Canada lynx habitat management guidelines for Maine

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Acknowledgements

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Introduction

The U. S. Fish and Wildlife Service (USFWS) listed the Canada lynx as a threatened species on April 23, 2000 (USFWS 2000). Subsequently, as the result of a lawsuit by Defenders of Wildlife and other groups, the U. S. Fish and Wildlife Service was required to designate Critical Habitat for the Canada lynx. In November 2005 Critical Habitat was proposed for 10,600 square miles (6.7 million) acres of forestland in northern Maine. A final rule will be published in November 2006.

These lynx habitat management guidelines were developed for private landowners who wish to manage for lynx habitat in a forest managed primarily for forest products. These guidelines achieve multiple objectives of managing a forest for forest products, providing habitat for lynx and other species that use young, regenerating forest, and allowing for recreation and multiple use of the forest. These guidelines reflect the best science available in 2006. New research findings may alter the conclusions contained in this document or result in future changes to these guidelines. We consider lynx management to be an adaptive process, incorporating new science as it becomes available and adjusting guidelines as we learn how snowshoe hare and lynx respond to forest management.

Implementing these guidelines is voluntary. These guidelines may help landowners who already have endangered species or biodiversity management objectives under forest certification programs or conservations easements. Implementation of these guidelines will help meet recovery objectives for the lynx (USFWS 2005). These guidelines will also serve as the standards for management agreement between landowners and the Service.

The guidelines contained in this document are outcome-based and not prescriptive. We recognize that forest landowners in Maine have diverse markets, goals, areas of landownership, stand histories and composition, and silvicultural traditions. The guidelines are intended to express desired outcomes for a landscape and stand structure that will benefit Canada lynx. Landowners may use these guidelines as a basis for individualized plans. Landowners are given the latitude, in working with the Service and state, to develop their own measurable objectives to describe how they will attain these desired outcomes.

There are other forest management guidelines for lynx:

- The *Lynx Conservation Assessment Strategy* (LCAS)(Ruedeiger et al. 2000) was developed by the U. S. Forest Service and U. S. Fish and Wildlife Service to guide forest management for lynx, and is intended for use only on federal lands. A revised version will be available in 2007.
- The *Lynx Habitat Management Plan for DNR-Managed Lands* (Washington State DNR 2006) guides forest management on the state of Washington's public lands.

Both of these documents address forest management for lynx primarily in western forest ecosystems. Although many management concepts may apply in Maine, forest ecology in the Northeast is different, and lynx and snowshoe hare in the Northeast may have different responses to forest management.

Ongoing research at the University of Maine, Maine Cooperative Fish and Wildlife Research Unit, Maine Inland Fisheries and Wildlife, and Manomet Center for Conservation Science may result in other guidelines or recommendations for lynx management in the context of a more comprehensive biodiversity framework:

- *Lynx and Pine Marten as Focal Species for Biodiversity Conservation* (D. Harrison and J. Heppinstal, UMaine, unpub. data) is a proposed system of forest management using lynx and pine marten as umbrella species. Management for both species is complementary. By managing for both species, a landowner can effectively manage a landscape for biodiversity. Some large forest landowners in northern Maine are already using a marten model for biodiversity conservation.
- *Beginning with Habitat* is a landscape approach to habitat conservation using riparian habitats, high value animal and plant habitats, and large habitat blocks. To date, this strategy has only been applied to organized towns. Research is underway at the University of Maine/ Maine Cooperative Wildlife and Fisheries Unit to develop and test a habitat management system for forest lands in unorganized towns in northern Maine.
- *Biodiversity Scorecard*, being developed by the Manomet Center for Conservation Science, will be a method to evaluate a landowner's progress toward achieving biodiversity objectives. A set of simple, science-based indices for biodiversity at the landscape and stand scale will provide land managers with a quantitative measure of the status of biodiversity on their land.

These lynx guidelines should compliment any of the biodiversity conservation approaches outlined above. Additions or revisions to these lynx guidelines may occur as new information is published or new biodiversity initiatives are developed. The most recent draft is September 13, 2007.

Lynx in Maine benefit from forest practices that create landscapes (100's km2) with extensive, young, dense stands of regenerating softwoods that supports high populations of snowshoe hares. Therefore, lynx management can be readily incorporated into a plan for multiple use that includes harvesting of forest products, providing for wildlife habitat, and allowing for outdoor recreation. **We do not recommend that lynx management should be a landowner's exclusive wildlife objective, but instead should be part of a balanced program addressing forest products, biodiversity, and recreational objectives.** For example, based on comparisons with data from the Maine Gap Analysis,

the majority of vertebrate species in northern Maine forest systems (86%) will benefit by managing for lynx and pine marten as umbrella species. Young, recently clearcut stands provide habitat for lynx, especially between 10-30 years after cutting. During the latter half of a 60-70 year rotation, these stands would benefit pine marten, provide deer wintering habitat, and support forest interior birds and mammals that require older forests. A management plan that integrates lynx management with other biodiversity goals is more likely to be feasible and to be successfully implemented. We recommend the *Biodiversity in the Forests of Maine: Guidelines for Land Management* (Elliott 1999) as the best resource for guiding management in Maine forests. A balance between young and mature forest habitats is key to maintaining forest biodiversity in Maine.

Natural history of the Canada lynx

Canada lynx are medium-sized cats, generally measuring 75 to 90 centimeters (cm) long (30 to 35 inches (in)) and weighing 8 to10.5 kilograms (18 to 23 pounds) (Quinn and Parker 1987). They have large, well-furred feet and long legs for traversing snow; tufts on the ears; and short, black-tipped tails.

Lynx are highly specialized predators of snowshoe hare (*Lepus americanus*) (McCord and Cardoza 1982; Quinn and Parker 1987; Aubry et al. 2000). Lynx and snowshoe hares are strongly associated with what is broadly described as boreal forest (Bittner and Rongstad 1982; McCord and Cardoza 1982; Quinn and Parker 1987; Agee 2000; Aubry et al. 2000; Hodges 2000a, 2000b; McKelvey et al. 2000b). The predominant vegetation of boreal forest is conifer trees, primarily species of spruce (*Picea* spp.) and fir (*Abies* spp.) (Elliot-Fisk 1988). In the contiguous U.S., the boreal forest types transition to deciduous temperate forest in the Northeast and Great Lakes and subalpine forest in the West (Agee 2000). The Acadian forest of northern Maine and the Canadian Maritime Provinces is dominated by red spruce (*Picea rubens*) in contrast to the true black spruce (*Picea mariana*)-black spruce boreal forest to the north. Lynx habitat can generally be described as moist boreal forests that have cold, snowy winters and a snowshoe hare prey base (Quinn and Parker 1987; Agee 2000; Aubry et al. 2000; Buskirk et al. 2000b; Ruggiero et al. 2000).

Snow conditions also determine the distribution of lynx (Ruggiero et al. 2000, Hoving et al. 2005). Lynx are morphologically and physiologically adapted for hunting snowshoe hares and surviving in areas that have cold winters with deep, fluffy snow for extended periods. These adaptations provide lynx a competitive advantage over potential lynx competitors, such as bobcats (*Lynx rufus*) or coyotes (*Canis latrans*) (McCord and Cardoza 1982; Parker et al. 1983; Buskirk et al 2000b; Ruediger et al. 2000; Ruggiero et al. 2000). Bobcats and coyotes have a higher foot load (more weight per surface area of foot), which causes them to sink into the snow more than lynx. Therefore, bobcats and coyotes cannot efficiently hunt in fluffy or deep snow and are at a competitive disadvantage to lynx (Krohn et al. 2004). Long-term snow conditions presumably limit the winter distribution of potential lynx competitors such as bobcats (McCord and Cardoza 1982; Hoving et al. 2003, 2005) or coyotes. Snowfall was the strongest predictor of lynx occurrence in the Northeast region (Hoving et al. 2005). In

the northeastern United States, lynx are most likely to occur in areas with a 10-year mean annual snowfall greater than 268 cm (105 in) of annual snowfall (Hoving et al. 2005). In addition to snow depth, other snow properties, including surface hardness or sinking depth, and duration of crust conditions are important factors in the spatial, ecological, and genetic structuring of the species (Stenseth et al. 2004).

Because of the patchiness and temporal nature of high quality snowshoe hare habitat, lynx populations require large boreal forest landscapes to ensure that there is a sufficient amount of high quality snowshoe hare habitat at any point in time and to ensure that lynx may move freely among patches of suitable habitat and among subpopulations of lynx. Individual lynx maintain large home ranges (reported as generally ranging between 31 to 216 km^2 [12 to 83 mi^2]) (Koehler 1990; Aubry et al. 2000; Squires and Laurion 2000; Squires et al. 2004b; Vashon et al. 2005a). The size of lynx home ranges varies depending on abundance of prey, the animal's gender and age, season, and the density of lynx populations (Hatler 1988; Koehler 1990; Poole 1994; Slough and Mowat 1996; Aubry et al. 2000; Mowat et al. 2000; Vashon et al. 2005a). When densities of snowshoe hares decline, for example, lynx enlarge their home ranges to obtain sufficient amounts of food to survive and reproduce. Generally, females with kittens have the smallest home ranges while males have the largest home ranges (Moen et al. 2004). Reported home range size varies from 31 km^2 (12 mi^2) for females and 68 km^2 (26 mi^2) for males in Maine (Vashon et al. 2005a) to much larger ranges of and 88 km^2 (34 mi^2) for females and 216 km^2 (83 mi^2) for males in northwest Montana (Squires et al. 2004b).

The overall quality of the boreal forest landscape matrix and juxtaposition of stands in suitable condition within the landscape is important for both lynx and snowshoe hares in that it can influence connectivity or movements between suitable stands, availability of food and cover and spatial structuring of populations or subpopulations (Hodges 2000b; McKelvey et al. 2000a; Ricketts 2001; Walker 2005). For example, lynx foraging habitat must be near denning habitat to allow females to adequately provision dependent kittens, especially when the kittens are relatively immobile. In north-central Washington, hare densities were higher in landscapes with an abundance of dense boreal forest containing small patches of open habitat interspersed, than in landscapes composed primarily of open forest interspersed with few dense vegetation patches (Walker 2005). Similarly, in northwest Montana, Ausband and Baty (2005) concluded connectivity of dense patches within the forest matrix benefited snowshoe hares. In the mountainous areas, lynx appear to prefer flatter slopes (Apps 2000; McKelvey et al. 2000d; von Kienast 2003; Maletzke 2004).

Lynx use large areas within a boreal forest landscape, which is naturally limited because it is at the southern edge of its range in the contiguous United States. They are specialized to subsist primarily on a single prey species, snowshoe hares. Therefore, lynx in the contiguous U.S. will naturally always be considered "rare" compared to a species such as a bobcat that is a habitat and prey generalist, even when habitat conditions for the lynx are at their prime.

Lynx are highly mobile; long-distance movements (greater than 100 kilometers

(km) (60 miles (mi))) are characteristic (Aubry et al. 2000; Mowat et al. 2000, MDIFW unpub. data). Lynx disperse primarily when snowshoe hare populations decline (Ward and Krebs 1985; O'Donoghue et al. 1997; Poole 1997). Subadult lynx also disperse even when prey is abundant (Poole 1997), presumably to establish new home ranges. Lynx also make exploratory movements outside their home ranges (Aubry et al. 2000; Squires et al. 2001, MDIFW, unpub. data).

The boreal forest landscape is naturally dynamic. Forest stands within the landscape change as they undergo succession after natural or human-caused disturbances such as fire, insect epidemics, wind, ice, disease, and forest management (Elliot-Fisk 1988, Agee 2000, Lorimer and White 2003). As a result, lynx habitat within the boreal forest landscape is typically patchy because the boreal forest contains stands of differing ages and conditions, only some of which are suitable as lynx foraging or denning habitat at any point in time (McKelvey et al. 2000a; Hoving et al. 2004).

Snowshoe hares comprise a majority of the lynx diet (Nellis et al. 1972; Brand et al. 1976; Koehler 1990; Apps 2000; Aubry et al. 2000; Mowat et al. 2000; von Kienast 2003; Squires et al. 2004b). When snowshoe hare populations are low, female lynx produce few or no kittens that survive to independence (Nellis et al. 1972; Brand et al. 1976; Brand and Keith 1979; Poole 1994; Slough and Mowat 1996; O'Donoghue et al. 1997, Aubry et al. 2000; Mowat et al. 2000). Lynx prey opportunistically on other small mammals and birds, particularly during lows in the snowshoe hare population, but alternate prey species may not sufficiently compensate for low availability of snowshoe hares, resulting in reduced lynx populations (Brand et al. 1976; Brand and Keith 1979; Koehler 1990; Mowat et al. 2000).

In northern Canada, lynx populations fluctuate in response to the 10-year cycle of snowshoe hare (Hodges 2000a; Mowat et al. 2000). Although snowshoe hare populations in the northern portion of their range show strong, regular population cycles, these fluctuations are generally much less pronounced in the southern portion of the range in the contiguous United States (Hodges 2000b). In the contiguous United States, the degree to which regional local lynx population fluctuations are influenced by local snowshoe hare population dynamics is unclear. However, it is anticipated that because of natural fluctuations in snowshoe hare populations or changing patterns of forest succession, there will be periods when lynx densities are extremely low.

Because lynx population dynamics, survival, and recruitment are closely tied to snowshoe hare availability, snowshoe hare habitat is the most important component of lynx habitat. Lynx generally concentrate their foraging and hunting activities in areas where snowshoe hare populations are high (Koehler et al. 1979; Parker 1981; Ward and Krebs 1985; Major 1989; Murray et al. 1994; O'Donoghue et al. 1997, 1998). They may select less dense stands with intermediate hare density where prey access and mobility are greater (Fuller et al. 2007). Snowshoe hares are most abundant in young forests with dense understories that provide forage, cover to escape from predators, and protection during extreme weather (Wolfe et al. 1982; Litvaitis et al. 1985; Hodges 2000a, b). Generally, hare densities are higher in regenerating, earlier successional forest stages

because they have greater understory structure than mature forests (Buehler and Keith 1982; Wolfe et al. 1982; Koehler 1990; Hodges 2000b; Homyack 2003; Griffin 2004, Fuller 2006). However, snowshoe hares can be abundant in mature forests with dense understories (Griffin 2004).

Within the boreal forest, lynx den sites are located where coarse woody debris, such as downed logs and windfalls, provides security and thermal cover for lynx kittens (McCord and Cardoza 1982; Koehler 1990; Slough 1999; Squires and Laurion 2000; J. Organ, U.S. Fish and Wildlife Service, in litt. 2001). The amount of structure (e.g., downed, large woody debris) appears to be more important than the age of the forest stand for lynx denning habitat (Mowat et al. 2000).

Threats

The reasons for listing the lynx as threatened are described in the final listing rule published in the Federal Register on March 24, 2000 (65 FR 16052) and the clarification of findings published in the Federal Register on July 3, 2003 (68 FR 40076).

Presently within the contiguous United States, human alteration of forest distribution, abundance, species composition, successional stages, structure and connectivity plays a dominant role in affecting the boreal forest landscape's capacity to sustain lynx populations. Timber harvest and its related activities are the predominant land uses affecting lynx habitat in the contiguous United States. Timber harvest and associated forest management can be benign, beneficial, or detrimental to lynx depending on harvest methods, spatial and temporal specifications, and the forest ecology of the site.

Forestry practices can be beneficial for lynx when the resulting understory stem densities and structure meet the forage and cover needs of snowshoe hare (Wolff 1980; Litvaitis et al. 1985; Monthey 1986; Koehler 1990; Hoving et al. 2004; Vashon et al. 2005a, Fuller 2006). Although areas that are cut initially may not be used by snowshoe hare and lynx, regeneration from some forms of silviculture (e.g., clear-cuts or other even-aged management) in appropriate habitat types can grow (in 10 years or more depending on local conditions) to become stands with dense understories preferred by snowshoe hares and, therefore, lynx (Monthey 1986; Koehler 1990; Koehler and Brittell 1990; Ruediger et al. 2000; Homyack 2003; Hoving et al. 2004; Vashon et al. 2005a). For example, in Maine, forest regeneration after extensive clearcutting that occurred 10 to 25 years ago is providing high quality hare habitat over extensive landscapes and, thus, sustaining the lynx population (Homyack 2003, Vashon et al. 2005a, Fuller 2006).

Some timber harvest regimes can result in forest openings and large monotypic stands with sparse understories that are unfavorable for lynx and snowshoe hare (Koehler 1990; Homyack 2003; Hoving et al. 2004). Thinning (e.g., mechanized pre-commercial thinning or herbicide treatments) to promote vigorous growth of fewer trees diminishes the understory and horizontal cover preferred by snowshoe hares (Griffin 2004; Homyack et al. 2004). As a result, thinned stands support lower snowshoe hares densities than unthinned stands (Ruediger et al. 2000; Homyack 2003; Griffin 2004).

Fire is important in creating the mosaic of differing forest stand ages and structures in some boreal forest types used by lynx. Fire suppression policies likely have had little overall impact to lynx habitat because most forests where lynx habitat occurs have natural fire return intervals that are longer than the period of time that has elapsed since the inception of these policies. In addition, fires that occur in lynx habitat are often large, high-intensity fires that are difficult to suppress, regardless of management objectives. Reducing fuel loads to reduce the risk of fire (U.S. Department of Agriculture and U.S. Department of the Interior 2001) can diminish the value of lynx habitat by clearing the understory vegetation that is an important component of snowshoe hare habitat.

An unresolved theory is whether packed snow trails, such as from snowmobiles or skis, facilitate the access of potential lynx competitors (e.g., coyote) into winter lynx habitats that are otherwise inaccessible, enabling them to effectively compete with lynx (Buskirk 2000a). Within lynx home ranges in northwest Montana, coyotes made limited use of compacted snowmobile trails for travel and primarily scavenged for food; snowshoe hare kills made up 3 percent of coyote kill sites (Kolbe 2005). In potential lynx habitats, Bunnell (2005) found that coyotes require packed snow trails to access deep snow habitats in mountain ranges in Utah, eastern Idaho, and northern Wyoming. Thus, the threat of increased competition for food or interference between species due to increases in packed snow trails remains hypothetical.

A substantial amount of lynx habitat in the contiguous United States is found on Federal lands, primarily National Forest lands. At the time of the final listing rule, the U. S. Fish and Wildlife Service found that federal land management plans did not adequately address risks to lynx and allowed actions that cumulatively could result in significant detrimental effects to lynx in the contiguous United States. As a result, the Service concluded in the final rule that the lack of Federal land management plan guidance for conservation of lynx, and the potential for plans to allow or direct actions that adversely affect lynx, were a significant threat to the contiguous United States lynx population. Currently, numerous Forest Service and Bureau of Land Management (BLM) Plans are in the process of revision or amendment (e.g., USDA Forest Service and USDI Bureau of Land Management 2004) by incorporating the Lynx Conservation Assessment and Strategy (LCAS)(Ruediger et al. 2000). The LCAS is a multi-agency strategy that uses the best scientific information available to provide a consistent and effective approach to conserve lynx on federal lands (Ruediger et al. 2000).

Global climate has been warming as evidenced by changes in the amount of snow cover, among other indicators (Intergovernmental Panel on Climate Change 2001). The New England climate was significantly cooler in the 1700s (Zielinski and Keim 2003), which likely benefited lynx (Hoveing et al. 2003). Continued warming temperatures are likely to negatively affect the cold climatic conditions that create and maintain the boreal forest ecosystem for which lynx are highly adapted. As a result, models predict that continued warming trends may eventually cause some of the boreal forest vegetation

types to recede north and/or recede to higher elevations (Hansen et al. 2001) or to affect snow depths, which could affect lynx distribution (Hoving 2001).

Parasites and disease are not well documented in North American lynx. In 2006 several radio-tagged Maine lynx died with infections of the protostrongylid nematode lungworm *Aelurostongylus abstrusus.* The parasite is found throughout the northern hemisphere and is common in domestic cats (Ribeiro and Lima 2001) . It has been documented in Eurasian lynx (Schmidt-Posthaus et al. 2002, Szczesna et al. 2006), but not in North America lynx. The parasite has a lynx-snail-small mammal (possibly hares?) life cycle. It is unknown how prevalent the parasite is in Maine's lynx population. A research project is being initiated by the University of Maine.

Snowshoe hare density, more than any other factor is the most important factor explaining the persistence of lynx populations (Steury and Murray 2004). A minimum average landscape density of snowshoe hares necessary to maintain a persistent, reproducing lynx population within the contiguous United States has not been determined, although Ruggiero et al. (2000) suggested that at least 0.5 hares per ha (1.2 hares per ac) may be necessary. Steury and Murray (2004) modeled lynx and snowshoe hare populations and predicted that a minimum of 1.1 to 1.8 hares per ha (2.7 to 4.4 hares per ac) was required for persistence of a reintroduced lynx population in the southern portion of the lynx range.

Habitats supporting abundant snowshoe hares must be present in a large proportion of the landscape to support a viable lynx population. The boreal forest landscape must contain a mosaic of forest stand successional stages to sustain lynx populations over the long term as the condition of individual stands changes over time. If the vegetation potential (or climax forest type) of a particular forest stand is conducive to supporting abundant snowshoe hares, it likely will also go through successional phases that are unsuitable as lynx foraging (snowshoe hare habitat) or lynx denning habitat (Agee 2000; Buskirk et al. 2000b). For example, a boreal forest stand where there has been recent disturbance, such as fire or timber harvest, resulting in little or no understory structure is unsuitable as snowhoe hare habitat for lynx foraging. That temporarily unsuitable stand may regenerate into suitable snowshoe hare (lynx foraging) habitat within 10 to 25 years, depending on local conditions (Ruediger et al. 2000). Ruediger et al. (2000) and Hoving et al. (2004) hypothesize that forest management techniques that thin the understory may render the habitat unsuitable for hares and, thus, for lynx. However, research on the effects of pre-commercially thinned stands on lynx habitat use, fitness, or movements has not been done. Stands may continue to provide suitable snowshoe hare habitat for many years until woody stems in the understory become too sparse, as a result of undisturbed forest succession or management (e.g., clearcutting or thinning). Thus, if the vegetation potential of the stand is appropriate, a stand that is not currently in a condition that is suitable to support abundant snowshoe hares for lynx foraging or coarse woody debris for den sites has the capability to develop into suitable habitat for lynx and snowshoe hares with time.

As described previously, snowshoe hares prefer boreal forest stands that have a

dense horizontal understory to provide food, cover and security from predators. Snowshoe hares feed on conifers, deciduous trees and shrubs (Hodges 2000b). Snowshoe hare density is correlated to understory cover between approximately 1 to 3 m (3 to 10 ft) above the ground or snow level (Hodges 2000b). Habitats most heavily used by snowshoe hares are stands with shrubs, stands that are densely stocked, and stands at ages where branches have more lateral cover (Hodges 2000b). Generally, earlier successional forest stages support a greater density of horizontal structure (stem density, stem cover units) in the understory and more abundant snowshoe hares (Buehler and Keith 1982; Wolfe et al. 1982; Koehler 1990; Hodges 2000b; Homyack 2003; Griffin 2004); however, sometimes mature stands also can have adequate dense understory to support abundant snowshoe hares (Griffin 2004).

In Maine, the highest snowshoe hare densities were found in regenerating softwood (spruce and fir) and mixedwood stands (Homyack et al. 2005, 2006, Fuller and Harrison 2005, Fuller et al. 2007). In the north Cascades, the highest snowshoe hare densities were found in 20-year-old seral lodgepole pine stands with a dense understory (Koehler 1990). In montane and subalpine forests in northwest Montana, the highest snowshoe hare densities in summer were generally in younger stands with dense forest structure, whereas in winter snowshoe hare densities were as high or higher in mature, multi-story stands with dense understory forest structure (Griffin 2004).

Lynx den sites do not seem to be limiting. Den sites are found in mature and younger boreal forest stands that have a large amount of cover and downed, large woody debris. The structural components of lynx den sites are common features in managed (logged) and unmanaged (e.g., insect damaged, wind-throw) stands. Downed trees provide excellent cover for den sites and kittens and often are associated with dense woody stem growth. Sub-stand characteristics were evaluated for 26 lynx dens from 1999 to 2004 in northwest Maine (J. Organ, USFWS, unpubl. data). Dens were found in several stand types. Modeling of den site variables determined that tip-up mounds (exposed roots from fallen trees) alone best explained den site selection (J. Organ, unpubl. data). Tip-up mounds may purely be an index of downed tress, which were abundant on the landscape. Horizontal cover at 5 m (16 ft) alone was the next best performing model (J. Organ, unpubl. data). Dead downed trees were sampled, but did not explain den site selection as well as tip-up mounds and cover at 5 meters. Lynx essentially select den sites in dense cover.

Lynx status

Maine's lynx population is contiguous with populations south of the St. Lawrence River (southern Quebec, Gaspe Peninsula, and northern New Brunswick)(Hoving et al. 2005). A population of lynx has persisted in Maine throughout during historic times. An historic review by Hoving et al. (2003) documented 188 records between 1833-1999 including records of 39 kittens from a minimum of 21 litters, indicating a long-term breeding presence in the state. Historically, lynx ranged statewide, but their range contracted in the 1900s primarily to the western and northern parts of the state. Range contraction is believed to be caused by changing habitat, climate, and carnivore

community (particularly the northward expansion of bobcat populations) (Hoving et al. 2003).

Historic data suggested lynx populations fluctuated widely. For example, during the Civil War (1864-65) a Maine fur dealer (Hardy 1907a, b), purchased "several hundred" pelts annually, followed by a few years with no skins, then several years of 200 lynx hides. At least 30 lynx were bountied between 1833-1967 when the bounty ended. Maine Department of Inland Fisheries and Wildlife (MDIFW) classified lynx as a furbearer with no open season and a species of Special Concern (although the lynx was proposed for state-threatened status in 1987). In northern Canada and Alaska, lynx populations cycle in response to the 10-year snowshoe hare cycle. From 1995-2005 Maine hare populations showed no indication of cycling and seemed to be remain at high population levels (D. Harrison and W. Krohn, UMaine, unpub. data). However, from 2006 and 2007 hare populations declined by 50-75% on all hare pellet transects monitored by UMaine and MDIFW in northern Maine. Similar declines occurred in all stand types and stands with high and low quality hare habitat. Although no reliable population estimates exist, habitat assessments (Hoving 2001), population densities from a lynx telemetry study (Jen Vashon, MDIFW, unpub. data), and results of snow track surveys suggests that 200 to 500 animals could occur statewide. These data suggest that until 2005, lynx were more abundant than at any other time in recent decades. Current lynx populations are likely declining because of diminished snowshoe hare populations and possibly a lungworm parasite.

Today, lynx are most frequently encountered in areas north of Greenville, Millinocket, and Houlton, but individuals may be occasionally observed throughout much northern, western, and eastern Maine. From 2003 to 2006, MDIFW and USFWS surveyed approximately 60 townships throughout the lynx range in northern Maine to better document the distribution and collect data for new habitat models. The population seems to be well distributed throughout this area. In optimal habitat on the Gaspe Peninsula, fall lynx densities (adults and kittens) are estimated to be 10 lynx/100 km2 (or about 20,000 acres or one township)(Ray et al. 2002). Lynx densities on the Clayton Lake study area in northwestern Maine prior to 2006 were approximately 15 lynx/100km2 (J. Vashon, MDIFW, unpub. data)

The area of suitable lynx habitat is likely much greater in the early 2000s (L. Robinson, UMaine, unpub. data) than that documented from the early 1990s (Hoving et al. 2005). Prior to 2005 lynx experienced high productivity of lynx; 91% percent (30 of 33 potential litters) of available adult females (greater than 2 years-old) produced litters, and litters averaged 2.83 kittens (Vashon et al. 2005b). Snowshoe hares were at high densities in many areas in northern Maine, lynx home range sizes were small, productivity was high, and mortality was low. This pattern indicates that Maine's lynx population is healthy and likely increasing. After 2005, lynx have experienced very low productivity and litter size. Snowshoe hare densities have fallen by 50-75% and in many of the best quality habitats are less than 1.0 hares/ha. Telemetry studies are continuing to assess changes in home range size and population density. These data suggest that lynx populations may be declining until hare numbers increase. Current and future habitat

conditions for lynx are being modeled by the University of Maine and Maine Cooperative Fish and Wildlife Research Unit through several graduate student projects.

Lynx habitat requirements

Lynx populations respond to biotic and abiotic factors at different scales. At the regional scale (Northeastern U. S. and Maritime Provinces), snow conditions, boreal forest and competitors (especially bobcat) influence the species' range (Aubry et al. 2000; McKelvey et al. 2000b; Hoving et al. 2005). At the landscape scale (e.g. northwestern Maine), natural and human-caused disturbance processes (e.g., fire, wind, insect infestations and forest management) influence the spatial and temporal distribution of lynx populations by influencing the amount and distribution of high quality snowshoe hare habitat (Agee 2000; Ruediger et al. 2000, Robinson 2006). At the stand-level scale, quality, quantity, and juxtaposition of habitats influence home range size, productivity, and survival (Aubry et al 2000, Vashon et al. 2005a). At the substand scale, spatial distribution and abundance of prey and microclimate influence movements, hunting behavior, den, and resting site locations (Fuller et al. 2007). Lynx make resource-use decisions at all scales.

At a regional geographic scale (Northeast and eastern Canada) Hoving et al. 2005 documented that Canada lynx distribution was strongly associated with areas of deep snowfall and 100 km2 landscapes comprised of little deciduous forest. Hoving et al (2005) concluded that the broad geographic distribution of lynx in eastern North America is most influenced by snowfall, but within areas of similarly deep snowfall, measures of forest succession are important.

At a landscape scale (northwestern Maine), Hoving et al. (2004) compared attributes of areas where lynx had been detected on snow track surveys to where lynx had not been detected. Logistic regression models predicted lynx were more likely to occur in 100 km^2 landscapes with abundant regenerating forest, and less likely to occur in landscapes with much recent clearcut, partial harvest, forested wetland, and deciduous forest. Late regeneration forest was described as clearclut >10 years prior and having >50% overhead closure at a height of 1 meter. Lynx were not associated positively or negatively with mature coniferous forest. Lynx were associated with young forests more than mature forests, however old growth forests were functionally absent from the landscape. The Hoving et al (2004) model predicted that potential habitat for lynx in northern Maine in the early-1990s was rare, patchily distributed, and comprised 6% of the landscape (546 km2 or 134,916 ac with a >50% probability of supporting lynx). Lynx were positively associated with 100 km^2 landscapes altered by clearcutting 15-30 years previously. The proportion of mature conifer forest in the landscape was not a powerful determinant of lynx occurrence, and the influence of mature deciduous forest on lynx occurrence was ambiguous. Lynx snow track surveys completed from 2003 to 2006 documented that lynx were widely distributed across the northwestern Maine.

A preliminary analysis of the habitat use of 17 radio-tagged lynx in 2002 in the Clayton Lake region in northwestern Maine compared habitat use vs. availability within

the surrounding landscape, within the home range, and core use areas within home ranges (Vashon et al. 2005a). Within their home range, lynx preferred mature softwood stands and softwood and mixed mid-regenerating stands. Lynx avoided early regenerating, pole, mature hardwood, mixed forest and other non-forested habitat. Mid-regenerating stands comprised 85% of telemetry locations for females and 77% for males. Mid-regenerating stands in Clayton Lake were 3.4-6.1 meters in height and were created by clearcutting stands to salvage trees after the spruce budworm outbreak in the 1970s and 1980s. A more complete analysis is pending.

Fuller et al. (2007) backtracked six radio-tagged lynx for 65 km during two winters on the Clayton Lake study area to document winter habitat selection at the stand scale. She compared vegetation characteristics in areas used by lynx with random points located within lynx home ranges. She also analyzed habitat for sites where lynx killed hares. She documented that lynx selected older (11-26 year-old), tall (15-24 foot), mid-successional regenerating clearcut stands, and established (11-21 year-old) partially harvested stands. Lynx avoided young (<11 years) clearcut stands, short (11-14 foot) mid-successional regenerating clearcut stands, recent (1-10 years) partially harvested stands, and mature stands. Most of the stands were dominated by softwood (spruce and fir). Eighty-one percent of 16 hare kills were in short regenerating clearcut stands (n=5) and tall regenerating clearcut stands (n=8).

These studies indicate that lynx prefer to place their home ranges in landscapes dominated by softwood-dominated mid-regenerating stands. The also prefer these mid-regenerating stands within their home ranges, within foraging and high use areas, and to locate their dens. Regenerating stands used by lynx generally develop 12-35 years after forest disturbance and are characterized by dense horizontal structure and high stem density within a meter of the ground. These habitats support high snowshoe hare densities (average of 1.6 to 2.4 hares/ha)(Fuller 1999, Lachowski 1997, Homyack 2003, Vashon et al. 2005a). Lynx seem to use regenerating stands until about 30-35 years of age when the canopy closes, the stand begins to self-thin, and the understory is reduced, but it is unknown whether hare densities decline dramatically or gradually after a stand reaches this level of development. Maine lynx avoid recently clearcut and recent partial harvested areas, which lack the structure to support high hare densities. However, these stands will likely become preferred lynx habitat as they mature, especially if dense regenerating softwoods dominate the understory. Lynx selected established partial harvested stands in winter (Fuller et al. 2007), which support moderate hare densities (~0.8 hares/ha Robinson 2006). However, Fuller et al. (2007) caution inferring suitability of established partial harvest for supporting lynx across substantial portions of their home ranges.

Old growth forest (>150 years-old, Lorimer and White 2003) does not currently exist as a functional component of Maine's boreal forest. Thus the current research provides little information about positive or negative associations of Canada lynx with old growth forest. Older, multi-story, multi-age stands may develop adequate understory structure to support moderate snowshoe hare populations, especially if the canopy has been opened by wind-throw, insect damage, or selective or patch cuts. Mature stands (>60 years-old) may be also used as movement corridors or for hunting (esp. in

summer)(Vashon et al. 2005a). Across northern Maine, mature stands were not prevalent and were not a powerful determinant of lynx occurrence in landscape scale analyses (Hoving et al. 2005). At a regional scale, mature hardwood stands were negatively associated with lynx occurrence (Hoving et al. 2005). At the stand scale mature stands were negatively selected by lynx (Fuller et al. 2007) and had low relative abundance of hares.

There is no evidence to indicate that Maine's hare population undergoes regular, periodic population cycles. Hare density data collected at several locations in northern Maine since 1995 -2005 show a sustained high population of hares with little variation (Homyack 2003, D. Harrison and W. Krohn, UMaine, unpub. data). In 2006 and 2007, hare populations declined over all stand types by 50 -75%. Maine's lynx population has benefited by unusually favorable habitat conditions for snowshoe hares in a forest regenerating from extensive clearcutting. A substantial decline in hare populations seems to be occurring and may be of a magnitude and duration to influence lynx populations. In the early 2000s, lynx populations in the Gaspe region of Quebec were similarly high, but substantial hare fluctuations have been noted there in the past (Fortin and Tardif 2003). The province reduces lynx trapping quotas on the Gaspe Peninsula when hare harvest trends downward (H. Jolicoeur, Quebec Ministry of Wildlife and Fisheries, pers. comm..). Recent satellite imagery analysis by The Nature Conservancy shows a preponderance of regenerating softwood forest in Maine, southern Quebec, New Brunswick, and Nova Scotia, which suggests that lynx could be increasing throughout the region (Ray et al. 2002, Carroll 2005).

Early surveys of Maine spruce-northern hardwood forests showed little evidence of landscape-scale destruction by natural forces (Graves 1899). Instead surveyors documented extensive tracts of mature forest with individual trees dying resulting in a uneven-aged forest. Lorimer and White (2003) estimate that between 5-9.5% of the presettlement spruce-northern hardwood forest in northern Maine was in the 1- to 30-year seedling-sapling age class. Slightly higher proportions of young forest (up to 14%) occurred in swamps, wet soils, and thin rocky soils where windthrow was more likely. Old growth stands (>150 years-old) typically comprised 35-76% of the landscape. Young forest stands (<30 years-old) resulted from stand-replacing disturbances like windthrow, small fires, and insect outbreaks. Large landscape-scale disturbances were rare in northern Maine. Lorimer and White (2003) estimated severe windthrow frequency of 2,585 years on better soils and 290 on lowland sites and poor, rocky soils. Large scale insect epidemics (especially spruce budworm *Choristoneura fumiferana*) occurred more frequently, at least once or twice a century. Fire frequency is relatively low in Maine's moist forest and Lorimer and White (2003) estimated fire rotations of 330-1253 years.

Stand- and landscape-level disturbances (especially budworm) were likely of a frequency and magnitude to maintain historic lynx populations in Maine (Hoving et al. 2003). Lynx often use older, multi-storied stands in the West (e.g. Murray et al. 1994, Buskirk et al. 2000b) where gaps in the canopy from dead or fallen trees produce patches of dense, regenerating conifer and snowshoe hare habitat. Commercial forest

management typically uses even-aged management harvesting that truncates conifer stand development at 60 to 80 years, long before gap dynamics begin and patches of regenerating habitat are created in the understory. Historically, Maine lynx may have occupied habitat created by large landscape-scale disturbances and gap dynamics of older uneven-aged forests. Because older forests that supported lynx in pre-settlement times in the Northeast are missing on the private timberlands in northern Maine, lynx are now largely dependent on habitat created by intensive forest management that has replaced the landscape altering affects of severe windthrow and fire.

Salvage of extensive areas of dead and dying timber during Maine's last budworm outbreak (1972-1986) has created ideal conditions for snowshoe hares and Canada lynx. Today, 20-30 years post-budworm, the amount of early successional habitat in northern Maine spruce-fir stands has increased from about 500,000 acres in 1982 to 1.75 million acres in 2003, or about 25% of the landscape (Trani et al. 2001). This large supply of young, regenerating softwood stands provides habitat benefits for lynx, moose, snowshoe hares, and other early successional species. By 2010-2015, most of the budworm-era clearcuts will grow out of optimal habitat conditions for hares and lynx.

Forestland ownership patterns

Much of the following comes from the Maine Tree Foundation.

Maine is over 90% forested (17.7 million acres) and is the most extensively forested state in the United States. Over 94% of the state's forest lands (16.7 million acres) are privately-owned. The largest tracts of undeveloped forestland in the eastern United States are found in the western, northern, and eastern areas of the state.

Only 6% of Maine's forestland (1 million acres) is publicly owned. The state owns a total of about 800,000 acres of public land including Baxter State Park (235,000 acres), 55 State Wildlife Management Areas, 29 Public Reserve Lands (482,000 acres), and 32 State Parks (from 500 to 43,000 acres in size), The federal government owns 200,000 acres of forest, including the part of the White Mountain National Forest located in western Maine, Acadia National Park, and five National Wildlife Refuges scattered across the state.

More than 250,000 families and individuals own more than 35% (6.2 million acres) of Maine's forest. Small woodland owners are those who own between one acre and 1,000 acres. Counted together as a whole, they lay claim to the largest share of Maine's forest.

Companies that own paper mills, sawmills and other wood processing facilities own nearly 28% (5 million acres) of the forest, including large tracts in northern and eastern Maine. A handful of large, corporate landowners (>100,000 acres) own 14% (approximately 2.5 million acres) of Maine's forest. Owners of large tracts of non-industrial forest include individuals, families and public and private companies. Investment institutions, such as banks, insurance companies, mutual and pension funds

and university endowment funds, own about 15% (more than 2.6 million acres).

Between 1980 and 2005, approximately 23.8 million acres have changed ownership in northern Maine representing a shift from industrial ownership to a variety of financial investors, real estate development trusts, private individuals, and conservation organizations. In 1994, forest industry owned about 60% (4.6 million acres) of the large tracts (>5,000 acres) of timberland and investors owned about 3%. By May, 2005, financial investors owned about 33% of the large forest tracts and industry owned only 15.5% (1.8 million acres, mostly in a single ownership)(Hagan et al. 2005). Most forest blocks have remained intact, however, there is a trend toward subdivision and smaller parcel sizes. While forest industry had a long ownership tenure, the new investor-owners typically plan to sell land in 10-15 years. Furthermore, they are looking for much higher rates of return (sometimes several times that based on the actual growth rate of the forest) than was sought by the previous generation of owners. One implication is that interest in biodiversity practices has declined. Former corporate/industry landowners had stronger biodiversity ethic than many of the new landowners (Hagan et al. 2005).

Ninety-six land trusts and conservation organizations in the state own nearly 1.4% of the forested area of the state (251,000 acres). The Maine Chapter of The Nature Conservancy owns the largest parcel, approximately 180,000 acres along the St. John River in northwestern Maine. Native American tribes own roughly 1% (approximately 184,000 acres) of the Maine forest. The Penobscot Tribe owns 124,000 acres of land, most of which is forested. The Passamaquoddy Tribe owns 144,000 acres overall, including 60,000 acres of forest.

Lynx conservation strategy

Assumptions

The following biological assumptions serve as a basis for developing forestry guidelines:

- Lynx populations that are well-distributed throughout their historic range in Maine will be more secure than scattered, isolated subpopulations occupying a portion of their historic range.
- The more habitat being managed for lynx, the larger and more secure lynx populations will be.
- Lynx population persistence will be greater when habitat patches are interconnected through linkages of suitable habitat.
- The future quantity, quality and location of habitat in Canada and connectivity with habitat in Maine will influence lynx populations in the state.
- Because of the low rate of natural stand-replacing disturbances and prevalence of even-aged management, lynx habitat will be primarily limited to young forest stands created by forest management.
- Insect outbreaks and disease (native and non-native), climate change, and changing markets for forest products represent unforeseen circumstances that can

greatly influence the forest and its management.

Habitat goal

The following habitat goals and guidelines are based on the best available science for snowshoe hares and Canada lynx in Maine. We relied on peer reviewed literature, dissertations and theses, and unpublished information in that order of reliability. Throughout this document, we cited the literature used to support management recommendations, where it exists. Assumptions and inferences were made on collective experience and professional judgment, in consultation with other lynx experts. The rationale for each guideline is documented and shortcomings of the science are noted, where appropriate.

There are ongoing studies of snowshoe hare and lynx ecology, habitat modeling, and effects of forest management on snowshoe hare and lynx. These guidelines represent the best knowledge available in 2006, but these guidelines may be updated as new information becomes available.

Large landowner goal (>35,000 acre): In the absence of natural landscape disturbances, landowners in northern Maine that own large tracts of land (>35,000 acres or approximately 1 ½ townships) have the ability to manage sufficient habitat to support a resident population of lynx. The habitat goal for large landowners, where appropriate and meet with landowner objectives, is to manage at a landscape level to maintain a continuous supply of large (>100 acre) patches of mid-regeneration (12-35-year old) conifer habitat in 35,000 acre or greater units to support adult resident lynx and family groups and to maintain connectivity of forested habitat between lynx habitat units.

Small landowner goal (<35,000 acre): Landowners owning parcels <35,000 acres may have opportunities to provide habitat to support several home ranges, a portion of a home range, or a dispersal or travel corridor for lynx moving through the landscape. The habitat goal, where appropriate and meet with landowner objectives, is to manage at the stand level to create large patches (>100 acres) of mid-regeneration (12-35 year old) conifer-dominated habitat that supports high densities of snowshoe hares, especially if these stands abut areas known to support resident Canada lynx.

Desired outcomes:

- Maintain the current amount and distribution of commercial forest land in northern Maine.
- Maintain a managed forest comprised of native boreal forest species.
- Create a landscape that will maintain a continuous presence of a mosaic of successional stages, especially mid-regeneration patches, that will support resident lynx.
- Employ silvicultural techniques that create, maintain, or prolong use of stands by high populations of snowshoe hares.
- Retain coarse woody debris for denning sites.

- Manage lynx in the context of multiple species or biodiversity objectives.

Forest management guidelines

1. Avoid upgrading or paving dirt or gravel roads traversing lynx habitat. Avoid construction of new high speed/high traffic volume roads in lynx habitat.

Desired outcome: Avoid fragmenting potential lynx habitat with high traffic/high-speed roads.

Rationale: Paved, high speed/high traffic roads likely have the greatest potential to adversely affect lynx by fragmenting habitat, limiting dispersal and movements, and causing mortality. Lynx mortalities on highways have been recorded throughout their range (Ruediger et al. 2000, Hoving 2001). Paved roads were a mortality factor for lynx reintroducted in New York;18 of 37 mortalities of reintroduced lynx were highway kills (Brocke et al. 1990). Similarly, lynx reintroduced to Colorado have been killed on paved highways, but lynx have also been documented successfully crossing interstate highways (T. Shenk, unpub. data). An analysis done by Brocke et al. (1993) for the USDA Forest Service indicated that loss from highway kills was a factor in the extirpation of lynx from the White Mountain National Forest in New Hampshire. Highway underpasses constructed in Banff National Park have been used by lynx (Heuer 1995). Highway traffic volumes of 2-3,000 vehicles/day are thought to be problematic and 4,000 vehicles or more per day are considered to be serious causes of mortality and habitat fragmentation (Ruediger et al. 2000). As the size of roads increase from gravel to 2-lane highways, traffic volume and speed increases. Lynx and other carnivores may avoid using adjacent habitat or may be reluctant to cross high volume traffic (Gibeau and Heur 1996).

There is little information about the effects of logging roads on lynx. Home ranges of all lynx radio-tagged in Clayton Lake area include a variety of sizes of forest roads from frequently-traveled haul roads to seasonal skid trails (MDIFW, unpub. data). Logging road density in the lynx study area (containing some of Maine's best quality lynx habitat) exceeds 1 km of road/km2. High logging road density is not unusual in Maine's best lynx habitat and is a characteristic of an intensively logged landscape. Hoving (2001) did not find that logging road density was a significant determinant influencing lynx distribution in the Northeast region. Fuller et al. (2007) found Maine lynx selected against road edges within home ranges. On the other hand, tracking of radio-tagged lynx, winter snow tracking surveys, and anecdotal observation of lynx in Maine document that lynx routinely cross logging roads and use them for traveling (MDIFW, USFWS, pers. comm..). Radio-tagged lynx from Clayton Lake have traveled hundreds of km to the Gaspe Peninsula and southern Quebec, crossing many roads in their travels. Logging roads did not seem to affect lynx habitat use in lightly roaded areas in northcentral Washington (McKelvey et al. 2000) and lynx followed road edges in Nova Scotia (Parker 1981).

Since listing in 2000, 9 of 11 road-killed lynx in Maine occurred on logging roads

(MDIFW unpub. data). Most mortality occurred on two-lane haul roads where higher traffic volume (about 100 vehicles/hour) and speed would occur. These roads are open to the public. Private vehicle traffic volume exceeds logging traffic by several-fold. The density and distribution of logging roads greatly influence recreational use of the landscape by humans and may have secondary effects on lynx. Trapping, hunting, and other potential sources of human mortality are indirectly influenced by logging roads. However, at this time, there is no compelling evidence to suggest that forest roads or their secondary impacts limit lynx populations (Ruediger et al. 2000).

Railroad and utility corridors can have both short and long term effects on lynx habitats, depending on location, width, type (e.g. gas pipeline, power lines), vegetation clearing requirements, and maintenance access. The primary effect is to disrupt connectivitiy of the habitat (Ruediger et al. 2000). When located adjacent to highways and railroads, utility corridors can further widen the right-of-way, thus increasing the likelihood of fragmenting habitat and influencing lynx movements. Several authors (Murray et al. 1994, Poole et al. 1996, Roe et al. 1999) have reported lynx selecting against openings such as water and open meadows. Lynx may be reluctant to cross large, open areas (greater than several hundred meters). Given that railroad and utility corridors are relatively narrow and that utility corridors are often maintained in a brush or pole stage forest, they would not be expected, in most instances, to be barriers to movements.

2. Maintain through time at least one lynx habitat unit of 35,000 acres (~1.5 townships) or more for every 200,000 acres (~9 townships) of ownership. At any time, about 20% of the area in a lynx habitat unit should be in the optimal mid-regeneration conditions (see Guideline 3).

Desired outcome: Create a landscape that will maintain a continuous presence of a mosaic of successional stages, especially mid-regeneration patches that will support resident lynx.

Rationale: Lynx utilize large areas, which requires that management strategies be developed both at landscape and stand scales. During a period of high hare density, average home ranges of Maine lynx in the Clayton Lake study area vary from 26.5 km^2 (6,550 acres, 10 mi^2) for females and 57.8 km^2 (14,300 acres, 22 mi^2) for males. Fall densities on the Clayton Lake study area in northwestern Maine (optimal habitat) were estimated to be about 15lynx/100km^2 (24,700 acres)(J. Vashon, MDIFW, unpub. data). Male home ranges overlap slightly. Female home ranges overlap broadly. An average of 3.7 adult female home ranges occurs within each male home range (J. Vashon, MDIFW, unpub. data). A lynx habitat unit of 35,000 acres (1 ½ townships, 141 km^2) of high quality habitat could support approximately two adult male, six adult female lynx home ranges, and 22 kittens and subadults or a total of about 30 lynx of all ages (Figure 1). An assured, continuous supply of this quantity and quality of habitat would likely meet population and habitat goals adequate for recovery of the species. A lynx habitat unit of 35,000 acres would continue to support a smaller number of lynx if snowshoe hare numbers cycle or decline, home ranges increase, and productivity and survival decrease.

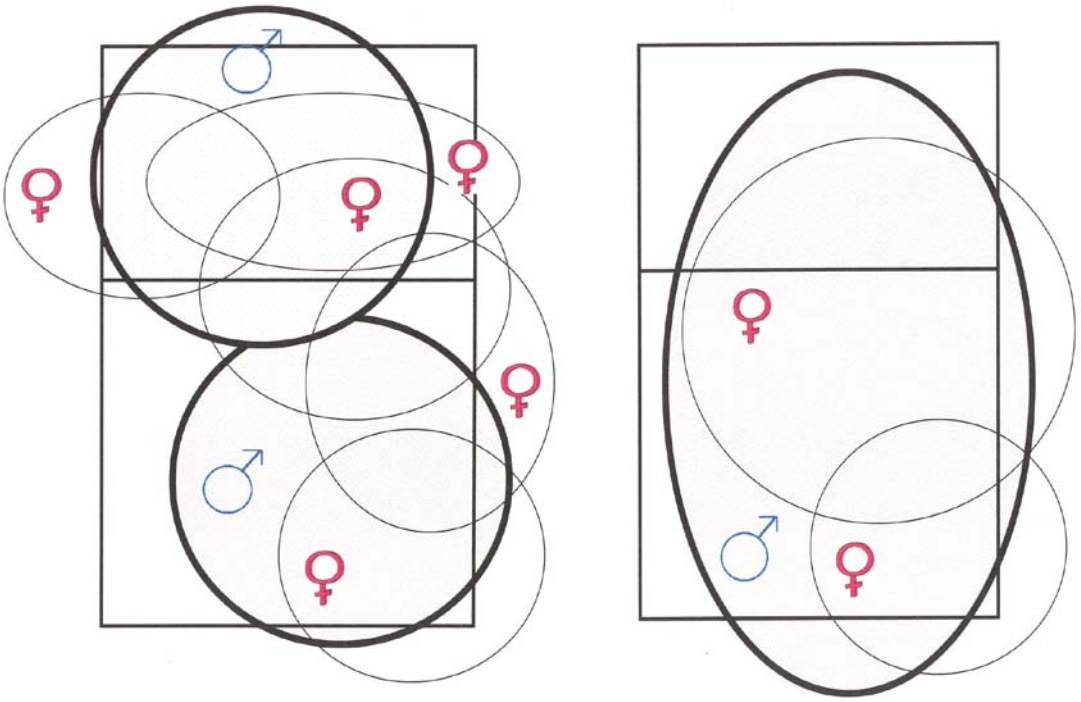

Figure 1. Lynx habitat units at high hare/lynx density (left) and low hare/lynx density (right). Each diagram depicts a 1 ½ township area (35,000 acres, 141 km2). At high hare/lynx populations average adult male lynx home range are depicted at 57.8 km2, (22 mi.2, 14,300 acres) and average adult female home range are 26.5 km2, (10 mi.2, 6,550) acres. Under these conditions a lynx management unit could support 2 adult males, 5-6 adult females, 10-14 kittens and subadults or 17-22 lynx of all ages. At low hare/lynx populations, adult male lynx home range is depicted at >100 km2. Under these conditions a lynx habitat unit would accommodate 1 adult male lynx, 2-3 adult females, 3-7 kittens and subadults or 6-11 lynx of all ages.

For comparison, in the northern Rockies where lynx home ranges are much larger and populations less dense, the LCAS (Ruediger et al. 2000) recommends areas of about 1,800 km2 (445,000 acres) as necessary to support a local population of 25 lynx. At the smallest scale, lynx on federal lands are managed at Lynx Analysis Units (LAUs) of 16,-25,000 acres, which roughly equate with the home range size of one lynx in the northern Rockies.

Not all habitat within a 35,000 acre lynx area need be in optimal condition. The Clayton Lake study area is one of several high quality lynx habitats (Hoving et al. 2004). In this area, lynx selected densely stocked, mid-regenerating, softwood-dominated stands (clearcut 11-26 years prior, regeneration 15-24' tall) and established partial harvested stands (partially harvested 11-21 years prior) (Fuller 2006). These preferred habitats comprised 23.5% of the study area (Fuller 2006). Maintaining about 20% of the forest in

a lynx habitat area in optimal habitat conditions (see Guideline 3) is believed adequate to support resident lynx with home ranges on the landscape. In some areas that were previously extensively clearcut in the 1970s and 1908s, the percentage of habitat in optimal conditions may be currently greater than 25%. Intense harvesting resulting in >25% of stands in a young condition, may benefit lynx, but can fragment habitat and may not support resident pine marten (Chapin et al. 1998, Payer 1999).

Based on this information, about 20% of a lynx area should be in optimal mid-regeneration habitat conditions recognizing that 1) an additional 20% of the landscape may be comprised of younger, recently harvested stands that will provide future lynx habitat, 2) 20% of the landscape may be comprised of older forests completing the final decades of a forest rotation, and 3) a percentage of the landscape (e.g. lakes, roads, shoreland zones) will be in non-forested or non-harvested conditions. (Note: These age-distribution guidelines are for lynx only. It may be difficult to simultaneously manage for pine marten in the same townships if 40% of the land area is in forests <35 years of age. See further information below.)

The minimum stand size used by lynx in Maine is not known at this time. Average stand area for tall regenerating clearcuts and established partial harvest selected by lynx in Clayton Lake were 13.0 ha (29 acres) and 17.6 ha (35 acres), respectively (Fuller 2006). Until further information becomes available, we recommend creating patches $\geq$100 acres. Tall regenerating clearcuts (referred to as mid-regeneration by some authors) and established partial harvest support high hare densities approximately 10-12 years after disturbance to 30-35 years after disturbance. The length of time these stands provide optimal habitat for hares and lynx depends on initial treatment, site conditions, species composition, and precommercial treatments. Additional stand characteristics used and unused by lynx will be available in the summer of 2006 (L. Robinson, UMaine, unpub. data, MDIFW, unpub. data), which may further inform these guidelines.

If all landowners in northern Maine could assure that future lynx habitat met or exceeded the landscape objectives in Guideline #2, then an important recovery goal for lynx would be completed. The proposed critical habitat for lynx equates with the current occupied range of lynx in Maine and encompasses approximately 10,500 square miles (~6,720,000 acres). One lynx habitat unit of 35,000 acres created for every 200,000 acres would create 34 high quality habitats in northern Maine (Figure 2). Collectively, 34 lynx areas would encompass 1,000,000 acres, of which 200,000 acres would be in mid-regeneration clearcut or established partial harvest conditions at any time. These habitats could support 578-748 lynx at high hare conditions and 204-374 lynx at low hare conditions.

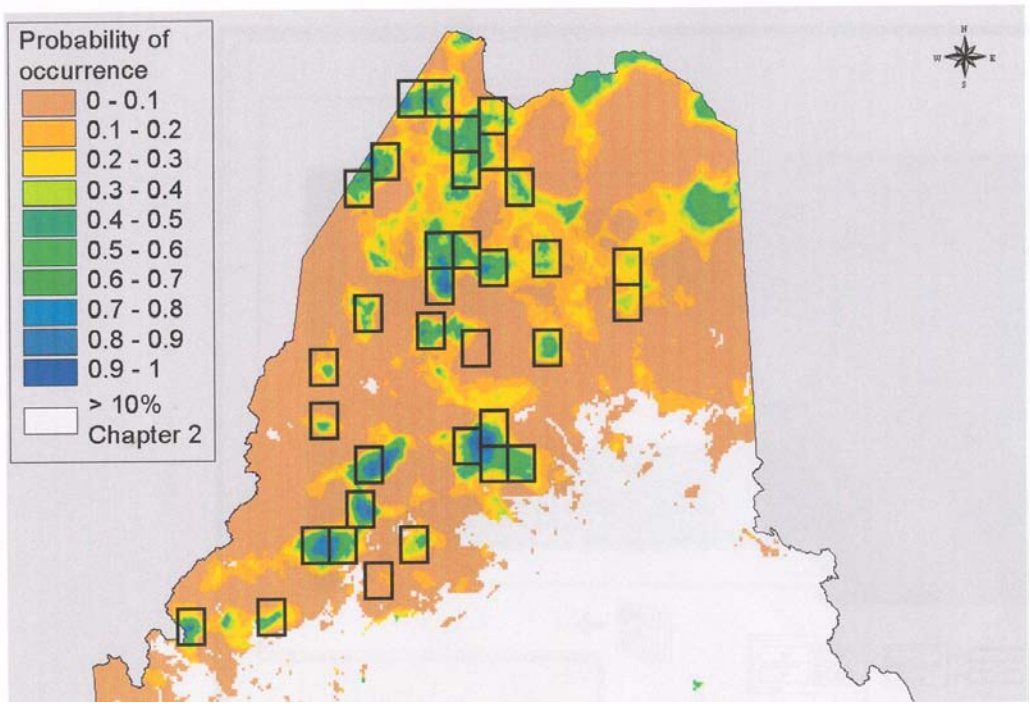

Figure 2. A hypothetical distribution of lynx habitat units on the Hoving et al. (2004) lynx habitat map. Dark blue and green areas represent habitats with the highest probability of supporting lynx.

Landowners are encouraged to identify current lynx habitat areas and plan the location of future large habitat blocks. Lynx habitat areas could remain in the same area over time or be located at different places on the landscape in a shifting mosaic. Ideally, two or more lynx habitat areas could abut each other. A landowner may decide to exceed a goal of 35,000+ lynx area/200,000 acres ownership. A landowner may currently have abundant lynx habitat, and it may be easy to identify areas that already meet Guideline #2. It is important that such landowners be able to demonstrate that future management will continue to provide quality lynx habitat that is configured in a way that will support resident lynx. These guidelines are not prescriptive, but are outcome based, and offer opportunities for innovative planning and implementation.

Certain site characteristics may favor conifers and be locations where lynx have occurred consistently in the past. Spruce-fir flats and sites with shallow, rocky soils are areas with higher prevalence of conifers and may be managed to benefit hares and lynx. Many of these areas prone to higher windthrow and higher probability of insect damage and lend themselves to even-aged management.

As stands mature to 30-35 years post-harvest, the canopy closes and they begin to self-thin. At this age, stands begin to produce good habitat for pine marten, forest interior birds, and other species that use older forests. We recommend that stands should mature

for at least another 30 to 40 years to complete a 60 to 70-year rotation to provide habitat for species that require older forests. At 70 years of age, conifer stands are just beginning to develop the structural characteristics of ecologically mature stands. The pine marten umbrella species model used by some forest landowners in Maine is one model for assuring adequate mature stands remain on the landscape. This model recommends creating 3 to 6 pine marten units of 1,250 acres each (D. Harrison and J. Heppinstal, UMaine, unpub. data) per township. Pine marten and forest interior bird objectives could be achieved as areas of lynx habitat mature into pine marten habitat. Studies by Bissonette et al. 1997, Hargis and Bissonette 1997, Chapin et al. 1998, Payer 1999, and Potvin 2000 suggest that habitat occupancy by marten declines when 25-40% of the landscape is composed of young forest. Landowners wishing to manage for pine marten and Canada lynx simultaneously may want to ensure that no more than 25% of stands in a lynx habitat unit are less than 35 years in age. Note that the use of the lynx and marten as umbrella species may be suitable for most forest vertebrates, some species of plants and lichens and perhaps other low-mobility species associated with older and uneven-aged forests that may not develop under a combined lynx-marten management strategy.

Our knowledge of lynx habitat selection in Maine is based primarily from the Clayton Lake area, which has a unique silvicultural history. This area was heavily clearcut to salvage timber after the spruce budworm epidemic. Partial harvesting represents <6% of the landscape (Fuller et al. 2007) and methods used in Clayton Lake also differ from those used elsewhere. Pre-commercial thinning is rarely used in the area, but is more prevalent elsewhere. Our current knowledge of lynx habitat selection is thus biased toward the post budworm/clearcut paradigm and not the new partial harvest paradigm. For this reason, lynx habitat selection may be different in other areas of northern Maine, which may lead to different conclusions about forest practices, snowshoe hares, and lynx. Studies of lynx habitat use are needed in landscapes created by different methods of silviculture, particularly the prevalent forms of silviculture used in Maine today - partial harvesting, selection cuts, plantations, and pre-commercial thinning. For instance, lynx home ranges may be larger and population density may be lower in a landscape that is predominantly created by partial harvest having lower hare densities. These lynx forest management guidelines may change if new information becomes available.

A summary of recommendations:

Condition	**Percent of area**	**Age (yrs.)**	**Height (ft.)**	**Stems/acre**
Recent harvest	20%	0-10 years	<12 feet	11,000-40,000
Mid-regeneration	20%	10-30 or 35 (depending on site conditions)	12-35 feet	7,000-15,000
Older	60%	30-70+	30-70 feet	

One 1 ½ township/35,000 acre lynx habitat unit/200,000 acres

3. Employ silvicultural methods that will create regenerating conifer-dominated stands 12-35 feet in height with high stem density (7000-15,000 stems/acre) and horizontal cover above the average snow depth that will support >1.1 hares/ha.

Desired outcome: Employ silvicultural techniques that create, maintain, or prolong use of stands by high populations of snowshoe hares.

Rationale: Lynx generally select habitats with abundant snowshoe hares (Mowatt et al. 2000). Snowshoe hares reach their highest densities in stands with the highest horizontal cover or stem density units (e.g. Homyack et al. 2006). However, lynx may prefer to hunt in stands that are less dense and have lower hare density (O'Donaghue et al. 1998). This may be because lynx access (greater visibility of hares and easier mobility of lynx) and hare vulnerability may be greater in more open stands (Fuller 2006).

In Maine, mid-regeneration stands support the highest densities of snowshoe hares (Lachowski 1997, Homyack 2003, Fuller 2006). Snowshoe hare habitat models (Homyack et al. 2005, Fuller 2006, and L. Robinson, UMaine, unpub. data) show that optimal habitat for snowshoe hares in Maine are found in conifer-dominated stands 12 to 35 feet in height, with high stem cover units and an open canopy (generally < 25% canopy closure). These stand conditions are usually created 10 to 30-years after a disturbance. Site conditions, stand composition, and silvicultural treatment (e.g. use of thinning and herbicides) may affect the amount of time for stands to attain and remain in optimal conditions and support high populations of snowshoe hares. Vashon et al. 2005 demonstrated that radio-tagged lynx in the Clayton Lake area selected coniferous dominated stands that were 10 to 30 years-old post-clearcutting and up to 35 feet in height. On the same study area Fuller et al. (2007) documented from back-tracking radio-tagged lynx that they selected tall regenerating clearcuts (13 – 22 feet, 11-26 years post harvest) and established partial harvests (11-21 years post-harvest). Fuller (2006) hypothesized that that lynx selected more open regenerating clearcuts and older partial harvests because they had intermediate to high hare densities (but not the highest on the study area) and hares were more vulnerable in a more open understory.

Hare densities required to support a viable lynx population at the southern part of their range are uncertain. Ruggiero et al. (2000) suggested a hare density of 0.5 hares/ha was necessary for lynx population persistence, although this value is only an estimate. Steury and Murray (2004) modeled lynx and snowshoe hare populations based on a compilation of data from North American lynx research and suggested a density of 1.1 to 1.8 hares/ha was required for lynx persistence. They determined that hare density, more than any other factor (population size, emigration rates, trapping-hunting-vehicle mortality, phase of the 10-year cycle), is the most important factor explaining the persistence of lynx populations. Below a threshold of 1.1 hares/ha their model predicts kitten survival and lynx populations will decline. Until better information becomes

available, stands contributing habitat within 35,000 acre lynx habitat areas should be managed to achieve at least 1.1 hares/ha.

Ruggiero et al. (2000) and Steury and Murray (2004) are unclear as to whether the hare densities needed to support a lynx population are in the best hare habitats, habitats selected by lynx, or an average hare density over a extensive ($100km^2$) landscape. Much of the data used to derive Steury and Murray's (2004) estimate comes from Canada and Alaska where habitat occurs in nonmanaged and contiguous (not patchy as in Maine) habitats where hare populations cycle 1- to 4-fold. We are unsure how these estimates pertain to Maine. Robinson (2006) found landscape hare densities of 0.86 hares/ha in areas occupied by lynx vs. 0.64 hares/ha in areas not occupied. Further research is underway at UMaine to document threshold landscape hare densities needed to support lynx.

Homyack (2003) summarized hare density data for Maine. Hare densities >1.1 hares/ha were found in regenerating softwood and mixedwood stands (1.63 hares/ha Fuller 1999, 1.83 hares/ha Homyack 2003, and 2.43 hares/ha Lachowski 1997). Hare densities less than 1.1 hares/ha were found in pre-commercially thinned stands (0.99 hares/ha Homyack 2003), budworm killed stands (0.59 hares/ha Lachowski 1997), mature conifer stands (0.23 hares/ha Lachowski 1997 and Fuller 1999), mature mixed stands (0.21 hares/ha Fuller 1999), mature deciduous stands (0.15 Lachowski 1997, 0.16 Fuller 1999), and partial harvest stands 3 to 6 years post-harvest (0.15 hares/ha, Fuller 1999). For comparison, in northern Canada and Alaska snowshoe hare densities average 1.5 to 6 hares/ha during the peak of the 10-year hare cycle and decline to about 0.2 to 0.4 hares/ha at the low point (Hodges in Ruggiero 2000). Unthinned stands supporting 1.83 hares/ha in Maine were associated with average stem densities of 11,601 stems/ha (n=13 stands, 1 to 11 years after clearcutting)(Homyack et al. 2004).

Regenerating clearcut	2.43 hares/ha	Lachowski (1997)
Regenerating clearcut	1.83 hares/ha	Homyack (2003)
Regenerating clearcut	1.63 hares/ha	Fuller (1999)
Precommercial thinning	0.99 hares/ha	Homyack (2003)
Budworm kill	0.59 hares/ha	Lachowski (1997)
Coniferous mature	0.23 hares/ha	Fuller (1999)
Deciduous mature	0.16 hares/ha	Lachowski (1997)
Partial harvest (young)	0.15 hares/ha	Fuller (1999)
Partial harvest (older)	0.80 hares/ha	Robinson (2006)

Silvicultural techniques

Maines's relatively large, widely-distributed population of lynx today is a legacy of the extensive clearcutting to salvage spruce and fir during the spruce budworm epidemic of the 1970s and 1980s. Silvicultural methods that remove substantial portion of the overstory, maintain dense conifer-dominated regeneration, and minimize repeated disturbances (i.e. multiple reentries) when the stand is in optimal conditions will provide high quality habitat for snowshoe hares. In addition to clearcutting, other forms of even-

aged management including some types of partial harvest (shelterwood/overstory removal, seed tree, group selection) may be done in a way to create good snowshoe hare habitat. Silvicultural systems that result in low stem density, hardwood dominated stands, high canopy closure, and are self-thinning do not provide good hare and lynx habitat. Clearcutting and forms of shelterwood harvest are even-aged silvicultural systems that would be expected to create lynx habitat in spruce-fir forests in Maine. Selection harvests (uneven-aged) management would not be expected to produce quality hare and lynx habitat.

Passage of the Maine Forest Practices Act in 1989 greatly changed silviculture in northern Maine. Prior to the budworm outbreak (1960s) selection harvest (primarily of spruce) was prevalent in a forest that was maturing from the last round of budworm in the late 1800s. Widespread clearcutting and road building in northern Maine occurred during the last budworm outbreak (1972-1986) when about 45% of the annual forest harvest (47,000 hectares) was by clearcut and 55% by partial harvest (Maine Forest Service 1995). A primary intent of the Maine Forest Practices Act was to regulate the amount and size and distribution of clearcuts. By 1999, clearcuts accounted for only 3% of the annual harvest, whereas partial harvest methods (including shelterwood, seed tree, group selection, and others) accounted for 96% of the forest area harvested (Maine Forest Service 2000). Many factors contributed to the shift from clearcutting to partial harvesting after the passage of the Forest Practices Act, including the cessation of the budworm epidemic, sensitivity to public concerns by landowners, and increased understanding of the silvicultural benefits of the shelterwood system, and the massive change from industrial to institutional/investor land ownerships. In contract to Maine, clearcutting remains the most frequently used silvicultural system in spruce-fir forests in eastern Canada.

Maine's new partial harvest paradigm portends an uncertain future for lynx. In Clayton Lake, established partial harvested stands were selected by lynx in winter (Fuller et al. 2007) and provide moderate hare densities (range 0.26-1.65 hares/ha Robinson 2006). Fuller et al. (2007) postulated that lynx may select partial harvested stands because they are less dense and provide easier access to hares and cautioned against extrapolating the value of partial harvested habitat for lynx across a larger landscape. Hare densities in partial harvested stands may be positively influenced by adjacent regenerating clearcut stands. It is unknown whether a future landscape comprised entirely of partially-harvested stands will provide adequate hare densities sufficient to support a lynx population similar to that occurring in Maine today. Until further information is obtained, it is uncertain how significant shifts in Maine's silviculture will affect lynx.

Clearcutting: Clearcutting in spruce-fir stands is a proven method in Maine to produce quality habitat for snowshoe hares. If regenerating clearcuts are of adequate size (larger is better), located close enough to each other, and comprise an adequate portion of the landscape they can support resident lynx. When clearcutting is used, it is necessary to provide adequate areas where windthrow can create suitable denning sites. Clearcutting is a cost-effective form of silviculture in spruce-fir systems and is still the most common

form of silviculture in spruce-fir stands in adjacent New Brunswick and Quebec.

The definition of a clearcut in the Maine Forest Practices Act is any timber harvesting on a site >5 acres that results in a residual basal area of growing stock over 4.5 in. with a DBH of less than 30 square feet per acre. Standards in the Maine Forest Practices Act apply to different sizes of clearcuts. Category 1 clearcuts, 5-20 acres in size require the least amount of documentation. Implementation of these small cuts and wide separation zones create a characteristic checkerboard pattern on the landscape. They require a 250 foot separation zone between cuts, which can be removed 10 years later. Category 1 clearcuts create small patches of snowshoe hare habitat separated by mature habitat. The combination of small size and separation with older forest may not be attractive to lynx. These small clearcuts were employed by some landowners in the early 1990s, but are rarely used today. Category 2 and 3 cuts require a site harvest plan and comply with clearcut standards and reporting requirements. Maximum size is 250 acres. Because of the reporting requirements and concern about public reaction, larger clearcuts are rarely employed today. In most years there are no applications from landowners for clearcuts >75 acres (Maine Forest Service, unpub. data). Large clearcuts should be re-considered in certain situations for their value in providing early successional habitat at a scale valuable to lynx, bear, moose, and other species requiring large areas of young, regenerating softwood forest. After clearcutting, regenerating stands will provide habitat for snowshoe hare and lynx for about 10 to 30 years after harvest, and provide habitat for older forest species like pine marten and forest interior birds for the final 20 to 40 years of the stand rotation.

Young clearcuts (short regenerating clearcut, 3.4-4.3 m tall, up to 10-12 years post harvest) were avoided by lynx (Fuller et al. 2007, Vashon et al. 2005). Hare densities in these stands are low when regeneration has not developed to provide adequate cover (Homyack 2003). In Maine's moist environment, regenerating spruce and fir grows quickly creating a dense understory. As the understory becomes established hare populations increase. The highest hare densities are found in mid-regenerating clearcuts (~10-30 years of age) averaging 1.6 to 2.4 hares/ha. As the stands mature to approximately 30 to 35 years (or 30-35 feet in height) the canopy closes, the stand starts to self thin, and understory density declines. Snowshoe hare populations in stands exceeding 30 years have not been well-studied in Maine. Hare populations decline after 30 to 35 years, but it is unknown whether the decline is gradual or rapid. Hare densities in mature spruce-fir stands averages only 0.23 hares/ha (Fuller 1999).

Partial harvesting: Partial harvesting refers to a great variety of silvicultural treatments – some of which may create habitat for snowshoe hares and lynx and some may not. Partial harvesting is the most frequently reported form of silviculture in Maine today accounting for over 90% of the acreage harvested. Partial harvests include selection cuts, shelterwood cuts, seed tree, and other types of harvest. The merits of each to lynx are briefly discussed below. Further research of snowshoe hare response to partial harvesting and lynx habitat selection in a landscape dominated by partial harvest methods is needed before the effects of Maine's new forestry paradigm can be fully ascertained.

On average, older partial harvested stands support only one-third to one-half the snowshoe hare density (0.8 hares/ha) as clearcut stands (1.6-2.4 hares/ha). Partial harvested stands in the Telos area and Clayton Lake averaged about 0.8-0.9 hares/ha (range 0.27-1.63 hares/ha). This may be below the threshold density needed to support lynx. Furthermore, hare populations in partial harvested stands may be augmented my emigration from nearby clearcut stands having high hare densities. When the regenerating clearcuts of the 1970s and 1980s mature past the stage that they support high hare populations, a landscape dominated by partially harvested stands may have hare densities too low to support a lynx population.

Shelterwood system: Within the shelterwood system mature trees are harvested in two or more stages. The first stage removes a portion of the overstory to allow light to reach the ground level and establish young spruce and fir trees. The remaining trees are removed in a second (two-stage) or third (three-stage) harvests. Shelterwood harvest is the predominant form of cutting reported to the Maine Forest Service representing about 30-40% of the annual harvest. In reality, there are many forms of shelterwood harvesting. The initial harvest may be heavy or light. Subsequent harvests in the stands may be none, one, or two or more times. Not all partial harvest or shelterwood cuts have equal value to snowshoe hares. The value of shelterwood harvested stands to snowshoe hare and lynx is influenced by several factors:

- Nature of the regeneration. Conifer-dominated regeneration provides up to three times more cover than hardwood.
- Severity of the first harvest. Opening the overstory to 25% or less of the original canopy closure will promote response by the conifer understory. Excessive overstory removal sometimes favors hardwood regeneration, which does not provide as good habitat benefits for hares.
- Number of re-entries. More re-entries may diminish the value of the cover provided by regeneration. The effects of reentry on understory depends on the equipment and methods used and the extent of residual trees being removed.

Some shelterwood harvests remove all trees up to the legal definition of a clearcut in the Maine Forest Practices Act (30 square foot basal area/acre). Residual trees may have some commercial or biological value (seed trees, legacy trees, future snags and coarse woody debris). However, in many instances the remaining trees are windthrown or have no commercial value, and there is no second entry to remove the residual overstory. Since the Maine Forest Practices Act provides no restrictions to the size of these heavy shelterwood cuts, they can be created large enough to be of landscape value to lynx. The resulting regenerating stand created in this fashion may be similar in nature to a regenerating clearcut. If heavy shelterwood or partial harvests create dense, regenerating conifers they will provide habitat for snowshoe hares. Like a clearcut, optimal habitat conditions for hares will likely occur approximately 10 to 30 years after harvest, although this has not be studied in Maine. (Some have hypothesized that partial harvests may extend the period of intermediate to high hare densities.) Variability in hare densities in heavy partial harvested stands is likely related to the nature of the regenerating stand (softwood is superior to hardwood), canopy closure, and time elapsed since disturbance.

Shelterwood harvests that retain a higher percentage of residual trees can be managed to provide good habitat for snowshoe hares and lynx. Foresters need to employ forest stand prescriptions that favor conifer regeneration. After conifer regeneration is established, subsequent overstory removal(s) can occur to allow sufficient sunlight to reach the ground level and release the conifer regeneration. Multiple-stage shelterwood cuts of this type in conifer-dominated stands may mimic the regeneration response in clearcuts and provide habitat for lynx.

Selection system: Selection cuts are harvests where trees are removed individually or in small (<5 acre) patches. This form of harvest is often used in hardwood stands and in conifer stands found in family forests. Selection results in an uneven-aged form of management. In most selection harvests, canopy closure is maintained and light does not penetrate the forest floor to promote extensive regeneration of conifers. In group selection, small patches (about twice the height of mature trees) are created to regenerate a stand. Although small patches of hare habitat may be created, selection harvest would not be expected to produce good habitat for hares or lynx. Selection harvest is the most prevalent form of harvesting in Maine today (about 55-65% of reported harvests).

Precommercial silvicultural activities

Herbicides: Herbicides are used in forest management to control vegetation competing with crop trees and occasionally vegetation occurring along roads. Herbicides were widely used in the 1980s and 1990s to reduce hardwood competition and release softwood regeneration. Herbicides were typically applied 2 to 5 years after clearcutting to control competing hardwood regeneration. Herbicides likely have a net benefit for snowshoe hares by promoting softwoods, which provide superior cover. Hardwood species do provide an important element to snowshoe hare density. Hardwood browse quantity is consistently reduced shortly after conifer release with herbicides, but initial reductions often are compensated for by later increased browse availability in treated areas (Newton et al. 1989). That result, added to the developing conifer cover, leads to extended periods of browse availability and increased area use by moose or snowshoe hare through time (Lautenschlager 1993; Newton et al 1987; Escholz et al. 1996; Raymond et al. 1996). Sullivan (1994) found that herbicide application to boreal forest in early- to mid-successional (<25 year post treatment) stands in British Columbia did not affect hare abundance. Many areas used by lynx today received herbicide treatments and support hare populations greater than 2 hares/ha (Fuller 2006). Herbicide use has diminished greatly from 40-60,000 acres/year on industrial forestlands in the mid-1990s to less than 15,000 acres treated since 2000 (Maine Forest Service 2004).

Precommercial thinning or timber stand improvement: The combination of clearcut harvest and herbicide treatment was common in the 1980s and 1990s and often resulted overstocked stands. Forest landowners frequently use precommercial thinning (PCT) to reduce stem densities from >37,000 conifer stems per hectare to 2,000-2,500 per hectare (~6 X 6-foot spacing) to accelerate growth of the residual trees. In Maine PCT is usually done manually with brush saws in stands 10-20 years after harvest when crop trees average 1.5 to 3.0 m in height. The annual land area treated with PCT in Maine increased

steadily from 2,428 ha in 1987 to 8,700-11,300 ha from 2000-2004 (Maine Forest Service 2004). At the current rate, approximately 131,000 ha (or 2% of Maine's commercial timberland) will have been spaced by 2005 (Homyack 2003). Nearly all PCT activity occurs on corporate land ownerships greater than 100,000 acres (Maine Forest Service 2004). PCT treatments are expected to decline because most of the post budworm clearcut stands on higher quality sites have been treated and are aging past the point of effective PCT treatments and short-term investor landowners are reluctant to make this expensive investment. The use of PCT has increased in eastern Canada. From 1990 to 2000 the land area treated with PCT increased almost 3-fold in New Brunswick, 2-fold in Nova Scotia, and 4-fold in Quebec (Canadian Council of Forest Ministers 2002).

Some studies have documented short-term changes (4 years or less) in densities of hares after thinning (Sullivan and Sullivan 1988, de Bellefeuille et al. 2001). In Maine, Homyack et al. (2004) studied the effects of PCT in 30 regenerating, herbicide-treated conifer stands. PCT affected understory structure and complexity by reducing stem cover units at the ground level, an important habitat component for snowshoe hares. Homyack (2005) documented about a 50% decline in hare densities between stands treated with PCT and unthinned stands at 1 year after thinning (-45 to -54%), 6-years after thinning (-39 to -55%), and 11-years after thinning (-13% to -61%). Average hare densities declined from 1.83 hares/ha (unthinned, 18-26 year old clearcuts) to 0.99 hares/ha (pre-commercially thinned 18-32 year old clearcuts). Although stands treated with PCT support lower densities of snowshoe hares than unthinned stands, thinned stand retain densities of hares greater than stands managed using other forest harvesting regimes. The densities of hares remaining after PCT may be adequate to support lynx (Homyack et al. 2005), but this needs further study. On the Clayton Lake study area, lynx showed a preference for established partial harvested stands that have a more open understory and support intermediate hare densities (Fuller 2006). Lynx habitat preference has not been studied in Maine in a landscape where PCT is prevalent.

Other studies have evaluated the effects of PCT on snowshoe hare in Montana (Zimmer 2004, Griffin 2004), British Columbia (Sullivan and Sullivan 1988), and Quebec (de Bellefuille et al. 2001, Bujold et al. 2002). The results of studies from other regions should be applied to Maine with caution because of differences in forest ecology, climate, PCT methodology, and other factors (e.g. herbicide application in conjunction with PCT) that may influence the effects of PCT on snowshoe hares.

The LCAS (Ruediger et al. 2000) recommends that PCT be used on federal lands when stands no longer provide snowshoe hare habitat. This is when the canopy of the regenerating forest has closed and self-pruning has eliminated snowshoe hare cover and forage availability during winter conditions. As a result, federal land managers have discontinued PCT in younger stands.

Before conclusions are made about PCT in Maine, habitat use of lynx needs to be done in a landscape where PCT is prevalent. PCT is infrequently used in the Clayton Lake area where Vashon et al. (2005) and Fuller (2006) studied lynx habitat selection. Given the lack of research to evaluate lynx response to PCT (selection or avoidance),

small portion of the landscape affected by PCT, the anticipated reduction of PCT in the future, PCT can continue on private lands in Maine. This issue should be revisited if additional information becomes available from Maine showing an adverse effect of PCT on lynx.

Planting/plantations: Because of the abundance of natural regeneration and the expense of plantations, few forest managers in Maine use planting as a primary source of regeneration. Planting is not widely used in Maine, and only 7,000 to 11,000 acres are planted annually (Maine Forest Service 2004). The total number of acres planted in Maine during the last 25 years is only about 1.2% of Maine's forest land (Maine Forest Service 2001), however the use of planting may increase in the future (Gadzik et al. 1998). The most commonly planted species are all softwood species - black, white, red, and Norway spruce, jack pine, red and white pine and cedar, which if planted at adequate densities should provide horizontal cover for snowshoe hares. The habitat quality provided by plantations varies with the age, composition, native or exotic species, and the silvicultural practices employed, particularly with site preparation (Rowland et al. 2005). Machinery, herbicide applications, and prescribed burning are used to manage resideual vegetation and to remove debris to prepare a site for planting. There is no published research on the effects of site preparation in Maine (Rowland et al. 2005). Excessively clean site preparation could remove coarse woody debris, which is a valuable component of lynx denning habitat.

Lynx and snowshoe hare response to plantations has not been studied in Maine. Anecdotal information from New Brunswick suggests that dense hare populations can be achieved in black spruce plantations and that lynx tracks have been observed in these areas (J. Gilbert, Irving pers. comm.). If planting of native species can produce forest composition and structure similar to those than occur under natural conditions, including a dense understory of small diameter conifers and shrubs preferred by hares, then plantations may be selected by lynx. Site preparation for planting sites should leave coarse woody debris to provide additional structure and den habitat and some hardwood browse (e.g. by skipping areas during site preparation).

4. Maintain land in forest management. Development and associated activities should be consolidated to minimize direct and indirect impacts. Avoid development projects that occur across large areas, increase lynx mortality, fragment habitat, or result in barriers that affect lynx movements and dispersal.

Desired outcome: Maintain the current amount and distribution of commercial forest land in northern Maine. Prevent forest fragmentation and barriers to movements. Avoid development that introduces new sources of lynx mortality.

Rationale: Canada lynx require landscapes comprised of large, contiguous areas of coniferous forest with deep snow and provide an adequate prey base of snowshoe hares. Currently, a large, undeveloped area in northwestern Maine, approximately 6.7 million acres – the size of Massachusetts, provides quality lynx habitat. Within this area, permanent human habitation is very low and there are no towns or villages. Lynx

habitats are connected by forest boreal/northern hardwood stands that readily allow movement of lynx. There a few natural barriers to dispersal or movements. There is probably no important goal for lynx and other large area-requiring species than to keep northern Maine as it is today – an undeveloped, managed forest. Developing conservation easements and management agreements are important strategies for lynx recovery (Nordstrom et al. 2005).

Lynx exemplify the need for landscape-level management that maintains large areas of habitat (100s km2, Hoving 2001) and habitat connectivity between metapopulations within Maine and populations in Canada. Lynx occupy landscapes throughout their North American range that are undeveloped or only lightly developed. For this reason, there are few studies available to assess the influence of human development (buildings, towns, and associated human activity) on lynx behavior. Lynx are no longer present in historic range in some areas of northern and western Maine that are highly fragmented, developed, high density of paved roads, or have substantial portion of the landscape converted to non-forest land uses (Hoving 2001).

Lynx are described as being tolerant of humans (Staples 1995) and anecdotes suggest that lynx are not displaced by human presence, including moderate levels of snowmobile traffic (Mowat et al. 2000) and ski area activity (Roe et al. 1999). However, lynx (in contrast to bobcats, coyotes, and fishers) are not known to regularly occupy moderately-developed landscapes in North America even when appropriate habitat exists (Ruggiero et al. 2000). In Maine, lynx have not been documented in moderately to heavily developed areas on the fringe of their range (i.e. Greenville, Millinocket). A radio-tagged lynx in Maine established a home range in undeveloped, corporate forest land adjacent to the town of Ashland, but did not use the developed portions of the town (MDIFW, unpub. data). Similarly, Maine lynx roaming out of their home ranges have approached moderately-settled areas, but returned to their home ranges (MDIFW, unpub. data). In Minnesota, lynx have been observed, captured, and radio-tagged in lightly developed areas on private land within the Superior National Forest (Burdette, Univ. of Minnesota, unpub. data). Indications are that lynx do not tolerate moderately settled areas.

At this time, there is little scientific information to provide specific guidelines about the threshold or nature of development projects that could negatively affect the viability of lynx populations and reduce their distribution. Development has secondary effects on lynx beyond the footprint of development (e.g. road mortality, habitat fragmentation, increased human disturbance, introducing new sources of mortality, changing patterns of forest management). Mechanisms are in place to regulate development in lynx habitat areas in unorganized townships in northern Maine through the Land Use Regulation Commission. The sparse development that occurs within this region (sporting camps, single camps and cottages, limited shorefront development, boat launches) typically occurs at a small scale (a fraction of a single lynx's home range), do not significantly impede lynx movements, or introduce significant new sources of lynx mortality. Similar limited-scale, sparse development could be compatible with lynx conservation, however, the cumulative effects of many small projects could ultimately

have adverse effects on Maine's lynx population. Until better information is available, the following guidelines should be considered when development is considered in northern Maine:

- Avoid development projects that are dispersed over large geographic areas or occupy large areas (multiple townships). Development and associated activities should be consolidated to minimize direct and indirect impacts. Development projects would be better placed around the periphery of Maine's occupied lynx habitat adjacent to existing population centers than in the interior of lynx habitat to avoid increased traffic, human disturbance, and barriers to movements for lynx,
- Recreational development should be planned to maintain the viability of lynx habitat by preserving existing boreal forest habitats and providing connectivity of habitats and lynx movement.
- Avoid projects that result in barriers that affect lynx movements and dispersal or increase mortality, especially paved, multi-lane, high-speed highways.

5. Encourage coarse woody debris for den sites by maintaining standing dead trees after harvest and leaving patches (at least ¾ acre) of windthrow or insect damage.

Desired outcome: Retain coarse woody debris for denning sites.

Rationale: Denning habitat in Maine coincides largely with foraging habitat and does not seem to be limiting in Maine. Sub-stand characteristics were evaluated for 26 Canada lynx dens from 1999 to 2004 in the Clayton Lake study area in northwest Maine (John Organ, USFWS, unpub. data). Variables included basal area and volume, coarse woody debris, canopy closure, woody stem density, tip-up mounds (blow-downs), ground cover, and horizontal cover (visual obscurity, measured at 5 and 10 meter intervals). Dens were found in a several stand types including softwood mid/late regeneration (n=10), mature forest mixed regeneration (n=5), mature softwood (n=4), other regeneration (n=4), hardwood/softwood mid/late regeneration (n=2), and unknown (n=1). ANOVA was used to compare differences in structure at den sites to that of the residual stands dens were located in. Significant variables associated with lynx dens included tip-up mounds, horizontal cover at 5 meters, total coarse woody debris (metric tonnes/hectare), solid coarse woody debris off the ground, and decayed coarse woody debris off the ground. Herbaceous cover was less at den sites than the random stands.

Logistic regression models incorporating different combinations of these variables were developed and evaluated to assess what characteristic(s) best explained lynx den site selection. Tip-up mounds alone best explained den site selection. Horizontal cover at 5 meters alone was the next best performing model. Tip-up mounds are nearly four times as likely than horizontal cover at 5 meters to be represented the best model. Lynx are essentially selecting dense cover in a cover-rich environment. Tip-up mounds may purely be an index of downed tress, which are abundant on the landscape. Downed trees provide excellent cover for den sites (when off the ground), and often are associated with dense woody stem growth. The structural components of lynx den sites are common features in managed (logged) and unmanaged (spruce budworm damaged areas, wind-throw) stands. Den habitat does not seem to be limited in northern Maine.

Recommended practices to create downed woody material, snags, and cavity trees *Biodiversity in the Forests of Maine: Guidelines for Land Management* (Elliott 1999) should be adequate to create adequate coarse woody debris to provide lynx denning habitat in northern Maine forests.

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