] = 100, P[S] = 1.000
Mean size (all populations) = 798.36 ( 43.80 SE; 438.03 SD)
Means across extant populations only:

Population size = 798.36 ( 43.80 SE; 438.03 SD)
Expected heterozygosity = 0.994 ( 0.001 SE; 0.006 SD)
Observed heterozygosity = 0.996 ( 0.001 SE; 0.009 SD)
Number of extant alleles = 349.79 ( 14.75 SE; 147.50 SD)

Year 12
N[Extinct] = 0, P[E] = 0.000
N[Surviving] = 100, P[S] = 1.000
Mean size (all populations) = 751.65 ( 42.47 SE; 424.67 SD)
Means across extant populations only:
Population size = 751.65 ( 42.47 SE; 424.67 SD)
Expected heterozygosity = 0.993 ( 0.001 SE; 0.007 SD)
Observed heterozygosity = 0.996 ( 0.001 SE; 0.011 SD)
Number of extant alleles = 327.54 ( 14.12 SE; 141.19 SD)

Year 13
N[Extinct] = 0, P[E] = 0.000
N[Surviving] = 100, P[S] = 1.000
Mean size (all populations) = 755.43 ( 46.45 SE; 464.52 SD)
Means across extant populations only:
Population size = 755.43 ( 46.45 SE; 464.52 SD)
Expected heterozygosity = 0.992 ( 0.001 SE; 0.009 SD)
Observed heterozygosity = 0.995 ( 0.001 SE; 0.015 SD)
Number of extant alleles = 304.78 ( 13.50 SE; 135.02 SD)

Year 14
N[Extinct] = 0, P[E] = 0.000
N[Surviving] = 100, P[S] = 1.000
Mean size (all populations) = 771.46 ( 45.52 SE; 455.21 SD)
Means across extant populations only:
Population size = 771.46 ( 45.52 SE; 455.21 SD)
Expected heterozygosity = 0.991 ( 0.001 SE; 0.010 SD)
Observed heterozygosity = 0.995 ( 0.001 SE; 0.010 SD)
Number of extant alleles = 286.60 ( 12.90 SE; 129.04 SD)

Year 15
N[Extinct] = 1, P[E] = 0.010
N[Surviving] = 99, P[S] = 0.990
Mean size (all populations) = 710.29 ( 45.54 SE; 455.41 SD)
Means across extant populations only:
Population size = 717.46 ( 45.43 SE; 452.02 SD)
Expected heterozygosity = 0.991 ( 0.001 SE; 0.011 SD)
Observed heterozygosity = 0.995 ( 0.001 SE; 0.006 SD)
Number of extant alleles = 266.84 ( 12.54 SE; 124.81 SD)

In 100 simulations of Population 1 for 15 years:
1 went extinct and 99 survived.

This gives a probability of extinction of 0.0100 (0.0099 SE),
or a probability of success of 0.9900 (0.0099 SE).

1 simulations went extinct at least once.
Of those going extinct,
mean time to first extinction was 15.00 years (0.00 SE, 0.00 SD).

Means across all populations (extant and extinct) ...
Mean final population was 710.29 (45.54 SE; 455.41 SD)

| Age 1 | 2 | Adults | Total | |
|---|---|---|---|---|
| 115.41 | | 223.06 | 338.47 | Males |
| 113.19 | 77.64 | 180.99 | 371.82 | Females |

Means across extant populations only ...
Mean final population for successful cases was 717.46 (45.43 SE, 452.02 SD)

| Age 1 | 2 | Adults | Total | |
|---|---|---|---|---|
| 116.58 | | 225.31 | 341.89 | Males |
| 114.33 | 78.42 | 182.82 | 375.58 | Females |

During years of harvest and/or supplementation
mean growth rate (r) was 0.0323 (0.0111 SE, 0.4314 SD, mean n = 15.0 years)

Across all years, prior to carrying capacity truncation,
mean growth rate (r) was 0.0323 (0.0111 SE; 0.4314 SD)

529 of 4500 harvests of females could not be completed because of insufficient animals.
528 of 3000 harvests of males could not be completed because of insufficient animals.

Final expected heterozygosity was 0.9906 ( 0.0011 SE; 0.0114 SD)
Final observed heterozygosity was 0.9954 ( 0.0006 SE; 0.0062 SD)
Final number of alleles was 266.84 ( 12.54 SE; 124.81 SD)
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