NATURAL RESOURCES

Lynx Habitat Management Plan

For DNR-Managed Lands

April 2006

WASHINGTON STATE DEPARTMENT OF
Natural Resources
Doug Sutherland - Commissioner of Public Lands

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Acronyms and Abbreviations

dbh	Diameter at breast height
DNR	Washington State Department of Natural Resources
LAU	Lynx Analysis Unit
LMZ	Lynx Management Zone
LPO	Little Pend Oreille Block
LSF	Late Successional Forest
NRCA	Natural Resource Conservation Area
tpa	Trees per acre
USFS	United States Forest Service
USFWS	United States Fish and Wildlife Service
WAC	Washington Administrative Code
WDFW	Washington Department of Fish and Wildlife
WDW	Washington Department of Wildlife (merged into WDFW in 1994)
USDA	United States Department of Agriculture
WAU	Watershed Administrative Unit

1. Introduction

The Washington State Department of Natural Resources (DNR) manages more than 5 million acres of state land. Some of those lands are uplands within the range of the Canada lynx (*Lynx canadensis*) (Figure 1), a native cat that is listed as threatened with extinction—both in the state of Washington and under the federal Endangered Species Act.

Lynx habitat is forested, and most DNR-managed forests are managed using sustainable forest management practices to provide income for various state trust beneficiaries, including public schools, state universities, counties, and other public institutions. Forest management activities in Washington State are regulated by the state's Forest Practices rules, and DNR's forest management must comply with those rules.

This modified Lynx Habitat Management Plan (the 2006 Lynx Plan) was developed in response to the federal listing of the species (USFWS 2000). It revises the 1996 DNR Lynx Habitat Management Plan (WDNR 1996a), which had been developed in response to the state listing. This plan guides DNR's forest management activities to facilitate the creation and preservation of quality lynx habitat. It allows DNR to meet state and federal requirements for protecting lynx, while at the same time providing revenue through timber production and meeting its other land management obligations (i.e. recreation).

This chapter provides historical and management context and basic information about the Canada lynx natural history and distribution. The following chapters define categories of lynx habitat, outline DNR's implementation of the plan, and provide specific guidelines and provisions for monitoring and evaluation. A report on the implementation monitoring conducted for the period 1996-2004, in accordance with the 1996 Lynx Plan commitment, is presented in Appendix 1, and a report on the effectiveness monitoring conducted from 1997 through 2002 is presented in Appendix 2.

1.1 Conservation of Lynx in Washington

The Canada lynx became a Washington State candidate for listing in 1991 (Washington Department of Wildlife Policy 4802). In 1993, the Washington State Wildlife Commission listed the Canada lynx as threatened in the state of Washington. In response to the listing and at the recommendation of the Washington Forest Practices Board (February 1994), DNR developed a Lynx Habitat Management Plan (WDNR 1996a). This "special wildlife management plan" (WAC-222-16-080 [2]) was a substitute for a species-specific critical habitat designation, which the Forest Practices rule (i.e. WAC-222-16-080 [1]) requires and would otherwise have been developed in response to the listing. The Washington Department of Fish and Wildlife (WDFW) coordinated and approved DNR's Lynx Plan, along with plans from the two other major non-federal landowners within primary lynx range (Boise Cascade, Inc. and Stimson Lumber Co.).

The U.S. Fish & Wildlife Service (USFWS) listed Canada lynx as threatened under the Endangered Species Act in the 48 contiguous states, effective April 23, 2000 (USFWS 2000). The Washington Department of Fish and Wildlife (WDFW) developed a Lynx Recovery Plan for the State of Washington in 2001 (Stinson 2001).

In response to the federal listing, DNR worked with USFWS to modify the 1996 Lynx Plan to avoid the incidental take of lynx. In 2002 the USFWS sent DNR a letter of agreement acknowledging that the department's proposed modifications of the 1996 Lynx Plan are not likely to result in the incidental take of lynx (USFWS 2002). The letter is referred to in this document as the "take avoidance" letter.

DNR is committed to following the Lynx Plan until the lynx is de-listed, or until 2076 (80 years after the approval of the 1996 Lynx Plan), which ever is shorter. The plan will be updated as more is learned about lynx habitat relationships and management strategies, at least as frequently as every five years hereafter.

DNR's internal policies encourage consideration of lynx habitat on land managed by DNR. Specifically, Forest Resource Plan Policies 20, 22, and 23 (WDNR 1992) direct DNR to:

- Participate in efforts to recover and restore endangered and threatened species.
- Provide upland wildlife habitat.
- Establish Riparian Management Zones.

In accordance with the legal obligations specified in the Forest Resource Plan (WDNR 1992), DNR will contribute to the future of Washington's lynx population by improving habitat conditions and lessening probabilities for adverse effects on the habitat it manages.

1.2 Changes to the 1996 Lynx Plan

This 2006 revision of the 1996 Lynx Plan incorporates the take avoidance modifications as well as the new scientific information on Canada lynx and its major prey, the snowshoe hare (*Lepus amercanus*). It also incorporates the results from the implementation and effectiveness monitoring conducted after the 1996 Lynx Plan was adopted (Appendices 1 and 2) and the land transfers conducted since 1996.

The changes to the 1996 Lynx Plan are summarized below:

1) Extension of the area managed for lynx. The 2006 Lynx Plan covers approximately 125,980 acres, an increase of 945 acres, which accords with the revised lynx management zones (LMZ) and Lynx Analysis Units (LAU) identified by the Washington Department of Fish and Wildlife in the Lynx Recovery Plan (Stinson, 2001).

2) Seasonal timber harvest restrictions in all suitable denning habitat from May 1 – July 31.

3) No increases in designated or groomed over-the-snow routes or snowmobile play areas.

4) Delayed pre-commercial thinning until self-pruning processes have excluded most live lower limbs within 2 feet of the average snow pack level, unless the thinning activities are part of an experimental design approved by USFWS.

5) Conversion of no more than 15 percent of forested lynx habitat to a temporary non-lynx habitat condition within a 10-year period within any individual Lynx Analysis Unit (LAU). This applies to LAUs where DNR manages more than 20 percent of the LAU (Little Pend Oreille block and Loomis State Forest).

6) Within the Little Pend Oreille block (LPO) and Loomis State Forest, conversion of no more than 5 percent of forested lynx habitat within a LAU to a condition that meets the minimum requirements for travel habitat (180 trees/acre) in a 10-year period.

7) Lynx forage habitat is defined using the horizontal cover above the average snow level. A young timber stand qualifies as forage habitat when it has no more than four zero scores (no cover) measured in 40 readings (four readings taken at each of the 10 sampling points of a transect, within the 1.5-2.0 m range of a vegetation profile board viewed from 45 feet (15 m) from four cardinal directions). See page 19.

8) Implementation of the Lynx Plan in accordance with the existing DNR management plans for the Loomis State Forest. Much of the land that DNR manages within the range of the lynx is part of the Loomis State Forest (See Figure 2). Several Loomis-specific planning activities have occurred since the 1996 plan was first implemented.

   The Loomis Natural Resource Conservation Area (NRCA) was established in the Loomis State Forest in January 2000. The parcels transferred into conservation status (24,677 acres) are managed under the laws covering Natural Resource Conservation Areas (NRCA) and the Loomis NRCA Management Plan (WDNR 2003). The management goals of the NRCA management plan are to maintain the parcels in the most natural condition possible, to protect examples of native ecosystems, to protect habitat for listed species, and to comply with the ecosystem standards for state owned agricultural and grazing lands.

   The remaining 110,000 acres of the Loomis State Forest are managed under the Loomis State Forest Landscape Plan (WDNR 1996b). The Loomis Landscape Plan is being updated to reflect the changes in conservation status of part of the area and the results from the waterershed analyses conducted in the South Fork Toats Coulee and Sinlahekin Watershed Analysis Units (WAU).

1.3 Lynx Natural History

DESCRIPTION OF THE SPECIES

Canada lynx (hereafter referred to as lynx) are medium-sized cats, smaller than cougars, but slightly larger than bobcats. Mature individuals weigh 15-30 pounds (6.8-13.6 kg), and their average length is 33.5 inches (85 cm) for males and 32 inches (82 cm) for females. Lynx are characterized by a short and black-tipped tail, tufted ears, facial ruff, elongated hind legs, and large paws. These large paws enable lynx to travel through boreal forests in search of their favored prey—the snowshoe hare—in habitats often avoided by other predators, whose movements are more inhibited by deep snow. For example, in the southern edge of the lynx geographic range, bobcats, cougars, and coyotes spend the winter on south-southwest aspects, approximately 300-400 m (984-1312 feet) lower than lynx (Koehler 1990a, Koehler and Hornocker 1991).

FORAGING

Lynx are perhaps best known for their unique association with a single prey item—the snowshoe hare. Ecologists have focused on this predator-prey relationship since it was popularized in the 1940's (e.g., Elton and Nicholson 1942), developing a large quantity of literature and inspiring many theories (Keith 1963; Keith et al. 1984; Krebs et al. 1991, 1995; Sinclair et al. 1993). Nearly all the lynx literature concludes that hares rank as the main prey of lynx in all seasons, although data from snow-free seasons are relatively rare. Hares are found in lynx scats with frequencies of 35 percent (during a low in hare abundance Brand and Keith 1979) to 100 percent (Kesterson 1988). Volumes in stomach and intestine samples range from 41 percent (Saunders 1963a) to 100 percent (Brand et al. 1976). The study by Von Kienast (2003) conducted on the Okanogan Plateau (Washington) recorded snowshoe hare in 85-90 percent of lynx scats. Also, the loss of body fat by lynx during periods of low hare density indicates that they might not be able to consume enough alternative prey (e.g., grouse, squirrels, and carrion) to meet their energy requirements (Brand and Keith 1979).

Despite the strong association of lynx with snowshoe hare, there is also clear evidence that lynx take advantage of other prey opportunities, especially when hares are at low densities and during the summer. The alternative prey includes red squirrels, mice, voles, ground squirrels, grouse, and ptarmigan (Tumilson 1987, Hatler 1988, Butts 1992, Koehler and Aubry 1994, Ruggiero et al. 2000, Stinson 2001). High frequencies of red squirrels in lynx diets have been reported from Washington (Koehler 1990a, Von Kienast 2003), Yukon (O'Donoghue et al. 1998), and Alaska (Staples 1995). Lynx consumption of caribou, Dall sheep, and red foxes was reviewed by Stephenson et al. (1991). One of the most famous examples of lynx as predators on non-hare prey is from Newfoundland, where lynx had a dramatic and publicized effect on caribou herds (Bergerud 1971, 1983). Examples of seasonal opportunism include a more diverse diet in summer, when a greater variety of prey is available (Saunders 1963a, van Zyll de Jong 1966, Brand et al. 1976, Parker et al. 1983, Staples 1995).

Nonetheless, the density of lynx populations oscillates only in relation to the density of snowshoe hare, and this is demonstrated by changes in reproduction and survival patterns, especially in the reproductive success of yearlings and survival of kittens (see Koehler and Aubry 1994 for a review; Mowat 1993, O'Connor 1984). Lynx reproductive success and survival shows the strongest correlation with winter/early spring snowshoe hare abundance (e.g. Nellis et al. 1972, Brand and Keith 1979, Parker et al. 1983, O'Connor 1984, Mowat 1993, Poole 1994). Winter is likely the constraining season in hare populations (Walski and Mautz 1977, Krebs et al. 1986, Krebs et al. 1991) due to the high metabolic requirements to maintain a constant, warm body temperature during extreme cold temperatures, combined with a relative lack of browse. Periods of unusually cold weather have been correlated with increased mortality rates in both hare (Meslow and Keith 1971, Pease et al. 1979) and lynx (Poole 1994).

Because of the documented strong dependence of lynx on a single prey item (snowshoe hare), the USFWS concluded that, "the key to the presence of lynx populations is adequate snowshoe hare populations" (USFWS 2003).

DISTRIBUTION

The range of the Canada lynx encompasses the Canadian and Hudsonian life zones (Ingles 1965) of boreal North America (Figure 1). Nearly all of this area lies within Canada and Alaska, with only about 6 percent of the total species range in the contiguous United States. Lynx range in Washington State represents approximately 0.5 percent of the total area occupied by lynx. However, Washington may support a significant proportion of the resident populations of lynx in the contiguous United States (Brittell et al. 1989). Of the 14 states where lynx formerly resided, breeding lynx have recently been detected in Washington (Brittell et al. 1989, Koehler 1990a), Montana (Brainerd 1985, Giddings 1994), Maine (Vashon et al. 2003), Wyoming (Squires and Laurion 2000), and Minnesota (Star Tribune 3/7/2003). Introduced lynx are now breeding in Colorado as well (Colorado Division of Wildlife website 2005).

Historical evidence suggests that in Washington, lynx were found primarily in high-elevation forests of north-central and northeast Washington, including Okanogan, Chelan, Ferry, Stevens and Pend Oreille counties (Stinson 2001). Although 82 percent of 72 museum records of lynx are from these five counties, lynx presence was also recorded in the Blue Mountains of southeastern Washington and the southern Cascades (Dalquest 1948, Stinson 2001).

Currently, primary lynx habitat identified in the Lynx Recovery Plan for Washington State (Stinson, 2001) includes six Lynx Management Zones (LMZ) (Figure 2). They are characterized by high elevation, coniferous forests, and accumulation of deep snow. The LMZs do not encompass all areas potentially used by lynx, but habitat management in these zones is expected to hold the greatest promise for supporting lynx populations. Recent survey efforts (1995-2001) indicated that lynx remain in four LMZs (Okanogan, Kettle Range, Little Pend Oreille, and Salmo Priest) and are breeding in the Okanogan LMZ (Stinson 2001).

DNR manages 4 percent of the primary lynx habitat in Washington, approximately 126,212 out of 3,198,238 acres of designated lynx habitat in Washington. DNR manages some land in each of the six LMZs (Figure 2). Most of the lynx habitat managed by DNR (77 percent, approximately 97,124 acres) is within the Okanogan LMZ. This comprises 20-30 percent of the area occupied by lynx during the mid-1980's lynx studies in north-central Washington (Brittell et al. 1989, Koehler 1990a).

Figure 1. Distribution of the Canada Lynx (*Lynx canadensis*)

Modified from Quinn and Parker 1987

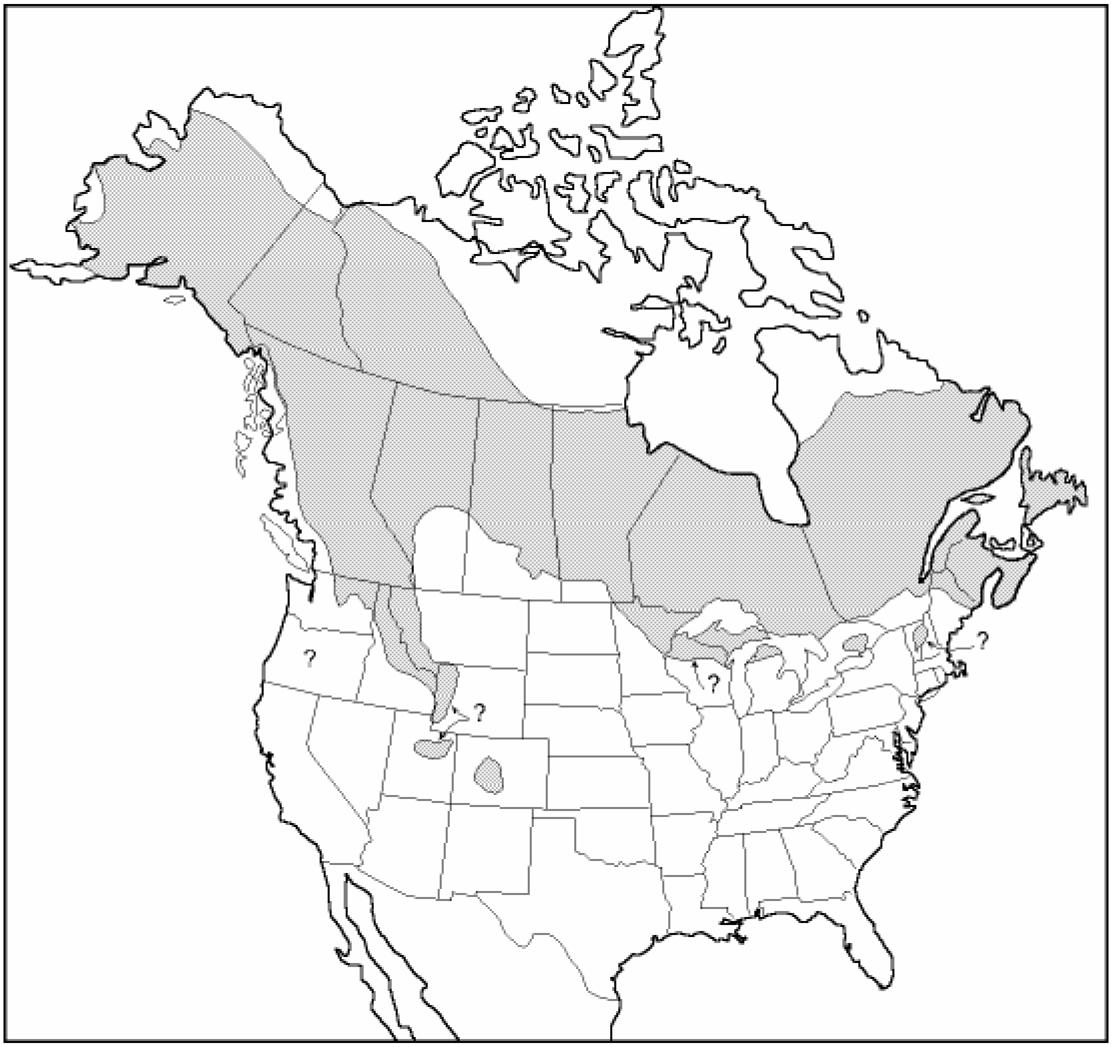
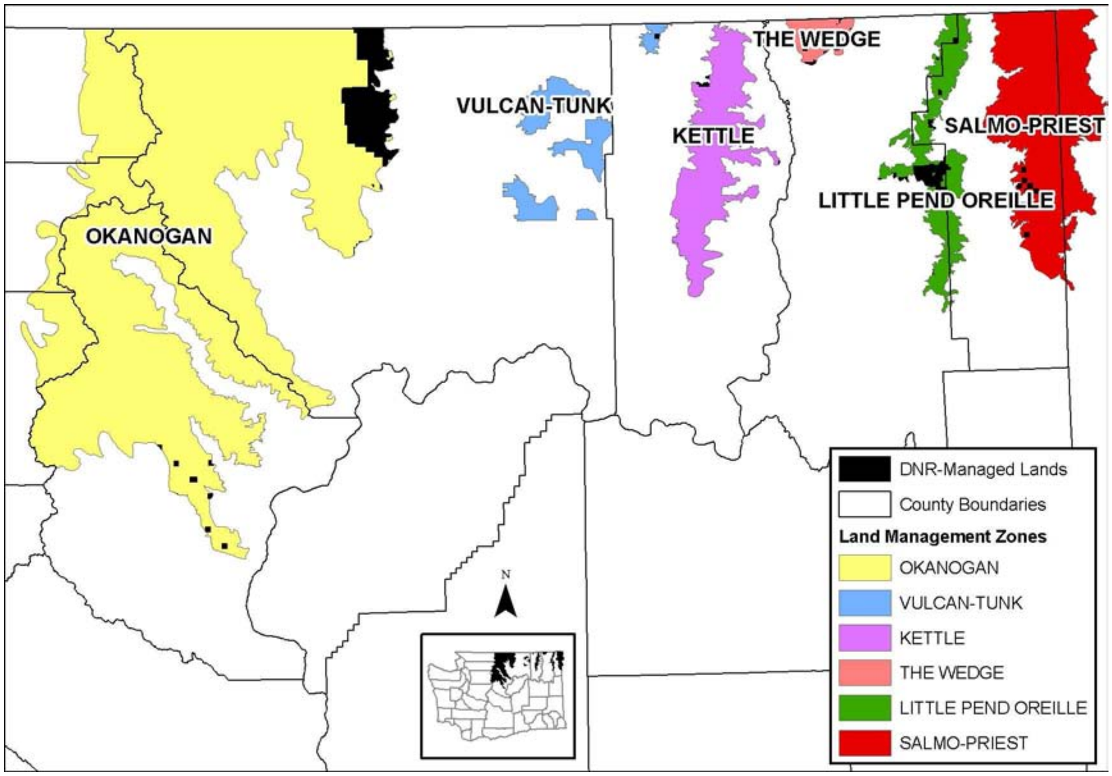


Figure 2. Lynx Management Zones in Washington

Modified from Stinson 2001



HABITAT RELATIONSHIPS

One of the least studied aspects of lynx ecology is lynx habitat relationships. Most lynx research has addressed population dynamics in relation to fluctuating prey availability rather than habitat associations.

Lynx avoid open and sparsely forested areas. The disassociation between lynx and open areas (meadows, frozen lakes, rivers, etc.) is a well-recognized and reported relationship (Koehler et al. 1979, Parker et al. 1983, Murray et al. 1994, Poole 1994, Von Kienast 2003).[1] When the Washington Department of Wildlife (WDW) (1993) calculated lynx densities for Washington State, they extrapolated from the average lynx density within the Okanogan study area (Brittell et al. 1989, Koehler 1990a), and from this estimated the acres of suitable habitat within the state, excluding generally avoided habitat types.

Lynx occur in a wide variety of forest types. The most undisputed habitat association is between lynx and mid-successional forests; —those resembling a 20-40-year-old forest that has regenerated after a low-to-moderate intensity burn (e.g. Thompson et al. 1989). The forests are characterized by high vertical and horizontal vegetative cover as the result of high stem densities, with average tree heights of 7-20 feet (2-6 m) and crown closure of 75-80 percent (e.g. Parker 1981). The scientific literature is nearly unanimous in supporting this relationship, offering examples of lynx establishing nearly their entire home ranges within such habitat, regardless of latitude or season:

- An area actively used by two lynx in Newfoundland almost exactly coincided with the boundary of a 10-20-year-old forest (Saunders 1961).
- 90 percent (n=29) of the relocations of two lynx were within densely stocked stands in Montana (Koehler et al. 1979).
- 87 percent (n=391) of the relocations of 11 lynx were in a 31-year-old burn on the Kenai Peninsula in Alaska (Kesterson 1988).
- Lynx were relocated in regenerating lodgepole pine more than expected ($p<0.001$) in the Yukon (Major 1989).
- Lynx tracks were most abundant in sites logged 20-30 years previous to a study in Ontario (Thompson et al. 1989).
- 98 percent (n=240) of lynx tracks observed on snow tracking surveys in central interior Alaska were located in a 25-year-old burn (Johnson et al. 1995).

1. "Avoidance" used here implies *general* avoidance. Lynx sometimes do cross open areas (most often <328 feet (100m) wide; Koehler and Brittell 1990; B. Slough, Yukon Dep. Renewable Resour., pers. commun.; Staples 1995) or sun themselves in them (Parker 1981), but most of the time they avoid them (e.g. Halfpenny and Biesiot 1986). For example, lynx crossed a 0. 6-mile (1 km) wide lake in the Yukon, but most often walked around it (G. Mowat, Timberland Consultants Ltd., pers. commun.). In Alaska, 0.8 percent of lynx tracks crossed open habitats despite these habitats covering 20 percent of the study area (Staples 1995). In Northwest Territories, lynx crossed frozen lakes, meadows and rivers (Poole et al. 1996, Poole 1997).

- In Northwest Territories (Poole et al. 1996), lynx were most often relocated in dense coniferous forest (20-60-year old burns) and dense deciduous forests.

Some of the highest lynx densities recorded (50 lynx/100 km^2 and 2 lynx/3mi^2) occurred in approximately 30-year-old burn in the Yukon (Breitenmoser and Haller 1993, Slough and Mowat 1996). In Riding Mountain National Park, Manitoba, 96 percent of lynx tracks occurred where there were hare tracks, and the optimum hare habitat was nearly 30-year-old regenerating jackpine forest (Nylen-Nemetchek 1999). The primary reason for the tight association between lynx and mid-successional forests is that this habitat contains the highest densities of snowshoe hare, the staple prey of lynx.

Lynx are also associated with mature forests,[2] but this relationship is not as clearly defined as the one between lynx and mid-successional forests. Sometimes mature forests are used in proportion to their availability (Parker et al. 1983, Brittell et al. 1989, Murray et al. 1994, Von Kienast 2003), sometimes they are preferred (Parker 1981, Major 1989, Koehler 1990a, Staples 1995), and sometimes they are avoided (Parker 1981, Kesterson 1988, Thompson et al. 1989, Staples 1995). When significant use of mature forests by lynx is detected, a commonly cited reason is for denning. However, structure (log piles, rocks, root tangles, shrub thickets) or similarly dense vegetation (e.g. subalpine fir; Slough 1999) rather than forest maturity is the common denominator of known denning areas.

1.4 Conservation Issues

Lynx fur harvest, snowshoe hare and lynx population dynamics, and habitat conservation increasingly became matters of concern in the late 1960's as fur harvests and decreases in sightings were reported, and human populations expanded into remote lynx country.

FUR HARVEST

Humans have been the historical, proximate influence on lynx density throughout most of the lynx's range (Parker et al. 1983, Ward and Krebs 1985; see Koehler and Aubry 1994 for review). Although untrapped lynx populations may undergo dramatic losses from natural mortality following low abundance of hare populations, these changes are compensatory. Evidence suggests that low lynx densities after heavy harvests cannot be compensated even after a period of high snowshoe hare densities: on the Kenai National Wildlife Refuge, the lynx fur harvest of 1973-1974 was 40 times greater than the harvest of 1966-1967 (Bailey 1981); in Washington, three times as many individuals were trapped in the 1970s (146 animals, from 1969-1978) as in the 1960s (44 animals, from 1960-1969). Many locations reported lower fur harvests in the 1980's compared with the 1970's: Alberta (Todd 1985), Washington (Brittell et al. 1989 and Koehler 1990a), Montana (Hash 1990, Roy 1990), Alaska (Stephenson 1986), Manitoba (McKay 1985), and British Columbia (Hatler 1988). All of the authors referenced above suspected that the declines were at least partially due to over-trapping in the 1970's, when pelt prices were relatively high. The Lynx Management Guidelines of British Columbia (B.C. Ministry of Environment 1990) describe a double peak in 1972-73 and 1973-74—more

2. "Mature forests" in this context refer to forests older than mid-successional forests, a general definition to account for the many ways the term has been presented in the lynx literature.

than 8,500 pelts were sold each year. Sighting records similarly indicated a decline in lynx abundance from 1983 to 1993 (WDW 1993), and lynx presence was confirmed in only 44 of 121 Lynx Analysis Units in Washington surveys between 1995 and 2001 (Stinson 2001).

Since 2000, with the federal protection of lynx in the contiguous United States, direct harvest of lynx is no longer a major threat. However, incidental hunting and trapping mortalities probably still occur (Stinson 2001).

METAPOPULATION[3] DYNAMICS

Many authors recognize Washington and other northern US states as sink areas (areas in which local mortality rates exceed local reproductive rates, and the populations would go extinct without immigration from source areas) for lynx emigrating from Canada during lynx population highs or when snowshoe hare abundance declines (Banfield 1974, Mech 1980, Koehler and Aubry 1994). Lynx metapopulation dynamics have been discussed at length in Ruggiero et al. (2000), Stinson (2001), and McKelvey et al. (2000). Future studies on lynx breeding in northern states, and on large scale habitat-change influencing lynx densities in Canada, may find that the northern states are at some times important sources of lynx for Canada. For example, Brittell et al. (1989) documented northerly movements of Washington lynx into British Columbia.

Lynx are capable of traveling extremely long distances (up to 1,100 km, Mowat et al. 2000). These travels are reflected in the genetic similarity of geographically dispersed populations (Schwartz et al. 2002, Rueness et al. 2003). However, given that the Rocky Mountains appeared to be a barrier to gene flow within Canada (Rueness et al. 2003), potential contributions from Washington and other southern lynx habitats to Canadian populations may be important to the species' survival. Also, the significance of northern US boreal forests is increased by the fact that they are at the geographic fringes of lynx range and thus likely places for rapid environmental adaptations and a unique setting for research on lynx ecology. Ecological, social, and physiological adaptations and habitat preferences may become more apparent as the contrast between preferred versus available habitat increases in southern latitudes.

HABITAT MANAGEMENT

As once-remote lynx habitat becomes developed, mined, and logged, the need to clarify lynx habitat associations and the effects of land management activities on lynx persistence and density has become imperative. The status of lynx may only be effectively ascertained and recovery strategies successful after these relationships are clarified. USFWS (2000) and the Lynx Recovery Plan for Washington State (Stinson 2001) list timber harvest, fire history and fire suppression, forest roads and recreation, grazing and grass seeding, forest insect epidemics, and highway barriers as factors that may affect the continued existence of lynx. Habitat changes associated with global warming may further influence lynx conservation in Washington State.

3. Metapopulation is defined as a set of spatially separated local subpopulations that are connected by dispersing individuals.

2. Lynx Habitat Classification

In order to plan and manage effectively for lynx habitat through time, DNR has defined and classified lynx habitat based on the available scientific literature (Chapter 3 in the 1996 Lynx Plan (WDNR 1996a)). Emphasis was put on the needs of lynx in Washington State through adoption of the habitat classification system from the Washington Department of Wildlife report on Lynx status (WDW 1993).

There is still much to learn about lynx habitat relationships, and not all observations of lynx habitat occupancy will precisely fit this (or any) particular classification system. However, the system provides a foundation that can be adjusted as knowledge of lynx habitat relationships expands, and the categories can be easily monitored. Five categories are defined in this plan:

1. Open Areas
2. Temporary Non-lynx Areas
3. Forage Habitat
4. Denning Habitat
5. Travel Habitat

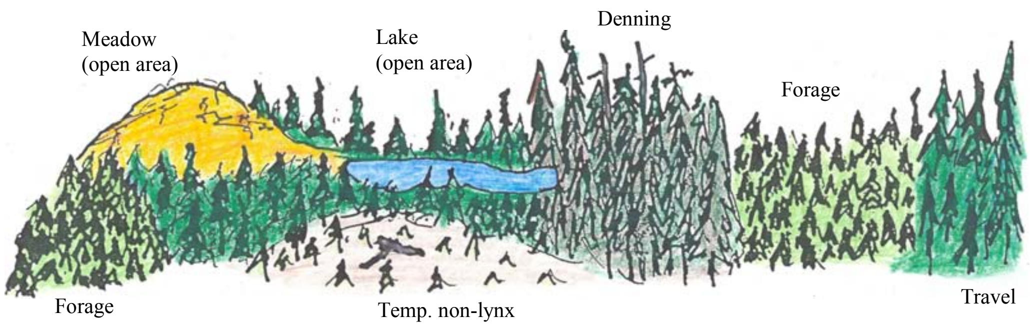
This classification system separates those areas within a landscape that are potentially usable by lynx (called "the lynx habitat matrix") from those that are generally avoided (called "open areas"). The lynx habitat matrix is further divided into four categories by type of use. (See Table 2.1 and Figure 3). Within the matrix, currently forested habitats (Forage, Travel, and Denning Habitat) are separated from areas which have the potential to become lynx habitat in the future (Temporary Non-lynx Areas). Additional lynx habitat components—travel routes, travel corridors, and den sites—are also recognized.

Table 2.1
Lynx habitat classification system

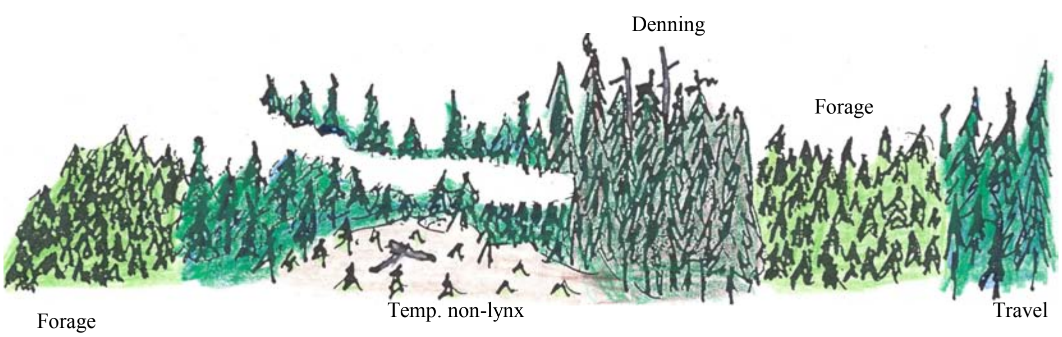
LANDSCAPE LEVEL MATRIX	COMPONENT	DESCRIPTION
Open Areas	**Open Areas**	Areas generally and permanently avoided by lynx: "permanent" or "natural" openings (e.g. meadows, lakes) not capable of meeting the requirements of lynx habitat.
Lynx Habitat Matrix		All habitats potentially used by lynx, either currently or in the future: areas capable of maintaining ≥180 tpa (445 trees/ha) or ≥40% horizontal cover within 3.3 ft (1m) above average snow level (e.g. 4-8 ft from ground).
	Temporary Non-Lynx Areas	Areas temporarily avoided by lynx. Such areas are in the process of becoming Forage or Travel Habitat: recently harvested, burned or other early successional sites, not yet attaining Forage or Travel Habitat status.
	Forage Habitat	Habitat where lynx consistently find high densities of snowshoe hare, especially in winter: stands with high horizontal cover provided by small diameter stems and branches, available above average snow level (<4 zero scores per 40 readings between 1.5 and 2.0 m above ground).
	Denning Habitat	Habitat where lynx prefer to den; in order of preference: stands with known den sites, late seral stands of spruce/subalpine fir or similar mesic plant association with denning structure on northerly aspects, late seral stands with denning structure on mesic plant associations with other aspects, or late seral stands with denning structure on other plant associations.
	Denning Sites	The specific structure that lynx use as dens: deadfall (including upturned root wads) with large-end diameters of 6"(15 cm) or greater, layered such that there is an average of >0.8 logs/yard (1 log/m) over a 150 foot (50 m) transect that are 1-4 feet (0.3–1.2 m) off the ground. Woody debris should cover the majority (75%) of a 5-acre (2 ha) patch.
	Travel Habitat	Forested habitat not otherwise classified as Forage Habitat or Denning Habitat, with ≥180 tpa (445 trees/ha) or ≥40% horizontal cover within 3.3 ft (1m) of average snow level
	Travel Routes	Linear landscape-level features that lynx often follow, such as major ridges, saddles, or riparian areas along rivers and streams.
	Travel Corridors	A special management zone at least 330 ft (100 m) wide along Travel Routes, connecting Forage, Denning, or Travel Habitats.

Figure 3. Lynx Habitat Categories

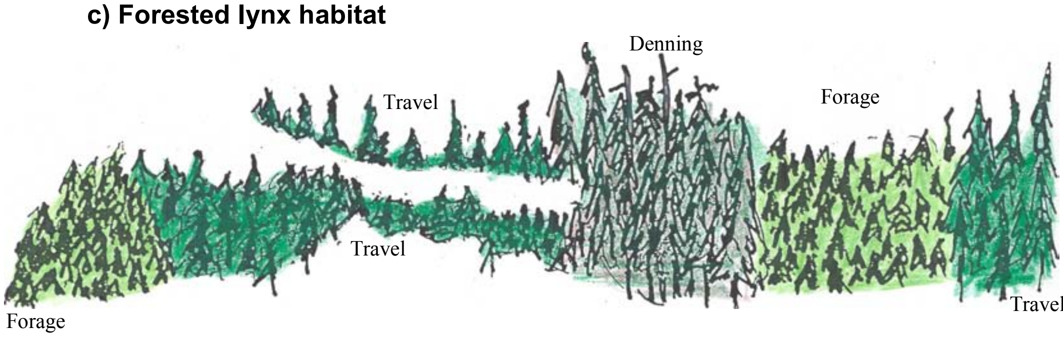
a) Partial landscape



b) Lynx habitat matrix within the Landscape: without permanently open (avoided) areas



c) Forested lynx habitat



2.1 Open Areas

The Open Areas category is assigned to those areas within a landscape that lynx generally avoid. Open Areas can be characterized as non- or sparsely forested areas, including talus slopes, exposed rock surfaces, grassy meadows, low shrub fields, and other "permanent" openings that have little potential to provide thermal cover, favored prey, or security cover for lynx (Brittell et al. 1989, Koehler 1990a, Staples 1995).

In this plan, "Open Areas" refers to all sites that *cannot* maintain:

- At least 180 trees/acre (tpa) (445 trees/ha) where tree height reaches at least 3.3 feet (1m) above snow level., or
- Horizontal cover of 40 percent or more within 3.3 ft (1m) above average snow level.

2.2 Lynx Habitat Matrix

The lynx habitat matrix of a landscape includes all lands that are capable of supporting "forested" conditions—that is, stands that meet at least the minimum habitat standards for lynx. According to Koehler and Brittell (1990), the minimum habitat condition for lynx includes forest stands that contain at least 180 trees/acre (445 trees/ha) and that are at least 6 feet (2 m) tall where snows reach average depths of 2-3 feet (0.5-1 m), so as to provide enough cover to hide and shelter lynx in winter. This estimate was derived from Koehler (1990a), who observed that lynx crossed stands thinned to 170-260 trees/acre (420-640 trees/ha). These trees had diameters at breast height (dbh) of 5-9 inches (12-23 cm) and no understory cover was present. Alternatively, stands with fewer but larger trees that provide at least 70 percent canopy closure may provide "forested" conditions (in this case travel habitat) when "vertical structure" exists 4-8 feet (1.3-2.3 m) above ground (Lloyd 1999).

TEMPORARY NON-LYNX AREAS

Temporary Non-lynx Areas arise from wildland fire, regeneration harvests, or partially harvested stands and are <180 trees/acre and <8 feet tall (<445 trees/ha and <2.5 m tall). Forest roads and the associated right-of-ways count towards Temporary Non-Lynx Areas. Temporary Non-Lynx Areas have the potential to grow into forested lynx habitat (see following section). It is the potential to become habitat that distinguishes the lands in this category from those in the Open Areas category. Therefore, Temporary Non-Lynx Areas are included as lynx habitat, whereas Open Areas are not.

Although lynx may avoid Temporary Non-lynx Areas as they do Open Areas, a complete description of lynx habitat must include Temporary Non-lynx Areas in enough quantity to maintain habitat for snowshoe hare. Because forests are constantly growing out of the reach of hare, forest managers may risk short-term displacement of lynx and hare that remain in mature forests, in order to renew succession and ensure the continued presence of hare in sufficient quantities to support successful reproduction in lynx.

FORESTED HABITAT

Forested Habitat includes those stands that currently have at least 180 trees/acre, ≥8 feet tall (445 trees/ha and 2.5 m tall) or if they have less trees per acre, they have ≥40 percent horizontal cover within 3.3 feet (1 m) above average snow level. Within the portion of the lynx landscape that is currently forested (Figure 3, part c), lynx require at least two elements: 1) areas to hunt and sustain prey (forage), and 2) areas to den.

Forage Habitat

Forage Habitat includes stands that have structure near the ground and above the snow level that is capable of supporting snowshoe hares. Such stands may have various histories and classifications according to traditional forest practices. Forage Habitat may originate from wildland fire, regeneration harvests, thinning of mid-successional stands, or partial harvests of mature stands. Forage habitat also includes tall shrubby vegetation along wetlands or other riparian areas.

One of the main objectives of the effectiveness monitoring of the lynx plan that DNR conducted between 1997 and 2004 was to develop a better definition of Forage Habitat. The process and results of this effort are described in the effectiveness monitoring report presented in Appendix 2. The new definition of Forage Habitat is based on horizontal cover continuity using horizontal cover scores. Horizontal cover was estimated using a cover board viewed from a distance of 45 feet (15 m) at 5 to 7 feet (1.5 to 2 m) above ground level. Four horizontal cover readings were taken at each point along a transect comprised of 10 sample points. Scores were measured on an ordinal scale ranging from 0 (no cover) to 5, representing 20 percent cover by each numerical category. Scores of zero reflect the patchiness of available cover (horizontal cover continuity). Lynx Forage Habitat included those stands (20 acres or more) where less than 4 zero scores (views with no cover) are counted per 10 transect points measured (i.e. per 40 readings). The advantages of this definition over the 1996 Lynx Plan definition of forage habitat are several: First, the scores are highly related to hare pellet densities; second, the field technique is easy to implement and gives high consistency between the observations; and third, some mature forests are included in the forage category.

Although Forage Habitat is presented in this plan as a separate habitat category, to truly manage for lynx, managers should manage for hare in all forested habitat. A relatively high density of snowshoe hare is needed on a landscape to accommodate the needs of lynx. Ruggiero et al. (2000) report that a minimum of 0.5 hares/ha are necessary to sustain lynx in northwestern Canada. Habitats other than young stands, such as mature forests and shrublands, should have some foraging role. This can be achieved by developing additional foraging opportunities for lynx in travel and denning habitats as well.

To encourage lynx persistence, prey must not only be abundant, but also vulnerable to predation. A number of factors may affect this vulnerability, including forest patch shape, size, and dispersion, as well as stand structure. Research suggests that snowshoe hare generally occupy denser habitat than lynx (O'Donoghue et al. 1998). Even if snowshoe hare are less vulnerable to lynx in some types of Forage Habitat (e.g. dense regeneration), it is assumed that hare will be vulnerable to predation in most habitats available to lynx in managed landscapes because:

1) Most stands provide prime snowshoe hare habitat during a relatively small portion of a rotation (roughly 20 years out of 80).

2) Not all Temporary Non-lynx Areas will grow dense enough to produce high quality snowshoe hare habitat.

3) Managed stands are likely to be less dense than unmanaged stands.[4]

Denning Habitat and Den Sites

This plan recognizes Denning Habitat as stands that might support lynx dens such as those reported from north-central Washington (Koehler 1990a). However, only four dens by two females have been located in Washington (Koehler 1990a), and it is difficult to draw conclusions on such limited information. These were on north/northeast slopes, in mature subalpine fir/Engelmann spruce stands, under jack-strawed coarse woody debris.

In order of preference, Denning Habitat in this plan includes:

- Stands with known den sites, and late-seral stands of spruce/fir or similar mesic (medium moisture) associations with denning structure on northerly aspects.
- Late-seral stands with denning structure on mesic associations with other aspects.
- Late-seral stands with denning structure on other associations.

Structure, in the form of debris piles or root tangles, is the common denominator in known den sites when data from other geographic locations are compiled (see review in WDNR 1996a, Table 5, Slough 1999). Mowat et al. (2000) also found that lynx did not appear to be constrained by specific stand types, but consistently selected areas with microsite structure, most commonly windthrown trees. For this reason, Den Sites are recognized in this plan. Den Sites are structures capable of being used by lynx as places to den. Denning structure includes deadfall with large-end diameters of 6 inches (15cm) or greater, layered such that there is an average of >0.8 logs/3 feet (>1 log per meter) over a 150-foot (50 m) transect,1-4 feet (0.3-1.2 m) off the ground. Deadfall includes upturned root wads.

Travel Habitat

All other forested habitats that do not fall into the specific categories of Denning Habitat or Forage Habitat are referred to in this plan as Travel Habitat. Travel Habitat supports at least 180 trees/acre (445 trees/ha) that are at least 3.3 feet (1 m) above snow level, or have at least 40 percent horizontal cover within 3.3 feet (1 m) above average snow level (e.g., between 4 and 8 feet above ground). This habitat category may be important for providing lynx with access to alternative prey, low densities of snowshoe hare, cover during inclement weather, cover from predators, and for connecting Denning and Forage habitat.

4. Mowat and Slough (2003) likewise concluded that regenerating managed stands will rarely support lynx densities equal to those occurring in naturally regenerated burns.

Travel Routes

Given the presence of Temporary Non-lynx Areas and Open Areas within landscapes used by lynx, there is need for an additional habitat component. This component is not a separate habitat category. Rather, it is a linear feature to indicate potential routes of travel taken by lynx through landscapes that may be composed of any Forested Habitat category (Forage, Denning, Travel). These "travel routes" (after Koehler and Brittell 1990) follow the topographic features that already exist in the landscape, such as major ridges, saddles, rivers, and streams. Stable travel routes provide connectivity within the lynx habitat matrix and between habitat elements, facilitating the dispersal of kittens and movements of adults. For these reasons, travel routes are important habitat components at all scales of lynx habitat use.

Travel Corridors

A special management zone called a Travel Corridor straddles the travel route so that a >330 feet (100 m) wide corridor is available to lynx at all times. On average, the forested zone along a travel route will likely be much wider.

3. Planning Approach

DNR's approach to the guidelines in this Lynx Management Plan incorporates three key elements:

- **Assumptions –** A basis for developing guidelines in the absence of adequate or definitive scientific information on lynx ecology.
- **Different spatial scales** – A structure to capture and integrate the landscape with stand level features of lynx habitat.
- **Desired future landscape conditions** – A description of the intended on-the-ground results.

3.1 Assumptions

The urgency of conservation efforts for threatened and endangered species often forces biologists and land managers to make decisions without statistically rigorous data to guide them. In some cases, an educated guess becomes an accepted policy before it is tested. This may not only prevent important relationships from being recognized in the data collected, but it may also be difficult to change the policy once it has already been incorporated into management plans. With most endangered species, there is little time for misdirection. For these reasons, management plans should take an experimental approach with careful planned actions centered on hypotheses that can be modified, tested, and refined (Walters 1986, Murphy and Noon 1992). Biologists, aware of the uncertainties involved, are responsible for reminding interested parties of the hypothetical nature of their endeavors and should clearly identify their assumptions.

Because information on lynx habitat relationships, forage ecology, and population demography in the southern boreal forests is limited, the strategies within this document are extensions of current hypotheses in lynx ecology. The information on lynx ecology used to develop the management guidelines in this plan is provided below each guideline. The intention is to help biologists and land managers to adapt more easily in the future to scenarios overlooked by the plan, and revise strategies as more is learned about the habitat associations and status of lynx.

The general considerations for the conservation of lynx that have been adopted for this plan were based on the conservation strategy developed for the northern spotted owl by Thomas et al. (1990), and presented by Weaver (1993). It is presumed that a plan based on these assumptions will contribute to the continued persistence of lynx in Washington.

A. Species that are well-distributed across their historic range are more persistent than species confined to small portions of their range.

B. Population persistence increases with the number and size of sub-populations and the size of habitat blocks.

C. Blocks of contiguous habitat in close proximity promote a higher probability of persistence than dispersed blocks of fragmented habitat.

D. Population persistence increases when blocks of habitat are interconnected through linkages of suitable habitat.

E. The persistence of exploited populations increases with a well-distributed network of refuges or safety nets.

3.2 Planning Scales

DNR's lynx conservation strategy has a multi-leveled structure that reflects the complexity of managing habitat for large terrestrial carnivores. An individual lynx has an extensive home range, makes extensive movements, and requires a mosaic of different habitats to meet its needs. Persistence of viable lynx populations requires an adequate amount and connectivity between the habitat types over large landscapes. Hence, lynx habitat planning requires land managers to use a multi-scaled approach in order to facilitate the ecological attributes of lynx habitat in Washington, and meet the biological needs of the individual animal as well as the species in general. Managers have to consider not only the habitat within their jurisdiction, but also the larger context in which their land is situated. For DNR, this approach includes coordination of lynx habitat management efforts with other state and federal agencies and British Columbia.

DNR's lynx habitat management strategy applies four nested spatial scales. In order from large to small, they are:

- Ecoprovinces/Ecodivisions
- Lynx Management Zones
- Lynx Analysis Units
- Ecological Communities

An example of a relatively small spatial scale is the lynx home ranges, as small as 3.8 square miles (9.9 km^2), recorded in an untrapped area in the Yukon (Slough and Mowat 1996). In the same area, 17 lynx traveled >62.2 miles (100 km), with 11 recorded at distances of 311-684 miles (500-1,100 km) from their original collaring locations, reflecting an immense scale of potential habitat use. Figure 4 and Table 3.1 show the hierarchy and relationship of the planning scales. Each scale is described in more detail with its associated guidelines in Chapter 4.

Figure 4. Relationship of lynx habitat planning scales

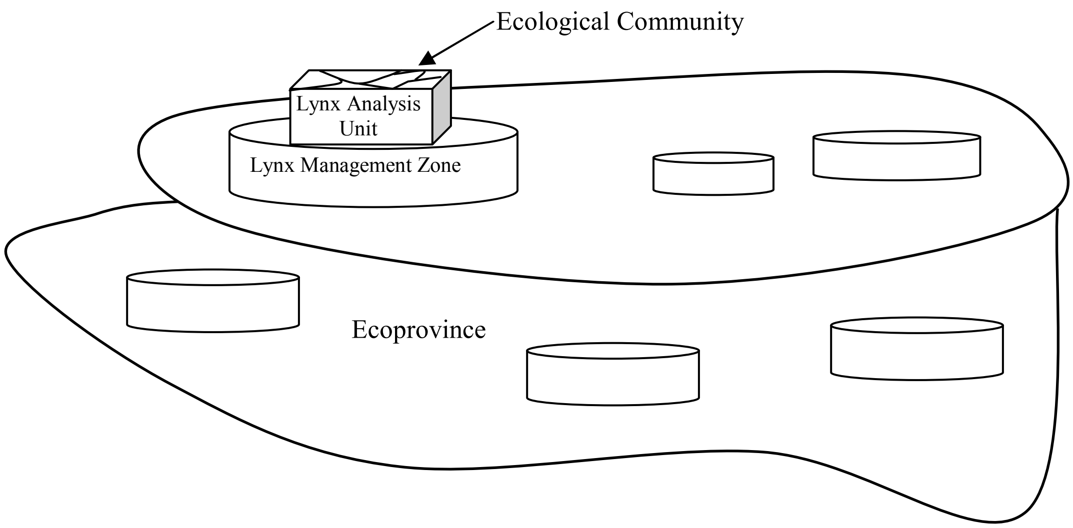


Table 3.1
Hierarchy of spatial scales in DNR's Lynx Habitat Management Plan

	S C A L E			
	Ecoprovince and Ecodivision	**Lynx Management Zone (LMZ)**	**Lynx Analysis Unit (LAU)**	**Ecological Community**
Source	Demarchi 1992 Demarchi and USFS 1994	WDW 1993 Stinson 2001	WDFW GIS data (2001)	DNR's Forest Resource Inventory (FRIS)
Size		6.6-2,885 mi^2 (10.6 – 4,642 km^2)	6 -130 mi^2 (9.7 –209.2 km^2)	20 - 400 acres (8 – 162 ha)
Description	Defined by macro-climatic processes and habitat types	Estimated from sightings, trapping records, habitat types, and elevation	Delineated by Watershed Administrative Unit (WAU) and ownership boundaries	Individual stands of similar vegetation, age, and structure

Management ratios and guidelines in this plan focus on the Lynx Analysis Unit (LAU) level, with the small-scaled goal of maintaining the integrity of habitat regularly used by individual lynx or family groups. With an average size of 43 square miles (Stinson 2001) LAUs are generally large enough to encompass the median home ranges reported for lynx in north-central Washington (Table 3.2). However, the LAU is simply a spatial unit chosen by DNR to monitor habitat and lynx presence on the landscape through time. Lynx will undoubtedly shift their habitat use as forests change, without regard to LAU boundaries. The LAUs are encompassed in two higher spatial scales (Ecodivision/Ecoprovince and Lynx Management Zones) to incorporate habitat connectivity from a broader perspective.

Table 3.2
Relative sizes of LAUs and lynx home ranges in Washington

	Sample Size	Median	Range
Lynx Analysis Unit	29 (containing DNR-managed land)	31.6 mi^2 (82 km^2)	6.6 - 79.7 mi^2 (17 - 206 km^2)
Female Home Range*	9	14 mi^2 (36 km^2)	3.2 - 33.9 mi^2 (8.3 - 87.8 km^2)
Male Home Range*	13	21 mi^2 (54 km^2)	9.6 - 38.2 mi^2 (14.2-99.0 km^2)

*minimum convex polygon method (Brittell et al. 1989, Koehler 1990a)

3.3 Desired Future Landscape Condition

The following description represents the desired future condition for DNR-managed lands within lynx range (Figure 2). This vision is the expected outcome of the plan's quantitative habitat ratios and guidelines:

- A balance of stands in different structural stages minimizes the probability of long-term adverse effects to lynx, realistically reflects the land's potential as lynx habitat, integrates other forest resource concerns, and reflects the current understanding of lynx habitat requirements:

  1) Forage habitat is interspersed throughout the landscape and connected to other forage habitat via other forested stands.

  2) Denning areas are adjacent to, within, or near forage habitat, connected by other forested stands,

  3) Human-related disturbance is managed at acceptable levels,

  4) Forested connections to adjacent lynx habitat, including habitat in British Columbia, are maintained.

- Harvest unit plans that result in temporary non-lynx habitat will avoid the probability of extirpating lynx by:

  1) Dispersing harvest units in relation to existing lynx habitat elements.

  2) Ensuring adequate regeneration within harvest units.

MODELING

By modeling the results of proposed guidelines, DNR can test how likely the guidelines are to create the desired future landscape conditions. Given the time it takes for stands to grow into lynx habitat, long-term planning is key to ensuring an appropriate mosaic of habitats through time and for optimizing timber sale planning options.

In the 1996 Lynx Plan, the long-term feasibility of LAU-level lynx management guidelines was tested using modeled habitat predictions. These predictions were based on models of stand growth using the North Idaho Variant of the Forest Vegetation Simulator (FVS) and considered DNR's most aggressive management alternatives. The model output on the occurrence of lynx habitat categories over time on Little Pend Oreille Block and Loomis State Forest was as follows:

- Forested Habitat ratio of 70% is met throughout the planning period of eight decades.
- Availability of potential Denning Habitat is high throughout the planning period.
- Forage Habitat levels varied throughout the planning period and among the three LAUs within Loomis State Forest, and increased over the planning period in Little Pend Oreille Block.

The modeling was not updated for this revision of the plan, but the habitat changes at the LAU level for the Loomis State Forest and at the landscape level for Little Pend Oreille block from 1996 to 2004 are reported in Appendix 1, Section 4. As staffing is available, the modeling will be completed to incorporate the change in planning and ownership on the Loomis State Forest (transfer of areas to conservation status, watershed analyses, and Loomis Landscape Plan update). In the Little Pend Oreille block, the new forest inventory data will be used to update the distribution of the vegetation zones and the management regime by vegetation zone. The goal of the modeling will be to reproduce figures 33 and 34 of the 1996 Lynx Plan—projected habitat components in the two blocks by decade.

4. Lynx Habitat Management Guidelines

The management guidelines presented below are organized by planning scale. Table 4.1 outlines the objectives and strategies for each scale. The remainder of the chapter describes each scale and identifies specific guidelines. The guidelines are numbered separately for each scale and are shown in **bold, san-serif type (e.g., 1)**; some include **sub-guidelines (e.g., 1a)** and sub-sub guidelines (e.g., 1a.i). Additional text provides the rationale behind the guidelines, based on current scientific information. Assumptions referred to are those listed (A-E) in Chapter 3.

Table 4.1
Objectives and Management Strategies by Planning Scale

Planning Scale	Ecoprovince and Ecodivision	Lynx Management Zone (LMZ)	Lynx Analysis Unit (LAU)	Ecological Community
Objectives	Encourage genetic integrity at the species level.	Maintain connectivity between sub-populations, within Washington.	Maintain connectivity between and integrity within home ranges used by individuals and/or family groups (within sub-populations.	Maintain the integrity of requisite habitat types within individual home ranges
Management Strategies	Prevent bottlenecks between B.C. and WA by limiting shape and size of temporary non-lynx areas along the border. Maintain major routes of dispersal between British Columbia and Washington.	Maintain dispersal routes between and within zones. Arrange harvest activities that result in temporary non-habitat patches among watersheds so that connectivity is maintained within each zone.	Provide a diversity of successional stages within each LAU. Connect denning sites and foraging sites with forested cover without isolating them with open areas.	Prolong the persistence of snowshoe hare habitat. Retain coarse woody debris for denning sites.

4.1 Ecoprovinces and Ecodivisions

"Ecodivisions" and "ecoprovinces" (Figure 5) are the largest scales considered in the Lynx Plan. They were developed by USFS and British Columbia's Ministry of Environment, Lands, and Parks and are supported by the scientific literature (Ruggiero et al. 1994). By using these common scales, it is easier for DNR to coordinate its lynx management efforts with other state, federal, and Canadian agencies.

Ecodivisions and ecoprovinces are based on macroclimatic processes or, "the relatively permanent atmospheric and geographical factors that govern the general nature of specific climates" (Demarchi 1992). Each ecodivision is usually subdivided by more than one ecoprovince. Within the primary lynx range of Washington, the Humid Continental Highlands Ecodivision of northeastern Washington and the Semi-Arid Steppe Highlands Ecodivision of the eastern Cascades are exclusively represented by the Southern Interior Mountains Ecoprovince and Southern Interior Ecoprovince, respectively (Figure 5).

According to traditional biogeographic theory, lynx in both ecoprovinces of Washington are especially susceptible to extinction due to their "peninsular" distribution (Weaver 1993). That is, the shape of the areas they occupy resembles a peninsula. This peninsular shape arises naturally from the distribution of habitats that lynx prefer. At southern latitudes, the boreal habitat and climate conditions needed by lynx are restricted to increasingly higher elevations. Because these narrow mountain ranges have north-south orientations, lynx distribution maps depict peninsula-shaped ranges of habitat separated by lower elevation, less suitable habitat.

From the lynx distribution map (Figure 1), it appears that Washington lynx habitat contributes to the species range integrity, broadening the habitat "peninsula" that extends into the contiguous United States. Maintaining this habitat connection between the Canadian lynx populations and southern populations may reduce the risk of southern populations becoming extinct due to stochastic events. Future research may reveal the degree to which the persistence of the Washington populations are dependent on the connection to Canada, and what role the habitat in Washington plays as a link between north and south.

The habitat management strategy at the ecodivision/ecoprovince scale addresses assumptions A and D of Section 3.1, Chapter 3:

A. Species that are well-distributed across their historic range are more persistent than species confined to small portions of their range.

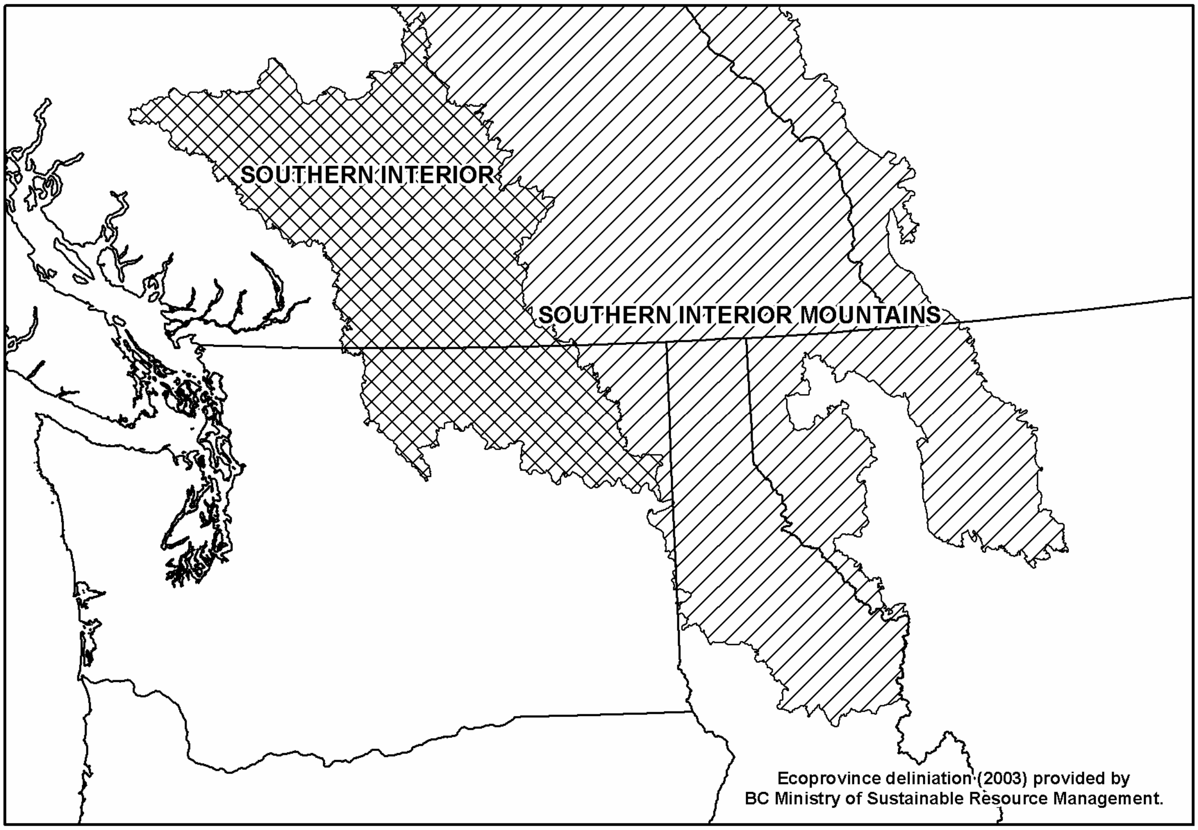
D. Population persistence increases when blocks of habitat are interconnected through linkages of suitable habitat

The strategy encourages genetic integrity at the species level (Table 4.1). It attempts to:

- Prevent bottlenecks between British Columbia and Washington by minimizing the size of open areas created by harvest activities along the US-Canadian border.
- Maintain major lynx travel routes between Washington and British Columbia.

Figure 5. Ecoprovinces of northeastern Washington

(modified from Demarchi and U.S. Forest Service 1994)



ECOPROVINCE GUIDELINES [5]

1. A system of travel routes will be maintained to connect DNR-managed lands with neighboring lynx habitat and to provide access to drainages throughout each Lynx Management Zone (LMZ). Travel routes will follow features that naturally connect landscapes, such as major ridges, saddles, streams, and wetland networks. Travel routes will be established in all Lynx Analysis Units (LAUs) regardless of the percentage of DNR-managed lands.

Ecoprovinces include landscape features that provide connectivity and influence lynx home range boundaries and movement patterns (Parker 1981, Parker et al. 1983, Koehler and Aubry 1994). The most important ridges, saddles, rivers, and streams are those that contribute to the overall connectivity within the LMZ. Minor rivers and streams, ridges and saddles, "dead end" ridges and saddles, and duplicate ridges and saddles can be incorporated as possible alternate routes.

The primary habitat concern at this scale is connectivity (Table 4.1). In particular, the travel route system attempts to address:

- Adult movements associated with breeding activities
- Juvenile movements associated with dispersal
- Individual movements, such as those associated with periodic fluctuations in prey density

The movements are not necessarily associated with the habitat quality of a particular LAU. For example, resident lynx avoid poor habitat when possible, but non-resident lynx might easily cross several LAU's and many different habitat types during long distance dispersal events. For example, lynx have crossed rivers, lakes (Poole et al. 1996, Poole 1997, Mowat et al. 2000), and farmland (Fortin and Huot 1995).

Lynx in north-central Washington often travel on ridges and saddles (Koehler 1990a). On the Loomis State Forest (Okanogan LMZ), 30 out of 100 occurrences (WDFW 2005) were in such areas. Lynx on the Kenai Peninsula, Alaska, similarly traveled on ridges (highest route near forage areas): 45.9 percent of 38 miles (61 km) of lynx tracks followed were on the "top of sharply defined ridges" (Staples 1995). This association with ridges and saddles seems intuitive for a number of reasons:

1) These areas may be easier to walk through than lowland forests because tree density is often limited by harsh climatic and/or soil conditions (Kenai Peninsula: these areas were often unburned and so therefore contained mature trees and relatively open forest, Staples 1995).

2) It may be easier to spot patches of prey habitat from elevated areas (lynx often sit on ridges and peer down-slope into hare habitat, Staples 1995).

[5] The guidelines in sections 4.1, 4.2, and 4.4 apply to all LAUs regardless of the percentage of DNR-managed land per LAU.

3) Light conditions may be more advantageous (i.e. twilight) for longer periods than in the shaded valleys.

Also, Staples (1995) suggested that lynx may find fresh carrion by traveling on ridges where they can see ravens and eagles across long distances (0.6 miles or 1 km).

Lynx have also been known to travel and hunt along riparian zones. Historical records from southern areas often report that lynx were observed or taken near rivers, creeks, and their junctions (e.g. Wyoming, Halloran and Blanchard 1954; Oregon, Coggins 1969). Riparian zones may provide travel routes when they are more open than the surrounding matrix (southern Yukon, Mowat and Slough 2003), although in other areas, riparian travel may be minimal (only 1.1 percent of trail segments of tracked Kenai lynx were located in low draws, Staples 1995). Poole et al. (1996) observed lynx along the shores of lakes. Major (1989) observed lynx hunting along riparian zones. Mowat and Slough (2003) described riparian willow stands as important lynx foraging habitat. In southern areas of snowshoe hare range, it is likely that riparian areas become more important habitat elements due to their favorable microclimate and ready supply of browse for hares. Guidebooks from southwestern areas of hare range commonly list riparian and boggy habitats as favored snowshoe hare habitat (Ingles 1965, Kurta 1995). Therefore, maintenance of forested areas along these geographic features may contribute to the connectivity of lynx habitat.

1a. Travel routes will be developed initially from topographic maps to provide a network across each LAU regardless of the percentage of DNR-managed lands. Where available, routes will reflect lynx habitat-use patterns as indicated from the WDFW Priority Habitat and Species database (2005). Maps of the currently designated travel routes on DNR-managed lands in each LMZ are presented in Figures 6, 7, 8, 9, and 10. Routes will be field-verified to ensure that the most suitable routes are selected. For example, routes through forested habitats will be preferred where available, to enhance the security of dispersing lynx. Routes may also change as new information on lynx habitat preferences accumulates. As a result, the GIS coverage of travel routes will be regularly updated.

1b. A special management zone (travel corridor) will straddle the route so that a >330 feet (100m)-wide corridor is available to lynx at all times. On average, the forested zone along the travel route will likely be much wider (Figure 11).

1b.i. Actual boundaries of the travel corridor along the travel route will reflect the existing contours of the landscape.

Lynx often hunt ridgelines by "zigzagging while moving parallel to the long axis of the terrain feature" (Staples 1995). Riparian routes may be especially important when the routes represent relatively easy and open travel compared to the rest of the forest matrix (Mowat and Slough 2003).

1b.ii. Where the travel route is naturally forested, Forested Habitat conditions will be encouraged within the travel corridor.

Given the lynx's tendency to avoid open areas, forested travel routes are likely preferred. However, considering the distances traveled by dispersing lynx (>300 miles or 500-1,100 km, Slough 1995), it is likely that at least some portions of routes traveled are relatively open. On the Loomis State Forest, the majority of ridge occurrences of lynx were

Figure 6. Designated Travel Routes on DNR-managed lands in Okanogan Lynx Management Zone (Loomis State Forest and Loup-Loup block)

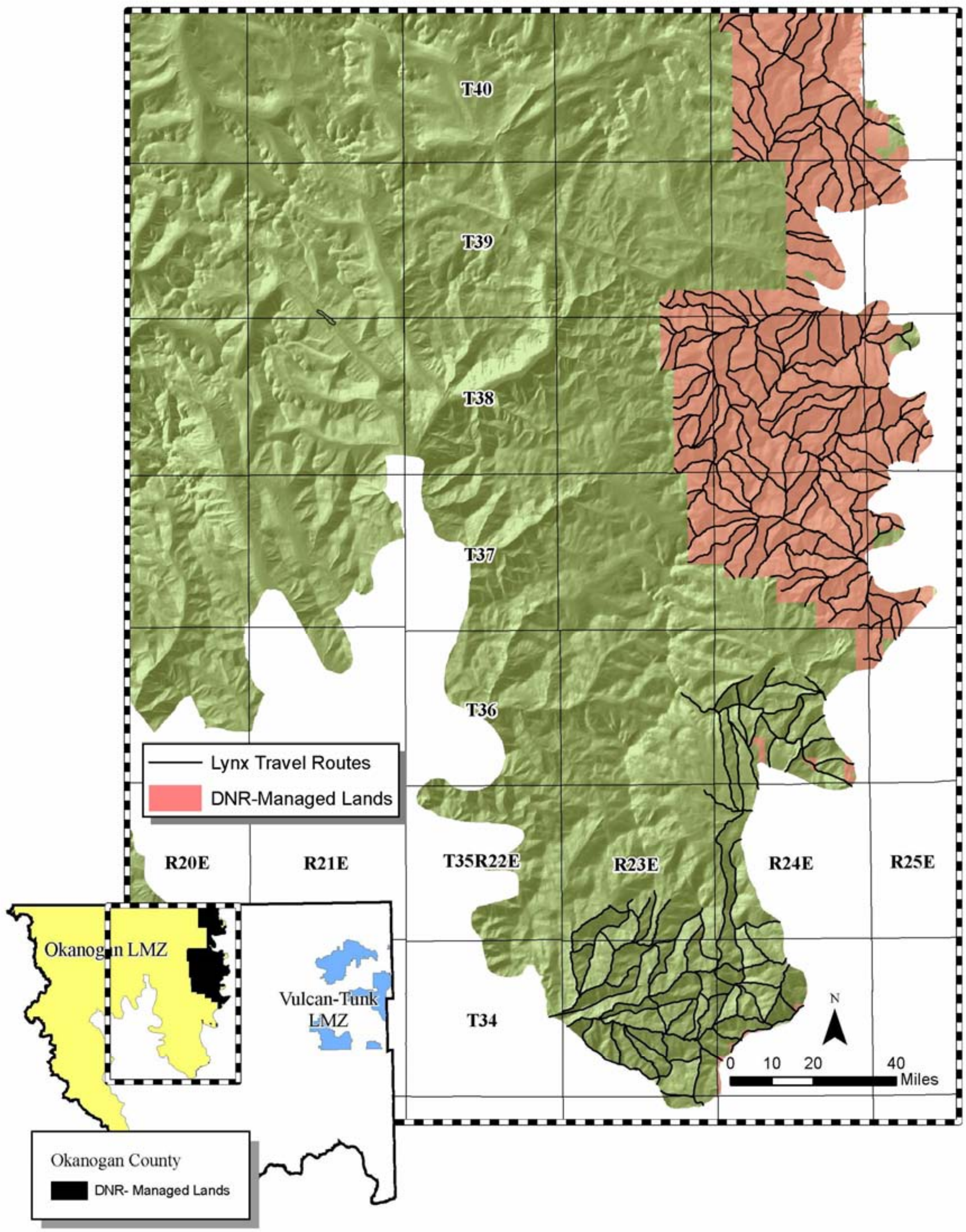


Figure 7. Designated Travel Routes on DNR-managed lands in Little Pend Oreille Lynx Management Zone

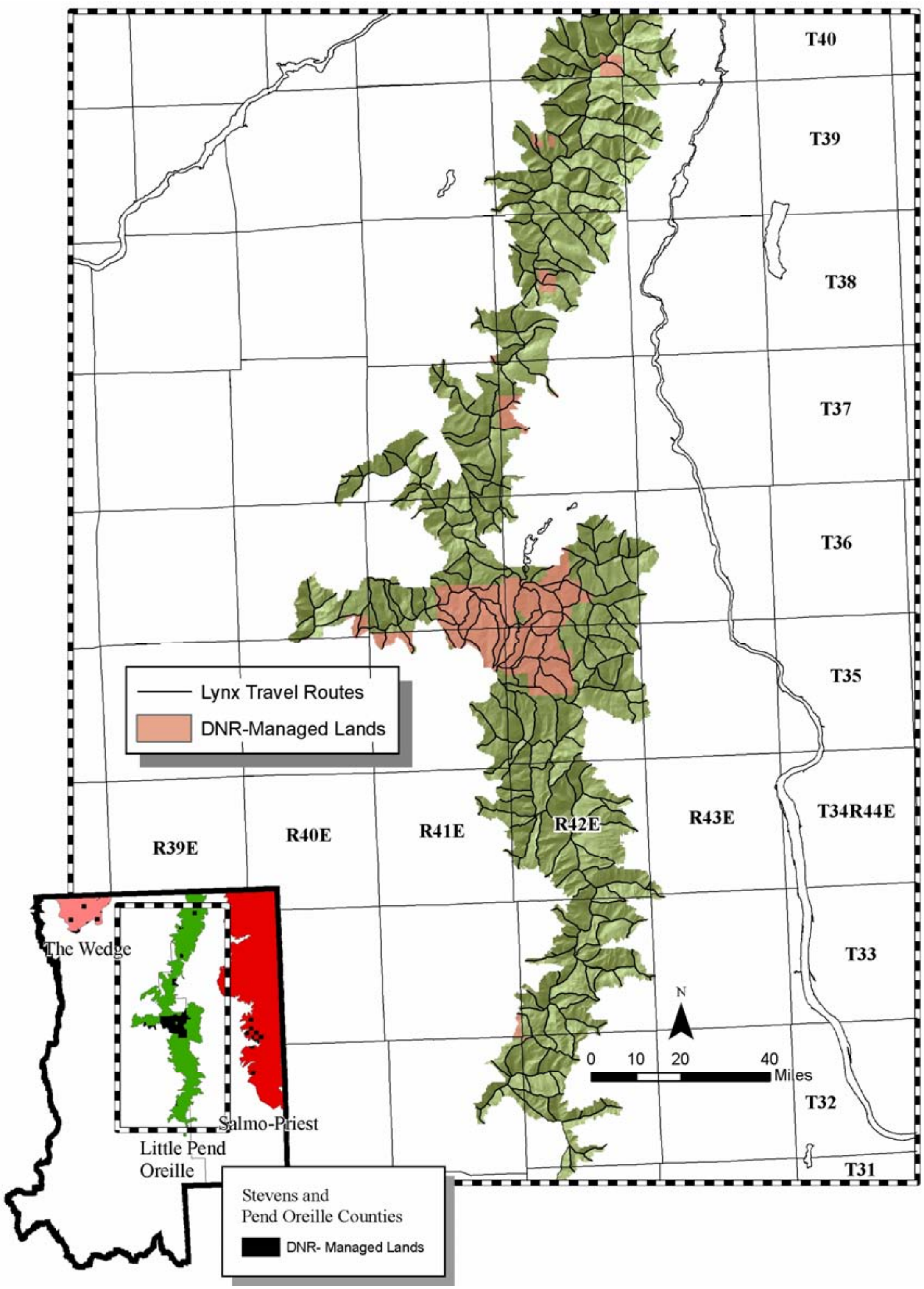


Figure 8. Designated Travel Routes on DNR-managed lands in Salmo–Priest Lynx Management Zone

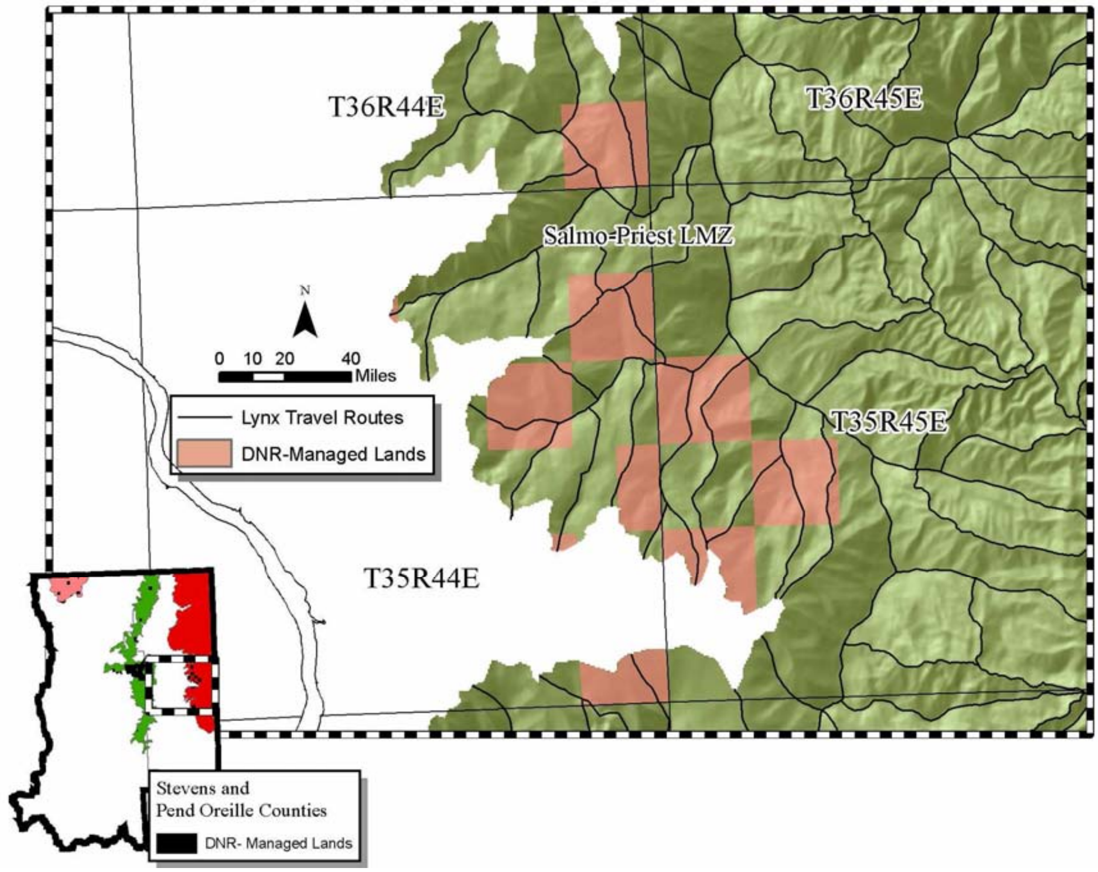


Figure 9. Designated Travel Routes on DNR-managed lands in Vulcan-Tunk, Kettle, and The Wedge Lynx Management Zones

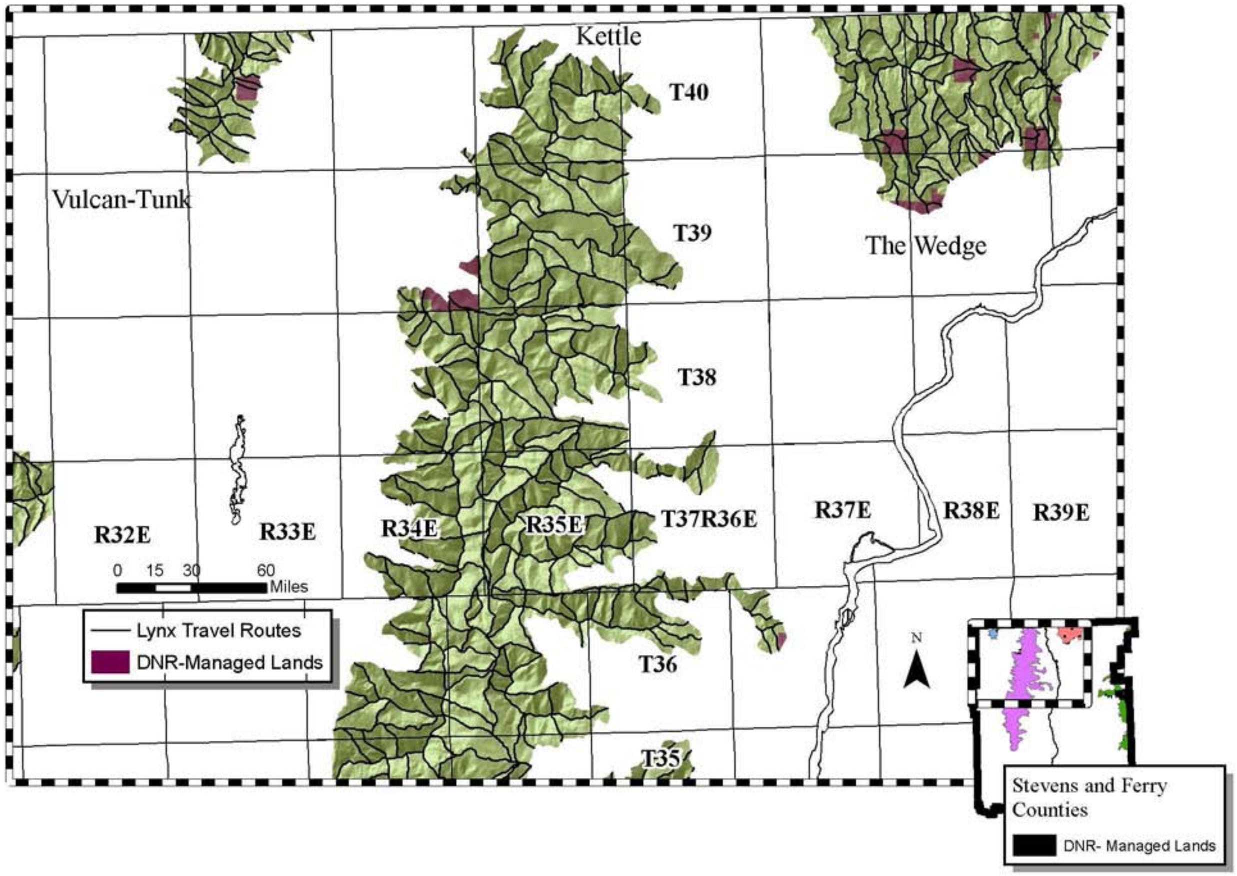


Figure 10. Designated Travel Routes on DNR-managed lands in Okanogan Lynx Management Zone (Chelan County)

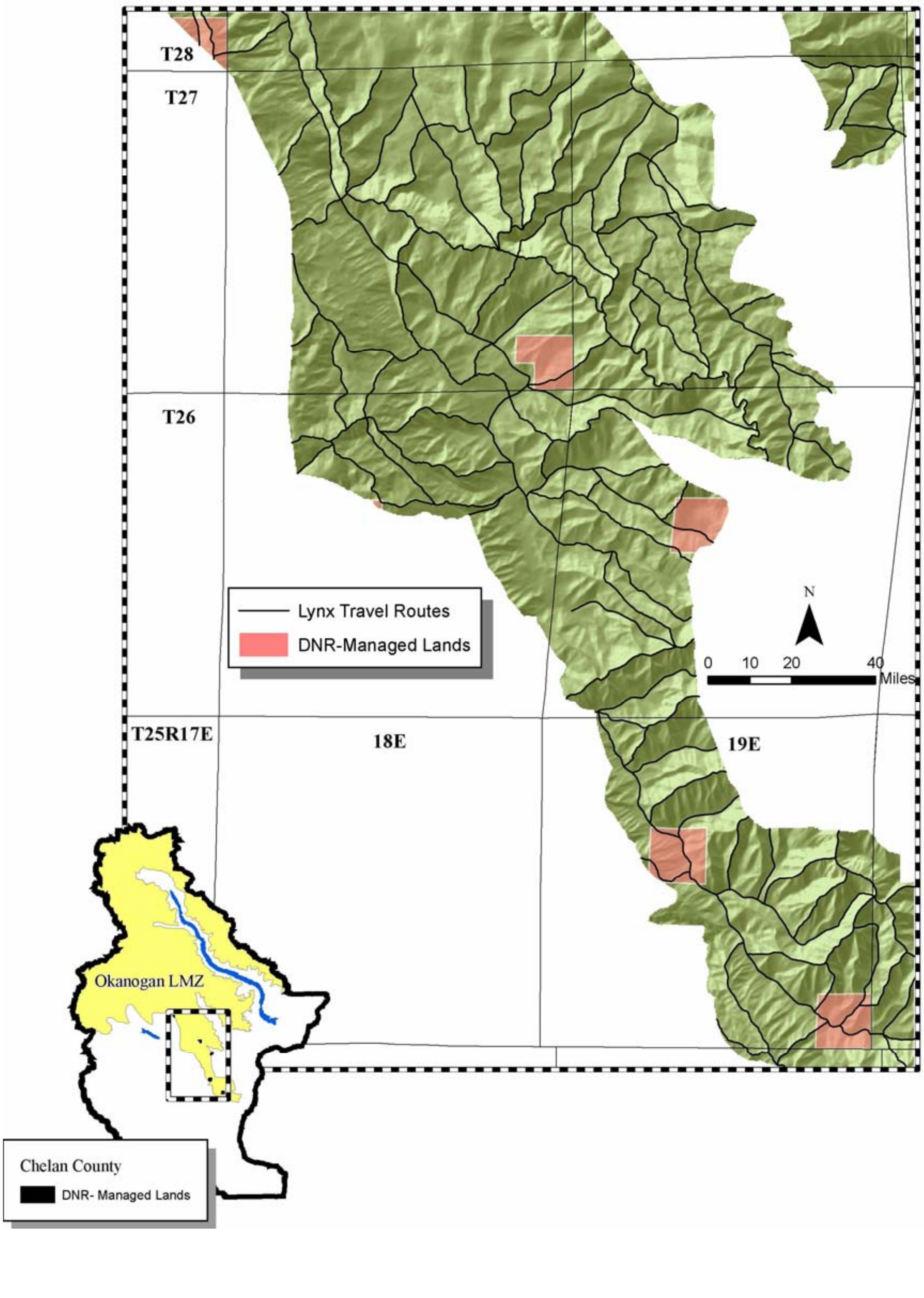
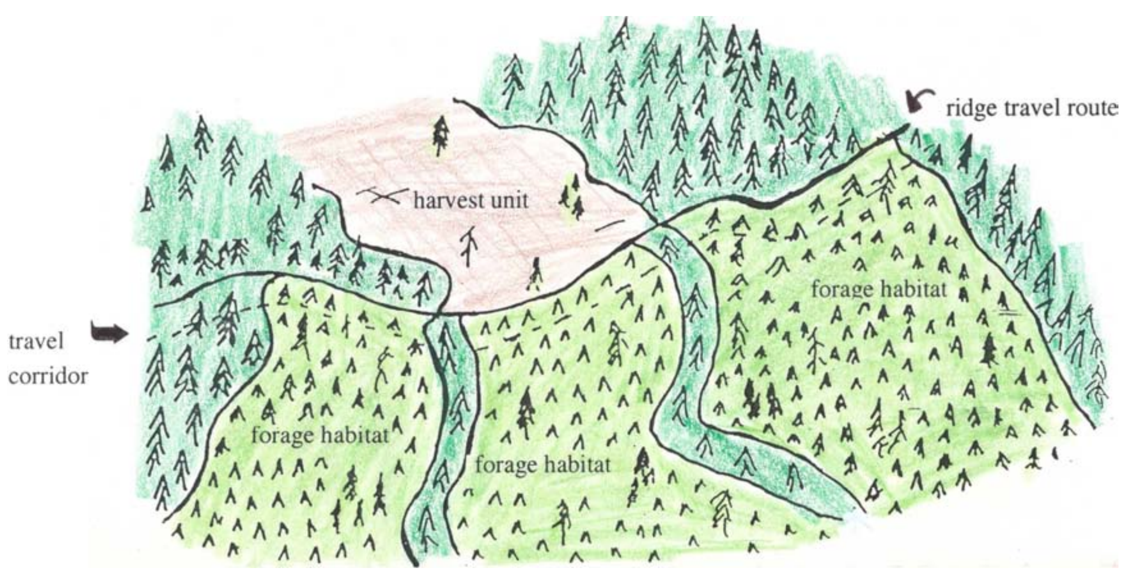


Figure 11. Sample travel route system and management over two phases

a) Sample initial harvest design

b) Second phase (>15 years later)



nonetheless within forested areas (77 percent, 23 out of 30 forested). Although open ridges may be important to resident lynx during periods of prey scarcity, as indicated by observations of lynx hunting high-elevation, open habitats for hoary marmots and Columbian ground squirrels in Glacier National Park, Montana (Barash 1971), maintaining forested conditions where possible will provide lynx with cover during daily movements and dispersal.

1b.iii. If harvest activities occur within the travel corridor along a ridge or saddle travel route, openings will be minimized (less than 330 feet or 100 m wide), techniques to ensure regeneration will be employed, and forested areas will be left on lower slopes and on the other side of the ridge/saddle to provide lynx with alternative travel routes (Figure 11). In situations where there is risk of regeneration failure, the preferred solution will be to avoid harvest within travel corridors. Also, the context of the corridor will be considered, so that an appropriate amount of cover is maintained within the corridor after harvest.

Ridges and saddles are difficult to regenerate due to their increased exposure. Alexander (1973) reported that spruce-fir forests have very high susceptibility to windthrow on saddles and ridges. Gaps on forest ridges should be kept <330 feet (100 m) wide because lynx in north-central Washington avoided crossing open areas >330 feet (Koehler 1990a). However, such gaps at higher elevations are also known to funnel winds, which further increases windthrow risk (Alexander 1973).

If regeneration and blowdown risks are minimal, part of a ridge or saddle could be harvested (Figure 11), provided that a >330 feet (100 m)-wide corridor of forested cover is maintained on the opposite side of the ridge/saddle and/or there are alternative routes that lynx could use to travel through the area. In such cases, the context of the travel route will be considered. For example, if the route is situated in an area dominated by Open Areas or Temporary Non-lynx Areas, cover within the travel corridor may be critical. Therefore, harvest that reduces cover will be avoided and the corridor left for lynx will contain the maximum cover available on the site. If the route is situated within Forage Habitat, a more open corridor would be desirable (allowing ease of travel and hunting along the forage habitat edge, such as the unburned remnants within the Kenai Peninsula burn, Staples 1995), and therefore harvest that reduces cover might be planned.

1c. If roads must be placed on ridges or saddles within the travel corridor due to other priority forest management concerns such as slope stability or water quality, road width will be minimized, vegetative cover will be encouraged on both sides of the roads, sight distance will be reduced (330 feet or 100 m), and/or the roads will be closed as soon as possible, or at least the frequent use of such roads will be discouraged.

Indirect negative effects of roads on lynx such as poaching, accidental hunting, incidental trapping, vehicle and snowmobile traffic, and competition with other predators that favor road systems may pose a serious threat to lynx (G. Koehler, WDFW; B. Ruediger, Northern Region, USFS; W. Staples, University of Alaska, Fairbanks pers. commun.; Brocke 1990).

4.2 Lynx Management Zones

The second planning scale uses the six zones of primary lynx range identified by WDFW (Table 3.1, Figure 2). The zones were originally identified by Brittell et al. (1989) and refined by WDW (1993) to reflect surveys, field notes, sightings, trapping records and reports, elevation, and vegetative communities. New information, provided by the USDA Forest Service in connection with the federal listing of lynx, led to further revision of Lynx Management Zone (LMZ) boundaries (Stinson 2001).

Although all six LMZ's are considered primary habitat, each zone has a slightly different history and potential as lynx habitat (WDW 1993, Stinson 2001). Accessibility, trapping history, past forest harvest activities, fire suppression practices, size of current lynx population, total area size, vegetative communities, and landscape heterogeneity are some of the variables contributing to the differences in potential between zones.

The management strategy for this scale focuses on maintaining connectivity between sub-populations in Washington (Table 4.1), and addressing assumptions B, D,E (Section 3.1):

B Population persistence increases with the number and size of sub-populations and the size of habitat blocks.

D Population persistence increases when blocks of habitat are interconnected through linkages of suitable habitat.

E The persistence of exploited populations increases with a well-distributed network of refuges or safety nets.

The habitat management strategy at the Lynx Management Zone scale is to:

- Maintain dispersal routes between and within zones (travel routes).
- Arrange harvest activities that result in non-forest patches or other dispersal barriers among watersheds so that connectivity is maintained within each zone.
- Manage human disturbance so that the effectiveness of connectivity measures is maintained.

LYNX MANAGEMENT ZONE GUIDELINES

1. **Connectivity within LMZs on DNR-managed land will be maintained. Where DNR-managed land is in a critical position (e.g. a narrow constriction within the LMZ, especially along the British Columbia border), forested strips >330 feet (100m) wide will be positioned to facilitate lynx travel through the area, and/or harvest units will be placed to promote connectivity. This may entail keeping harvest units narrow, small, and/or dispersed.**

2. **Human-related disturbance will be considered in road, harvest, and recreation plans on DNR-managed lynx habitat.**

Because lynx are often described as “curious” (Jackson 1961), “playful” (Saunders 1961, Halfpenny and Biesiot 1986), and perhaps indifferent to human activity (indicated by sightings in garbage dumps, residences, and camps: Halfpenny and Biesiot 1986, van Zyll de Jong 1966, Mech 1973, Staples 1995, Mowat and Slough 1998), they are susceptible to trapping, road kills, and other human-related sources of mortality. Staples (1995) reported that lynx did not flee in 92 out of 105 instances when they were encountered by humans at close range. As emphasized to DNR by T. Bailey (Kenai Natl. Wildl. Ref., pers. commun.), "I would recommend that every effort be made to minimize human-caused lynx mortality until the prey base and habitat quality significantly improves in your area of concern and you have definite indications of increased kitten production and survival."

2a. Strategies to promote lynx security in road and harvest plans may include decommissioning non-essential roads after harvest, placing gates to limit vehicle access, avoiding loop roads, considering roadless logging techniques, limiting sight distances on roads, and maintaining vegetation on the roads shoulders.

Lynx use of roads may be mediated by the design of the road and surrounding habitat. For example, Parker (1981) noted that lynx readily followed road edges and forest trails on Cape Breton Island, Nova Scotia. However, Staples (1995) reported that lynx "usually crossed roads at a right angle and did not use or follow roads for long distances" in a Kenai Peninsula study. In Washington, Koehler and Brittell (1990) stated, "Lynx frequently travel along roads with less than a 50-foot right-of-way, where adequate cover is present on both sides (of the road)." A re-analysis of the Washington data similarly led to the conclusion that small, narrow forest roads did not significantly alter lynx habitat use (McKelvey et al. 2000). Brocke (1990) recorded high numbers of road-killed lynx during a reintroduction program in the Adirondacks. Lynx were vulnerable because of the large distances they traveled and because of the attraction of lynx to hares, and of hares to roadside vegetation. Staples (1995) also noted that lynx fed on carcasses along roads.

2b. No increases in designated or groomed over-the-snow routes or snowmobile play areas will be allowed within lynx geographic range managed by DNR. Maps of the snowmobile routes that currently occur in the Loomis State Forest and Little Pend Oreille block are presented in Figures 12 and 13. Closure of some areas that are currently used will be considered if specific areas of increased concern are identified and mutually agreed upon by DNR and the USFWS. Strategies to discourage inappropriate use will include signing of gated systems and placement of physical barriers along the entrance to trail or road systems where appropriate. Additionally, increased organized snowmobile use within the LMZs will not be promoted.

Although lynx are known to regularly use snowmobile trails for travel (Slough and Mowat 2003), an indirect consequence of snowmobile trails for lynx may be increased competition for prey (Buskirk et al. 2000). Competitive predators that are normally excluded from deep snow habitats where lynx occur can access lynx habitat via compacted snow routes. Coyotes readily use snowshoe hare as prey, and have clear numerical and functional responses to snowshoe hare densities (O’Donoghue et al. 1998). Likewise, snowshoe hare can make a large portion of bobcat diets (e.g. Litvaitis et al. 1986, Parker et al. 1983), and bobcats may displace lynx (Parker et al. 1983). Encounters with other predators (e.g. like cougar and coyote) may also result in direct mortality.

4.3 Lynx Analysis Units

Lynx Analysis Units (LAU) are used to stratify the Lynx Management Zones in order to better evaluate the current and potential habitat conditions and management actions.

LAUs are based roughly on Watershed Administrative Unit (WAU) boundaries, but also take into account lynx home range sizes and the occurrence of permanent non-lynx habitats such as rock and ice (Stinson 2001) (see Tables 3.1 and 3.2). This use of WAUs is consistent with the observation that lynx home ranges in north-central Washington appear to correspond with drainage boundaries (Koehler and Aubry 1994). Parker (1981) likewise concluded that lakes and streams contribute to the definition of home range boundaries of lynx on Cape Breton Island, Nova Scotia. The numeration of the LAUs used in this plan and in the monitoring reports is the same as in the Lynx Recovery Plan (Stinson 2001).

The habitat management strategy at this scale focuses on maintaining connectivity between, and the integrity of, home ranges used by individuals and/or family groups (Table 4.1). It addresses assumptions C, D, and E (Section 3.1):

C. Blocks of contiguous habitat in close proximity promote a higher probability of persistence than dispersed blocks of fragmented habitat.

D. Population persistence increases when blocks of habitat are interconnected through linkages of suitable habitat.

E. The persistence of exploited populations increases with a well-distributed network of refuges or safety nets.

The habitat management strategy at the LAU scale is to:

- Provide a mosaic of successional stages within each LAU.
- Connect denning and forage areas, while avoiding the isolation of either by open areas or temporary non-lynx areas.

Figure 12. Snowmobile Trails and Play Areas in Loomis State Forest

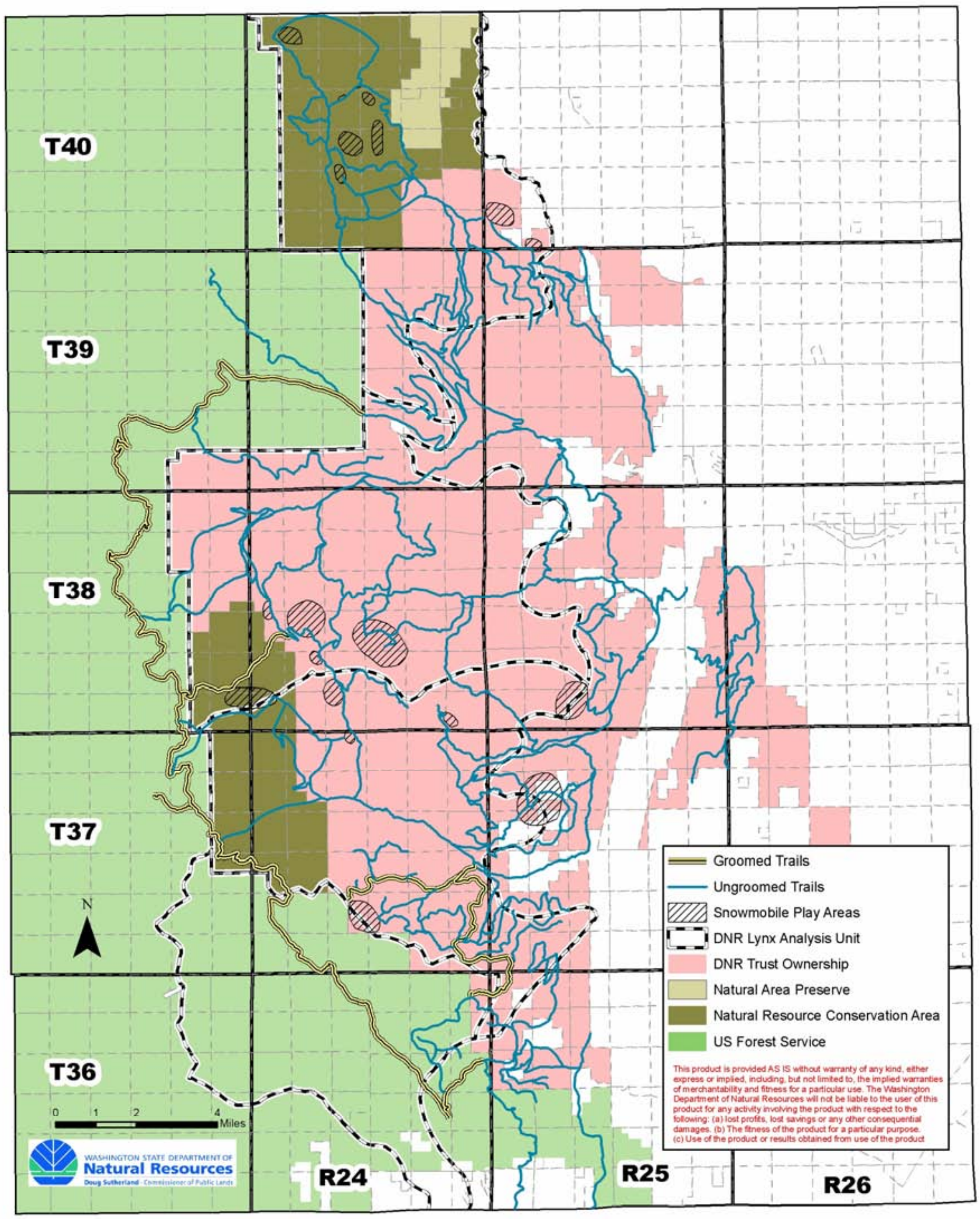
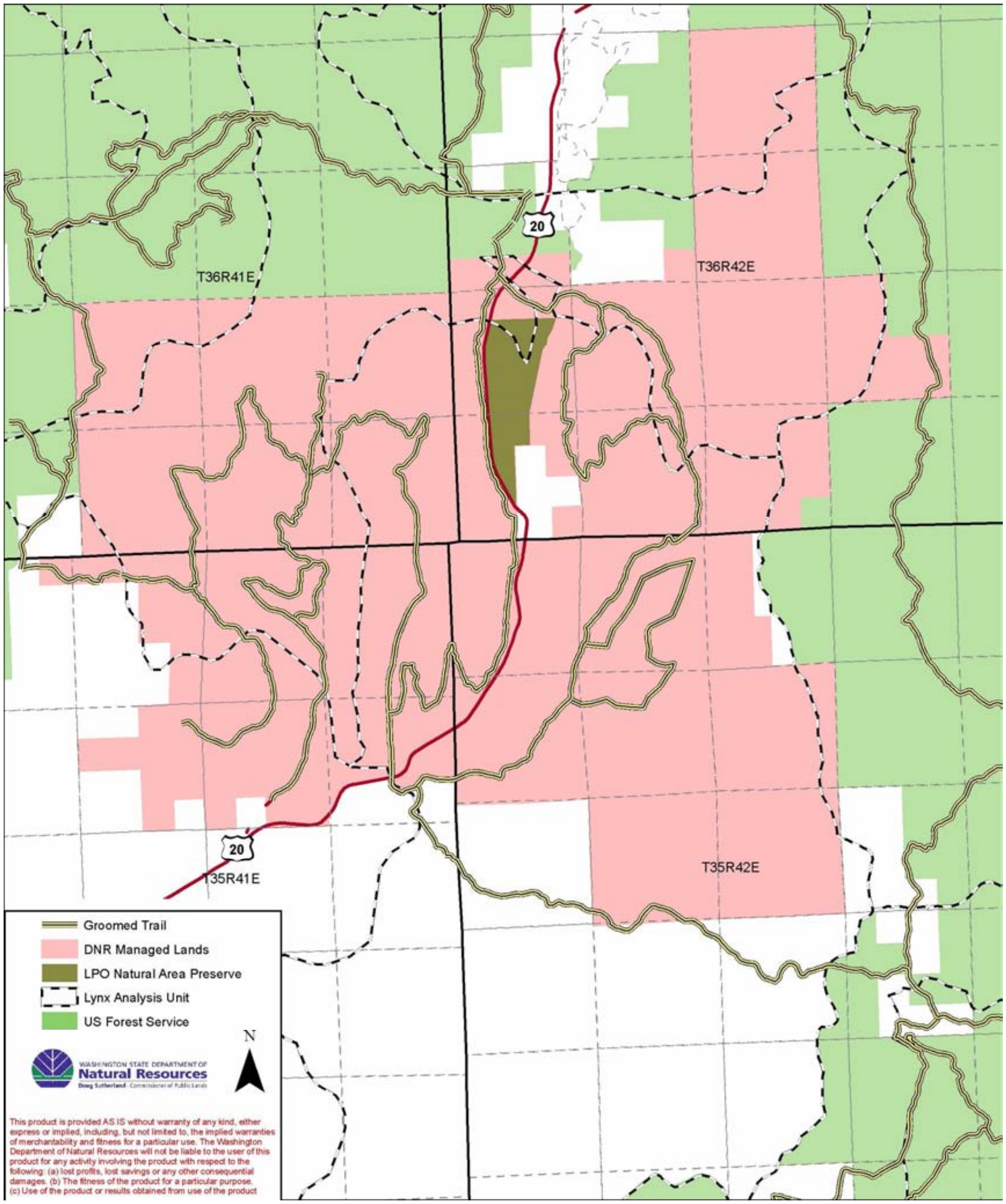


Figure 13. Snowmobile Trails in Little Pend Oreille block



LYNX ANALYSIS UNIT (LAU) GUIDELINES

1. The following ratios of lynx habitat components will be maintained in each LAU on DNR-managed lands where DNR manages 20 percent or more of the LAU (Loomis State Forest and Little Pend Oreille Block). See Table 2.1 for definitions of habitat categories.

Forested Habitat	**70% minimum**
Forage Habitat	20% minimum
Denning Habitat	10% minimum (including at least 2 den sites/mi^2)
Travel Habitat	40%
Temporary Non-lynx Areas	**30% maximum**

The percentage ratios are based on the total acres of potential forested lynx habitat per LAU (total LAU acres minus permanent natural openings and sparsely forested areas). For example, if a LAU had 30,300 acres, of which 300 acres were meadows, lakes, and talus slopes (i.e. Open Areas), 30,000 acres must be maintained as lynx habitat. This would include at least 21,000 acres of Forested Habitat and no more than 9,000 acres of Temporary Non-lynx Areas. The Forested Habitats would include at least 6,000 acres of Forage Habitat and 3,000 acres of Denning Habitat. The Denning Habitat would be available in at least 94 designated den sites (≥5 acres), dispersed as 2 sites for each square mile of the LAU.

Management activities within lynx range, such as maintaining lynx habitat ratios, must be considered "experiments" that include careful planning and monitoring for vegetative response and lynx and hare recovery, and the habitat ratios should be treated as hypotheses. Landscape level research will be required to test the response of lynx to the habitat ratios. This might involve correlating habitat change using GIS to an index of lynx use (i.e. lynx density, home range size, presence of kittens, etc.).

The rationale for the percentage ratio of different habitat types comes from the scientific literature on lynx habitat use (Appendix 3). By definition, lynx studies focus on habitats used by lynx, which are often ≥80 percent forested. The vital precursors to snowshoe hare habitat, early successional or Temporary Non-lynx Areas, are precluded because they are avoided by lynx for the relatively short duration of the studies that have been conducted. The literature does tell us that within lynx habitat, most of the lynx home ranges probably contain more than 20 percent Open Areas and/or Temporary Non-lynx Areas (Appendix 3). For example, 14 percent of lynx home ranges were categorized as non-forested habitats in north-central Washington (Brittell et al. 1989). The information from Appendix 3 suggests that if 100 percent of the lynx habitat matrix were to be considered suitable for lynx at all times, the extent of open areas within the matrix should not exceed 20 percent. This implies that LAUs may need to be larger than average lynx home ranges to accommodate the Temporary Non-lynx Areas needed to promote enough Forage Habitat to provide lynx with prey for successful reproduction.

How much Forage Habitat is enough to enable lynx to reproduce successfully?
From the lynx's perspective, the greater the amount of accessible prey a habitat can support, the better the habitat. Likewise, the greater the amount of this type of habitat available to the lynx, the better. Lynx likely encountered wide expanses of high quality habitat in Washington several decades ago, judging by the extent of relatively even-aged mature forest that currently exists in places like the Loomis State Forest in north-central

Washington. When these forests were younger and supporting high hare densities, lynx may have flourished. Methow water resource inventory area may be used as an illustration of this point. Estimates of historical forest conditions of the area (Table 4.2), based on fire history records, suggest periodic dominance of prime hare/lynx habitat on the landscape.

Table 4.2
Historical landscape composition of watersheds in the Methow River Basin estimated from recent fire history records

(adapted from USFS 1993)

STRUCTURAL STAGE	PRIMARY SPECIES	
	Lodgepole Pine	**Engelmann Spruce/ Subalpine Fir**
Early even aged, from seedling/sapling to small saw timber, lacking understory	27-45%	15-24%
Middle bilayered with 1) shade tolerant understory species in seedling/sapling or small pole; and 2) saw timber and larger overstory	35-74%	42-89%
Late understory is co-dominant to dominant and occupies all canopy layers as overstory declines; standing and down debris are mostly small to medium sized but some large trees have recently died and are becoming snags	5-11%	10-22%
Old considerable stem decay and top breakage visible in overstory, many seral trees have fallen; the former understory has replaced the original overstory, so that the stand is characterized as having an overmature seral overstory	0.7-1.3%	0.7-1.3%

Of course, historical disturbance regimes may not be a valid base for extrapolation given the social and ecological context currently surrounding forest management within lynx range. Air and water quality, recreation, mineral extraction, livestock grazing, and timber harvesting are social concerns that generally demand gradual change rather than the "boom or bust" cycles of the past. Even without the above concerns, lynx recovery could not be guaranteed if the historical disturbance regime were applied today. The presence of lynx and other species is the combined result of many variables and circumstances that have likely all changed to some extent since the last extensive disturbance event. For example, the total land base available for lynx in Washington is decreasing and fragmenting due to human development (e.g. Methow valley) and resource extraction activities (WDW 1993). It is not known how much habitat of what quality is required to maintain a persistent lynx population. Also, development and resource extraction has occurred in neighboring lynx habitat, reducing the potential of these populations to produce dispersers that might historically have re-populated lynx habitat after disturbance. Lastly, formerly remote areas are increasingly susceptible to human disturbance due to the popularity of snowmobiles and all-terrain vehicles. Disturbance within lynx habitat may reduce the present quality of that habitat in comparison to its quality in the past. This may be reflected in the area's current potential to support lynx. Taking all these factors into account, something less drastic than historical disturbance patterns is likely necessary to sustain lynx under today's habitat and social constraints.

Ideally, land managers can achieve some median density of hares (i.e. >1.0 hares/ha) over a median female Washington lynx home range (i.e. 16 square miles) for a median time period (i.e. 4-5 years out of every 8-11 years, Brand et al. 1976). However, the current scientific information on lynx and snowshoe hare habitat relationships is not enough to apply such a strategy. Instead, we must extrapolate from what is known and adapt management strategies to new information. Research in Washington (Koehler 1990a) indicates that landscapes with less than 10 percent Forage Habitat (20-year-old lodgepole pine) may not support successfully reproducing populations of lynx. Similarly, hares occupied only 10-18 percent of available habitat during periods of low hare density in Alberta (Keith 1966, Keith and Windberg 1978) and Alaska (Wolff 1980), and lynx do not reproduce successfully during hare lows. Parker et al. (1983) speculated that lynx landscapes in Nova Scotia should contain 20-25 percent of approximately 20-year-old stands. In this plan, the Forage Habitat target is established at 20 percent minimum per LAU, but includes Forage Habitat in older stands.

Modeling from Okanogan National Forest (Envirodata Systems Inc. 1993, Williams and Lillybridge 1983) suggests that having 20-26 percent of the area in Temporary Non-lynx Areas may result in 26-42 percent Forage Habitat, based on a 70-year rotation without pre-commercial thinning in three of the four habitat types present in the Meadows area. In the fourth group, a 70-year rotation would include 13 percent Temporary Non-lynx Areas and 19 percent Forage Habitat. Limiting the Temporary Non-lynx Area to a maximum of 30 percent per LAU should accommodate some overestimation of forage regeneration that might have resulted from the modeling. This ratio will still promote enough Forage Habitat to provide lynx with prey for successful reproduction. The LAUs managed by DNR are large enough to accommodate a mean lynx-home-range even with 30 percent Temporary Non-lynx Areas.

How much Denning Habitat is enough?

If Denning Habitat includes both "late" and "old" structural stages, the 10 percent minimum Denning Habitat ratio recommended by WDFW (1996) and used in this plan falls within the ranges historically occurring within the Methow River Basin (Table 4.3). The same is probably true for landscapes in the eastern Lynx Management Zone (LMZ), where the cooler, moister forests burn at a longer interval. Even if an entire Lynx Analysis Unit (LAU) were subject to wildland fire in a worst-case scenario, the proportion of area left unburned within the fire perimeter might be near 5 percent (using median LAU size of 32 square miles or 82 km^2, Table 3.2), as extrapolated from a study on large fires in Alberta (Eberhart and Woodard 1987). Dispersing denning habitat (two den sites per square mile) also increases the probability that some denning opportunities will be available after fire.

2. Forest management activities will incorporate interspersion of habitat components within the lynx habitat matrix where DNR manages 20 percent or more of the Lynx Analysis Unit (LAU) (Loomis State Forest and Little Pend Oreille Block).

2a. Harvest activities will be scheduled so that no more than 15 percent of the Forested Habitat within a LAU is converted to Temporary Non-lynx Areas per decade. The time frame for calculating the 15 percent threshold will consist of the 10 years prior to the proposed implementation of a project (e.g. timber sale).

2b. No more than 10 percent of a LAU will be managed at the lower end of the stocking levels that define Forested Habitat (>180 trees per acre or 445 trees/ha) at any one time, and no more than 5 percent of the Lynx Habitat within a LAU will be converted to this minimum condition within a decade.

2c. Forage Habitat will be connected by travel corridors to Forested Habitat within the LAU and located near Denning Habitat (<3 miles or 4.8 km).

WDFW (1996) suggested that Forage Habitat should be within 0.5 mile (0.8 km) of denning habitat. Koehler (1990a) hypothesized that the low survival rate of lynx kittens in north-central Washington was related to the large distances that two denning females traveled to reach forage habitat (up to 4.3 miles or 7 km).

2d. Timber harvests will be scheduled and designed so that more than 50 percent of the periphery of Denning Habitat will be bordered by Forested Habitat at all times.

Because lynx generally do not cross large openings (Koehler et al. 1979, Parker et al. 1983, Murray et al. 1994, Poole 1994, Mowat and Slough 2003), surrounding Denning Habitat with harvested units may temporarily restrict its use by lynx. Brittell et al. (1989) hypothesized that 50 percent of the border of Denning Habitat should be Forested Habitat.

4.4 Ecological Communities

Ecological communities are defined in this Lynx Plan as individual stands of similar vegetation, age, and structure. Activities at the stand-level scale are designed to maintain the function of requisite habitat elements within individual lynx home ranges (Table 4.1).

The habitat management strategies for the ecological community scale are to:

- Maintain and/or prolong the use of stands by snowshoe hares.
- Retain coarse woody debris for denning sites.

ECOLOGICAL COMMUNITY GUIDELINES

1. Timber harvest units (Temporary Non-lynx Areas) will be designed to promote swift vegetative regeneration and snowshoe hare/lynx recolonization. This guideline applies to all harvest units, regardless of percentage of DNR-managed land per Lynx Analysis Unit (LAU).

Snowshoe hare habitat contains two elements at the stand level: 1) food in the form of small diameter stems, needles, branches, and bark of shrubs and conifers; and 2) cover in the form of conifers and/or deadfall/slash/blowdown. Traditionally in the literature the definition of Lynx Forage Habitat is simplified to reflect the hare's winter habitat needs.

1a. Harvest unit size will reflect the regeneration capacity of the site and contribute to a diverse mosaic of habitat patches available to snowshoe hare and lynx. Units will be designed so that Temporary Non-lynx Areas never exceed 200 contiguous acres (81 ha). Where DNR manages more than 20 percent of a LAU, the total Temporary Non-lynx Area per LAU on DNR-managed lands is limited to 30 percent.

Conroy et al. (1979) suggested that the distance from newly cleared harvest units to cover should not exceed 656 to 1,312 feet (200-400 m) to benefit snowshoe hare and regeneration. Koehler and Brittell (1990) recommended unit size less than 40 acres (16.2 ha) to encourage natural regeneration. However, regeneration is site-specific, and a variety of harvest unit sizes might provide a better mosaic of habitat for lynx and hare, due to the effects of patch size and spatial relationships on hare densities. For example, small populations of snowshoe hare within 12 to 17-acre (5-7 ha) sites did not persist as long as larger populations in 56 to 69-acre (23-28 ha) sites in Wisconsin (Keith et al. 1993). Thomas et al. (1998) also found higher densities of hares in large patches than small patches in Colville National Forest. It is possible that the interior of larger patches provides a refuge for hares, enabling them to persist through periods of intense predation (see "1b" below). Small units also necessitate frequent human disturbance and road access, both of which are thought to be detrimental to lynx persistence (Koehler and Brittell 1990; Guideline 5). In her research in Okanogan National Forest, Walker (2005) found that relative hare densities were negatively related to the amount of open-structured habitat types, and positively correlated with the amount of boreal forest within 300 m of a patch of dense forest.

In recent history (early 20th century), the mean patch size of lodgepole pine in age classes preferred by hare and lynx averaged 155-185 acres (63-75 ha) in the Methow Valley (Lemkuhl et al. 1994). Areas up to 170 acres (69 ha)—median of the Methow range—in similar age classes might therefore be appropriate for the lynx landscape, if the large size of the unit did not impair regeneration within the stand. Adding for variability (only means were reported), up to 200 acres (81 ha) is a hypothesized upper limit, provided that these larger units do not dominate the landscape. Occasional larger sized patches might benefit lynx indirectly by reducing the traffic on roads and the total amount of roads needed, as well as addressing the prey vulnerability/abundance issue.

Given the uncertainties and issues detailed above, a combined approach to unit sizes is appropriate. Such an approach offers opportunity for recovery if the management experiment fails. For example, the combination might include: 1) larger regenerating stands (e.g. 100 acres or 40 ha), so that hare have refugia and a chance to reach higher numbers, and 2) similarly sized areas (e.g. 100 acres) with small, grouped harvest units (20-40 acres or 8-16 ha) separated by forested corridors, to favor hare vulnerability for lynx.

1b. Harvest unit shape will enhance the regeneration potential of the unit and provide a diversity of forage and browse opportunities for the lynx and hare. This may include periodic constrictions within harvest units resulting in openings less than 330 feet (100 m) to provide lynx with opportunities to cross larger units (Koehler and Brittell 1990).

A combination of unit shapes is recommended. Research in other southern areas of snowshoe hare range (i.e. Wisconsin: Buehler and Keith 1982, Sievert and Keith 1985) suggests that hares may be most vulnerable along stand edges. Lynx are capable of hunting both within and along the edges of thick stands that hare prefer (Murray et al. 1994), but coyotes (Theberge and Wedeles 1989) and avian predators mostly hunt the edges. Maximizing edge may therefore increase the vulnerability of hares to the latter, at a net cost of hares needed by the lynx. Also, a policy of maximizing edge will increase the amount of browse that snowshoe hares must share with browse competitors such as domestic sheep (Dodds 1960), moose (Dodds 1960, Oldemeyer 1983), white-tailed deer (Bookhout 1965), and perhaps domestic cattle (suggested for other leporids by MacCracken and Hansen 1984). Snowshoe hare browse grass and other herbaceous vegetation during the snow-free season (Brooks 1955, Severaid in de Vos 1964, Wolff 1980, Hik 1994, Nams et al. 1996). Because large ungulates might have less influence on the interior of a dense stand, relatively more forage would be available to hares if the area to perimeter ratio were larger.

If enough hares and hare browse are available in the landscape, both the competition for browse (hare vs. ungulate) and the competition for prey (lynx vs. other predators) may be ameliorated. For example, Witmer and DeCalesta (1986) attributed the coexistence of bobcat and coyotes in a managed forest to high prey abundance (both species consumed mainly mountain beaver). O'Donoghue et al. (1998) found no evidence for interference competition when hares were at peak densities in the Yukon.

1c. Harvest unit design will enhance the regeneration potential of the site and provide opportunities for rapid hare recolonization by containing clumps or islands of remnant vegetation and/or woody debris.

Standing trees or snags, shrubs, and slash can be important sources of seed within lodgepole pine harvest units (Lotan and Perry 1983). Leaving such structure behind may mimic moderate intensity wildfire that generates lynx forage habitat.

Hare use within clearcuts was higher than expected in uncut, non-merchantable clumps within clearcuts such as islands, riparian zone buffers, and wetland buffers (Monthey 1986). Compared with sites not used by hares, occupied managed forest habitat had more cover by stumps and slash (Scott and Yahner 1989). Hares used brush piles in New York where conifers were absent or sparse (Richmond and Chien 1976). Old burns with cover in the form of brush and fallen woody debris can also be used extensively (Grange 1932).

In Montana, dense clumps of Douglas fir within relatively open ponderosa pine forests were used by hares (Adams 1959). In summary, the less barren a regenerating stand is, the more hospitable it may be to lynx and hare. Also, the larger the unit, the more important such structures may become. The number of unburned islands within a burned area increases with fire size, and the disturbed area has more irregular shape and edge with increasing fire size in Alberta (Eberhart and Woodard 1987).

Remnant material may also provide a lingering benefit of within-stand diversity that is characteristic of prime hare habitat. Interspersion of vegetation/slash is likely better for hares than uniform forests (Morse 1939, Conroy et al. 1979, Ferron and Oulette 1992). Also, lynx visually search for prey from piles of slash and snow (i.e. forming over remnant vegetation and debris) on the Kenai Peninsula, Alaska (Staples 1995).

1d. Forest regeneration techniques will reflect the unit's potential to produce quality hare habitat (unit quality, according to vegetation association) and may involve use of fire or soil scarification techniques.

Not all forested sites may be able to attain stem densities preferred by hares. For example, the modeling (Envirodata Systems, Inc. 1993) rated lodgepole pine stands of ABLA2/VACCI, ABLA2/LIBOL, and ABLA2/CARU associations (for an explanation of plant association abbreviations see Appendix 4) as having higher potential to produce lynx habitat than ABLA2/VASC/CARU, ABLA2/VASC, and ABLA2/RHAL associations (Appendix 2, Table A2.13). Also, regeneration harvest alone or regeneration harvest followed by slash burning may not mimic fire in regenerating lodgepole pine stands. By leaving the soil less physically disturbed, opening serotinous cones, and providing many snags that shade new seedlings from the sun and protect them from the frost, regeneration after fires may be excessive whereas after harvest, regeneration may be poor or absent (Okanogan Area, ABLA2/VASC associations, Williams and Lillybridge 1983).

1e. To minimize potential impacts to snowshoe hare/lynx habitat from livestock grazing, DNR will continue to implement grazing guidelines and requirements that move the resources toward the conditions described by HB1309 Ecosystem Standards for State-owned Agricultural and Grazing Land.

Additional grazing guidelines for the Loomis State Forest are found in the Loomis Landscape Plan (1996b, p. 50), including:

1. **Limitation of grazing pasture units to no more than half the active growth period where geographically feasible.**
2. **Limitations on the quantity of top growth to be grazed; also, use of native plant species where possible, and control and minimization of the spread of noxious weeds.**
3. **Improvements of livestock distribution through multiple techniques, and deferment of livestock grazing on burned areas for one year after a fire, depending on fire intensity.**
4. **Evaluation and monitoring of cattle access to Riparian Management Zones after timber harvest, and provision of fencing or slash barriers where necessary to prevent cattle-induced stream bank damage.**

Within DNR-managed land covered by the Lynx Plan, 105,139 acres are subject to active grazing leases or permit ranges. Approximately 90,633 acres of those lands grazed are in the Loomis State Forest. Ninety eight percent of the total acreage grazed is under eight Grazing Permits (seven in the Loomis State Forest and one in the Little Pend Oreille block). Resource Management Plans have been developed for all DNR-managed lands that are grazed, including lynx habitat. The Resource Management Plans are designed to maintain the native plant community's structural complexity, vegetative cover, and plant species diversity that approximate the site potential. The plans are not designed to address the specific needs of individual species, including lynx. DNR works with permitees, other natural resource agencies, adjacent land managers, and other interests to implement Resource Management Plans on permit ranges.

No studies have directly addressed overlap between the diets of domestic cattle and snowshoe hare. However Johnson (1979) found a 51 percent overlap between cattle and black-tailed jackrabbits, and MacCracken and Hansen (1989) found that in Southeastern Idaho, cattle density can limit the density of jackrabbits and cottontails as a result of exploitative competition. Cattle stocking rates are apparently related to browsing damage on lodgepole pine seedlings, and increased cattle grazing pressure results in increased trampling damage to regenerating tree seedlings (>10 percent of sample trees; Pitt et al. 1998). Although trampling damage may be negligible if cattle movement and densities are adequately controlled (Mclean and Clark 1980), it can be substantial if the grazing period is too long.

2. **Quality snowshoe hare habitat, located within lynx Forage Habitat, will be maintained by providing adequate horizontal cover above average snow depth. Horizontal cover measurements will be taken in the 1.5-2.0 meter range of a vegetation profile board at 10 sample points along a transect. Four measurements will be taken from each sample point in the four cardinal directions viewed from 45 feet (15 m), resulting in a total of 40 measurements. Only those stands that receive no more than four "zero" scores (no cover) over the 40 readings will be considered Forage Habitat (for the definition of Forage Habitat, see Appendix 2, Section 7).**

Adams (1959) qualitatively asserted the positive relationship between cover density and hare density in Montana. Cover densities >40 percent within 3-5 feet (1-1.5 m) explained 85 percent of winter hare habitat use in northern Utah (Wolfe et al. 1982). "Refuges" with cover densities of approximately 75 percent (up to 12 feet or 4 m tall) were used by hares in winter near Fairbanks, Alaska (Wolff 1980). Cover 3-10 feet (1-3 m) above ground in the form of 50-60 percent conifer foliage cover values was identified as the single most important factor influencing snowshoe hare distribution in New Brunswick (Parker 1986). All of the above authors observed seasonal shifts in habitat use by hares to relatively more open (but still with cover) areas outside of winter. Orr and Dodds (1982) found lower hare densities in forests with trees >40 feet (12 m) tall and canopy closures of 60 percent (Nova Scotia). Adams (1959) observed that stands that were too dense to allow growth of forbs on the ground were less used than less dense stands but both categories were used more than open stands (Montana).

Although stem density and horizontal cover are correlated, the relationship is not precise (Swayze 1995), and the relationship between hares and stem density is not as clear as that of horizontal cover density (Litvaitis et al. 1985b). Nonetheless, stem densities reported in the literature are consistent across the hare's range: stands with approximately 6,000-14,000 stems/acre were intensively used by hares, especially in winter (Brocke 1975; Wolff 1980; Sullivan and Sullivan 1982, 1983; Litvaitis et al. 1985a,b; Monthey 1986; Koehler 1990b; Swayze 1995). In the Methow Basin, stems within hare's winter reach (max.

lowest live limb = 3.3 feet or 1m) were still used extensively at these high stem densities (Swayze 1995). According to Walker (2005), the density of saplings and medium-sized trees were the best predictors of snowshoe hare density at the stand level. In Idaho, Wirsing et al. (2002) found low snowshoe hare densities in study areas with less than 40 percent horizontal cover.

The critical characteristic of vegetation height within Forage Habitat is derived from the hare's limited ability to reach for browse above ground or snow level. Browse heights reported for snowshoe hare are generally within two to three feet (60-85 cm) of the average snow level (de Vos 1964, Brocke 1975, Grigal and Moody 1980, Parker 1986, Pease et al. 1979). Higher browse may be available to hares as the weight of winter snow depresses branches (de Vos 1964).

2a. Browse and tree cover will be provided by species preferred by hares (according to the vegetative association), if preferred species are identified for the area. Otherwise, forest regeneration efforts will focus on creating the structure (cover density) preferred by hares, rather than the tree species (Ferron and Oulett 1992).

In north-central Washington, Koehler (1990b) observed the highest densities of hares in 20-year old lodgepole pine stands, but no other forest types were sampled in that age range. Lynx tracking data in northern Washington show that Engleman spruce/subalpine fir forest types are important to and selected by lynx (Maletzke 2004). The author speculates that perhaps snowshoe hares are as abundant in Engleman spruce/subalpine fir forest as they are in lodgepole pine stands or that the stand structure of the former type results in higher predation success. However, high hare densities reported in dense lodgepole pine stands in the following locations also point to the importance of lodgepole pine as snowshoe hare habitat: British Columbia (Sullivan and Sullivan 1982, 1983), Montana (Koehler et al. 1979), and Yukon (Slough and Ward 1990). Also, de Vos (1964) suggested that pines are preferred browse. Other coniferous species may provide snowshoe hare habitat, especially in the eastern-most zones of lynx habitat in Washington (i.e. western hemlock and western redcedar). This probability is supported by the broad array of conifer species used by hares in other regions: Douglas fir (Bull Island on Flathead Lake in Montana: Adams 1959); red spruce (West Virginia: Brooks 1955; New Brunswick: Parker 1984); jack pine and black spruce (Hubbard Countyin north-central Minnesota: Pietz and Tester 1983); balsam fir, eastern arborvitae cedar, and white spruce (Itasca County in north-central Minnesota: Fuller and Heisey 1986); subalpine fir (48 percent of total collected pellets) and Douglas fir (28 percent) (northern Utah: Wolfe et al. 1982); subalpine fir (26 pellets/plot) and lodgepole pine (19 pellets/plot) (Utah: Clark (1973), cited in Dolbeer and Clark 1975); and mixed Engelmann spruce and subalpine fir forests and mixed spruce-fir-lodgepole pine forests (Colorado: Dolbeer and Clark 1975).

2b. Thinning, partial harvests, or other treatments to create forage opportunities in Travel Habitat will be considered. However, pre-commercial thinning will be delayed in Lynx Habitat until self-pruning processes have excluded most live lower limbs within 2 feet of the average snow pack level. The two exceptions are: stands included in an experimental program approved by USFWS and stands within DNR's Pend Orielle seed orchard (approximately 40 acres).

The effects of pre-commercial thinning on snowshoe hare habitat are being studied by the Rocky Mountain Experimental Station in Montana and the Forest Service in Oregon (Bull et al. 2005) among others. According to Sullivan and Sullivan (1988), although thinning in Forage Habitat may temporarily reduce the quality of a stand as lynx habitat, it may have long-term benefits by prolonging forage conditions within the stand. For example, thinning can release understory shrubs preferred by hares (*Salix spp*.) and make trees within the unit more accessible to hares by decreasing the distance of the lowest branch to the ground (Interagency Lynx Committee 1999; C. Lee, USFWS, pers. commun. and unpubl. field trip notes). The research of Bull et al. (2005) suggests that pre-commercial thinning of lodgepole pine in10-m-wide patch-cuts, dispersed across less than 50 percent of a stand, increased the abundance of snowshoe hares in the short term compared to traditional thinning and corridor thinning. Given the presumed limited availability of high-quality forage habitat currently present on DNR-managed lands it is preferable to take a conservative approach until more scientific data on the effects of pre-commercial thinning on snowshoe hare habitat is available.

2c. Riparian vegetation, such as willow thickets along wetlands, will be included as Forage Habitat.

Mowat and Slough (2003) observed both high densities of snowshoe hare within dense willow stands along creeks and lake edges, and lynx use of these habitats. Willow-alder thickets were thought to provide refuge for hares from avian predators in interior Alaska (Wolff 1980). Alder swamps provided good hare habitat in Minnesota (Green and Evans 1940) and Michigan (Bookhout 1965). Lynx were observed hunting along the edges of dense riparian willow (Major 1989).

3. To ensure that potential denning structure is available across the landscape, at least two den sites per square mile will be provided in all Lynx Management Zones (LMZs) where DNR manages at least one square mile.

Den sites will be at least five acres (2 ha), but many den sites will be located within larger areas of Denning Habitat in Lynx Analysis Units where DNR manages at least 20 percent of the area (see Guideline 4 below). According to this "best available" strategy, den sites will still be identified if site conditions do not match preferred structures, as indicated in the selection criteria.

Dispersion of Denning Habitat is believed to be important to lynx: Use of more than one den site was noted by Slough (1999), Koehler (1990a), and Koehler and Aubry (1994). Dispersing a number of suitable den sites within a short distance of each other may increase the survival of kittens because the female will be able to minimize the time the kittens must be left unprotected while she hunts for prey. This also minimizes the chance that all denning habitat would be eliminated during a fire event. The risk from fire may also be reduced by selection of sites with northerly aspects and low slope positions (Camp et al. 1997).

Priority for den site selection will be as follows:

3a. First priority for designation will be known lynx den sites.

3b. Second priority sites will be identified in pre-sale harvest unit inventories.

Den sites will have denning structure, defined as deadfall with large-end diameters of 6 inches (15 cm) or greater (including root wads), layered such that there is an average of >0.8 logs/3.3 feet (> 1 log/m) that are 1-4 feet (0.3-1.2 m) off the ground over a 150-foot (50 m) transect. Examples of preferred denning structure are depicted in the Lynx Habitat Field Reference Notebook (Interagency Lynx Committee 1999). Sites with larger deadfall diameters will be selected over sites with smaller deadfall diameters (Lloyd 1999), and sites will be preferred where deadfall covers at least 75 percent of a five-acre patch.

Koehler (1990a) described four dens (two each by two females) in north-central Washington as containing an average of 40 logs per 150 feet (50 m) of sample transect. Koehler and Aubry (1994) later described the debris as >1 log/3.3 feet (1 log/m), 1-4 feet (0.3-1.2 m) above ground. WDFW (1996) recommended logs at least 6 inches (15 cm) in diameter. Larger diameter logs likely have higher value as denning structure because they decay more slowly and provide a greater amount of sturdier cover. Windfall, insect or disease die-offs, and fire have historically been the source of this debris. This structure may be the most important characteristic of Denning Habitat, as suggested by Koehler and Brittell (1990) and discussed in Section 2.2 earlier. However, the den sites in Washington were in ≥250-year-old Engelmann spruce/subalpine fir/lodgepole pine stands on N or NE aspects (Koehler 1990a).

3c. Den sites within Denning Habitat will be preferred over den sites in other habitat types, following priorities listed in the Ecological Communities guideline 4.b. below. The priority of den sites within other types of habitats are as follows: Travel, Forage, and Temporary Non-lynx Areas.

3d. If no existing denning structure can be found, sites with insect or disease mortality or other potential to provide future denning structure via windthrow will be selected. Alternatively, den sites may be artificially constructed. DNR's region biologist will coordinate with WDFW to survey existing den sites and recommend details of artificial den size and structure. In addition:

3d.i. Logs used for artificial den site creation will reflect what is available on the site and within each section. If logs >6 inches (15cm) are available within a LAU, den site creation will be planned there. However, not all Denning Habitat that lynx occupy support such diameters. If no large diameter logs are available, log sizes used will reflect the largest available.

3d.ii. The maximum number of jack-strawed down logs possible will be used to create artificial den sites, given regeneration concerns and log availability.

3d.iii. Sites on north or northeast aspects will be selected over other aspects, if available.

3d.iv. Sites with mesic plant associations will be selected, if present.

3e. In the case of a large fire or other catastrophic event (defined as 640 acres (260 ha) or more where 40 percent of the trees or volume die or are at risk within 12 months of the event), designated den sites will still encompass the best available per section; that is, minimum 5-acre (2 ha) patches with standing trees, snags, and woody debris maintained for denning habitat recruitment.

4. Denning Habitat identified for the purpose of meeting the <u>denning habitat area requirement</u> (10 percent per Lynx Analysis Unit minimum, as described in LAU guideline 2b), where DNR manages 20 percent or more of a LAU, will be selected according to the criteria below. A map of the designated Denning Habitat in Loomis State Forest is presented in Figure 14. Denning Habitat designation in the Little Pend Oreille block is in process and a map will be available in the summer of 2006. Denning Habitat designation may change as habitat develops over time or as field verification finds better quality habitat available. As a result, the Denning Habitat GIS coverages will be regularly updated. Should some of the 10 percent be compromised by fire, pathogens, or other unforeseen events, new Denning Habitat will be added as indicated in Appendix 7.

The threatened status of lynx in Washington and the lack of information demand a conservative approach to Denning Habitat management. The difficulty is that this habitat type takes a relatively long time to develop. If the extent of these older forests is substantially reduced in the landscape, and future research reveals that this habitat is more important than originally suspected, it may take many decades before the habitat is again suitable for lynx. The philosophy in this habitat management plan is therefore to designate Denning Habitat based on what is known about lynx dens in Washington, and to make adjustments in the future as necessary. Denning Habitat may also benefit lynx by providing thermoregulatory cover and/or alternative prey opportunities.

4a. First priority Denning Habitat will contain known lynx den sites. WDFW and USFWS will provide the locations of known lynx dens to ensure that stands which currently or historically supported lynx dens are protected.

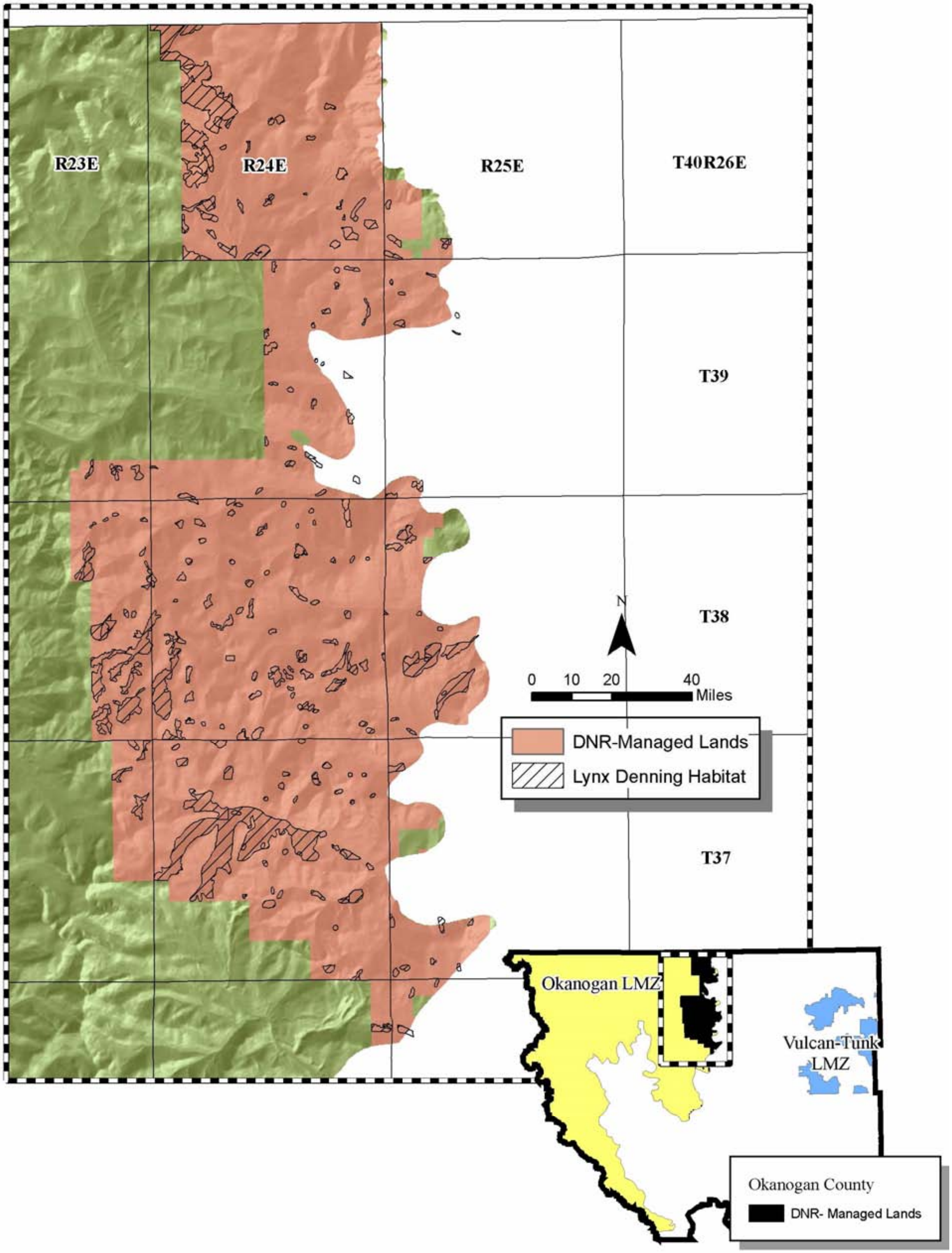
4b. Second priority Denning Habitat will be identified in pre-sale harvest unit Inventories. Denning Habitat will contain suitable denning structure, defined as deadfall with large-end diameters of 6 inches (15 cm) or greater (including root wads), layered such that there is an average of >0.8 logs/yard (1 log/m) over a 150 foot (50 m) transect that are 1-4 feet (0.3-1.2 m) off the ground. Stands with more than one potential den site will receive highest priority. Preference will be given to stands as indicated below:

- 4b.i. Mature to over-mature stands of spruce/fir or a similar mesic association with north or northeast aspects.
- 4b.ii. Stands that have mesic associations with other aspects and/or low slope positions.
- 4b.iii. Stands that have mature to over-mature overstories without mesic associations.
- 4b.iv. Stands with higher elevation, given similarities in structure, age, and aspect.

4c. If no existing den sites can be found, the Denning Habitat area requirement will be met with stands that have the potential to become Denning Habitat such as those with insect and/or disease mortality or other potential to provide future denning structure via windthrow.

4d. In the case of a large fire or other catastrophic event (defined as 640 acres (260 ha) or more where 40 percent of the trees or volume die or are at risk within 12 months of the event), designated den sites will still encompass the best available per section; that is, 5-acre (2 ha) patches with standing trees, snags, and woody debris maintained for Denning Habitat recruitment.

Figure 14. Designated Denning Habitat in Loomis State Forest



5. Potential human disturbance to den sites and Denning Habitat will be minimized.

WDFW (1996) recommended that harvest activity and use of motorized equipment be excluded within 0.25 mile (0.4 km) of any known denning sites during the lynx breeding season. Koehler (1990a) did not detect a detrimental influence of his presence at den sites on kitten survival. However, in more accessible areas, local predators may have learned to associate human scents with food. It is most important to be sensitive to this acclimation when prey is scarce. Therefore, the denning site disturbance buffer should also apply to passive human disturbance until lynx population recover from threatened status.

5a. Potential den sites will be located as far from roads as practical (the goal is 0.25 mile or 0.4 km, Lloyd 1999), where DNR manages 20 percent or more of a Lynx Analysis Unit (LAU). Passive human disturbance to known or suspected den sites will be discouraged.

5b. DNR will avoid harvesting non-designated Denning Habitat during the denning season (May 1 - July 31). Consultation with DNR biologists may also lead to application of seasonal timing restrictions if a sale area contains denning structure that is similar and contiguous to the best available in the section but lacks all structural components of the denning structure definition. For example, a sale in a LAU where DNR manages less than 20 percent of the LAU where only 5 acres of a 15-acre patch of denning structure is designated as a denning site.

5. Monitoring and Evaluation

This chapter describes how DNR will monitor and evaluate the implementation and effectiveness of this Lynx Habitat Management Plan. As part of implementation monitoring, DNR will report forest management activities, including timber sales, other silvicultural activities, road management and grazing program management, as well as management of human disturbances; conduct field checks; and re-assess the proportion of lynx habitat types across the landscape. Effectiveness monitoring will evaluate the suitability of the habitat being created under the guidelines, and the level of habitat use by snowshoe hare.

DNR's Northeast Region will conduct the implementation monitoring. DNR's Land Management Division will coordinate the effectiveness monitoring of the Lynx Plan, the biennial reporting to U.S. Fish and Wildlife Service and Washington Department of Fish and Wildlife, and future Lynx Plan evaluations and updates.

The information gained from monitoring will play a key role in the periodic evaluation of the plan and any revisions that may be necessary.

5.1 Implementation Monitoring

The purpose of implementation monitoring is to ensure that the guidance contained in the Lynx Habitat Management Plan is faithfully applied to DNR-managed lands within lynx range. Summarized information from implementing the 1996 Lynx Plan and the 2002 "take avoidance letter" for the period November 1996 through April 2004 is presented in Appendix 1. Future implementation monitoring reports will be provided to USFWS and WDFW biennially. The reports will continue to include three major components: 1) a report of the forest management activities (i.e., timber harvests, silviculture activities, road construction and management; and grazing program); 2) field checks of a sample of management activities to verify reporting; and 3) assessment of the landscape-level or Lynx Analysis Unit (LAU)-level lynx habitat conditions.

The reports will be delivered to USFWS and WDFW no later than 90 days following the end of the fiscal year (June 30th). The next report will be delivered to USFWS and WDFW no later than September 30, 2006 and will address activities that occurred between July 1, 2004 and June 30, 2006.

REPORTING OF FOREST MANAGEMENT ACTIVITIES

Timber Sales

The report will list the number, size, and location of all timber sales within DNR-managed lands covered by the Lynx Plan during the reporting period. For each sale, the report will describe the type of timber harvest that took place; describe the effects of timber harvest on forest structure and lynx habitat conditions; summarize the applicable Lynx Plan guidance that was applied to the sale design, associated road construction, and harvesting; describe any departures from guidance contained in this plan that may have been necessitated by local conditions; provide a detailed rationale for any such departures that occurred; and describe reforestation efforts.

Other Silvicultural Activities

The report will provide the same information (as for timber sales) for all other DNR silvicultural activities within DNR-managed lands covered by the Lynx Plan that influence forest structure and lynx habitat conditions.

Road Construction and Management

The report will list total miles of active and inactive roads on DNR-managed lands covered by the Lynx Plan, miles of roads newly constructed, miles of roads reconstructed, miles of roads moved from active to inactive status, and miles of roads permanently retired during the reporting period. For each newly constructed road, the report will describe how guidance contained in this plan was applied to road planning and construction.

Human Disturbance Management

Changes to snowmobile use areas, monitoring observations, and implementation of new strategies to discourage inappropriate use will be reported. Maps will be provided as necessary.

Grazing Program Management

The report will document annual monitoring of the permit ranges that occur within lynx range to document compliance with House Bill 1309 Ecosystem Standards for State-owned Agricultural and Grazing Land. Results will focus on annual utilization plot surveys, pasture rotations, range improvements, and adjustments made to the Coordinated Resource Management Plans during the reporting period. DNR staff is currently developing a process to collect and analyze field data on overall range conditions and trends using long-term nested frequency vegetation plots. The results will be reported in future implementation monitoring reports as budget and staff availability allows.

FIELD VERIFICATION OF THE LYNX PLAN IMPLEMENTATION AT STAND LEVEL

Each year DNR will field check a portion of its management activities within DNR-managed lands covered by the Lynx Plan to verify application of guidance contained in this plan and assess post-harvest conditions. The portion of management activities checked will vary from year to year, depending on the size of the timber sales' program and the resources available for monitoring; however, at least 20 percent of all timber sales or five timber sales, whichever number is smaller, will be sampled each year. Also, field checks will be carried out for all management activities that involve a departure from guidance contained in this plan. Field checks will include the collection of data necessary to assess the effects on lynx habitat conditions. WDFW and USFWS are invited to participate in all field checks, and results of field checks will be included in the biennial report furnished to WDFW and USFWS.

REPORTING OF LANDSCAPE LEVEL HABITAT CONDITIONS

Each year, DNR will update its assessment of the proportions of major lynx habitat categories (i.e., Temporary Non-lynx, Forage, Travel, Denning) within the North, Central, and South Loomis LAUs and the Little Pend Oreille Block. These assessments will address the effects of timber harvest and other management activities, fire and other natural causes of habitat loss, and habitat development as a result of both natural processes and silvicultural activities. Assessments will include the percentage of change by decade of Temporary Non-lynx areas and Travel habitat, according to DNR's "take avoidance" agreement. A description of the findings of the assessment and tables enumerating updated habitat proportions will be included in the biennial report furnished to USFWS and WDFW. For the 1996-2004 reporting period, this information can be found in Appendix 1, Section 4.

All GIS data layers on the distribution of different lynx habitat categories and snowmobile trails are stewarded by DNR's Land Management Division. They are available to all DNR staff as shared data and can be provided to USFWS and WDFW upon request.

5.2 Effectiveness Monitoring

The objective of effectiveness monitoring is to determine whether application of the guidance contained in the Lynx Habitat Management Plan results in anticipated habitat conditions. DNR does not have a commitment to monitor lynx on state lands. DNR has access to the WDFW database of lynx detections in Washington obtained by various agencies and individuals through snowtracking, radio-collaring or actual sighting of lynx, and DNR may use these data during management planning. Effectiveness monitoring will consist of two major components: 1) evaluating the suitability of the designated forest stands as Forage, Travel and/or Denning habitat, and 2) assessing snowshoe hare habitat use. Results of effectiveness monitoring conducted for the period 1997-2002 are presented in Appendix 2. In the future, results of effectiveness monitoring will be included with the biennial implementation report furnished to USFWS and WDFW. The first effectiveness monitoring report is due September 30, 2006, covering effectiveness monitoring activities from July 1 2004 through June 30, 2006.

EVALUATING FORAGE, TRAVEL AND DENNING HABITAT

Each year, samples of forest stands classified as Forage, Travel, and Denning habitat will be field checked to verify that forest structure required for forage, travel, or denning actually exists. Field checks will consist of repeated measurements of stand structure and assessment of key structural parameters of forage, travel and denning habitat definitions, such as trees per acre and horizontal cover. Initial emphasis will be placed on verifying the classification upon which the assessment of current conditions contained in this plan is based. Later, emphasis will shift to evaluating the effectiveness of the guidance contained in this plan to promote the development of new forage, travel, and denning habitat. Geographically, emphasis will be placed upon the three Loomis Lynx Analysis Units (LAUs) and the Little Pend Oreille Block. The amount of habitat sampled each year will depend on available monitoring resources. However, an average of at least 200 acres (81 ha) of forage habitat/temporary non-lynx areas, 100 acres (40 ha) of travel habitat, and 100 acres (40 ha) of denning habitat will be sampled each year. Additional information for habitat verification may be provided through inventory data, aerial photography and other remote sensing methods.

EVALUATING SNOWSHOE HARE HABITAT USE

Snowshoe hare use of different forest types and successional stages will be monitored to evaluate hare-habitat relationships. This is necessary because an adequate snowshoe hare abundance and distribution is a key component for lynx conservation and because the definition of Forage Habitat and Forage Habitat development strongly influences forest management activities on DNR-managed lands pursuant to guidance contained in this plan. Particular emphasis will be placed on evaluating hare response to timber harvesting and silvicultural activities. Monitoring will entail correlating hare habitat use data derived from pellet count transects with data on vegetation and other key habitat variables. The amount of habitat sampled each year will depend on the sampling design that is developed following the guidance in the 1996 Lynx Plan (WDNR 1996a) and the available monitoring resources. However, at least 6,565 feet (2000 m) of transects will be sampled each year.

COOPERATIVE RESEARCH

DNR is committed to participating in cooperative research, such as radio-telemetry studies of lynx and snowshoe hare habitat use or studies of hare and lynx population dynamics. DNR will provide logistical and financial support for these efforts to the extent that it is able to do so amidst other budget priorities. On its own, DNR will not undertake basic research of lynx or snowshoe hare ecology because DNR believes such research is primarily the responsibility of WDFW, federal fish and wildlife research units, and universities. Additionally, such studies are very expensive and are best undertaken as joint ventures supported by several partners. Cooperation allows each organization's resources to be used most efficiently, reduces overall costs, and ensures that all interested parties base their management programs upon the same data.

An example of DNR's participation in a cooperative research effort is the 1998 study, conducted jointly with Dr. John Weaver at the Wildlife Conservation Society, which was designed to determine the population status of lynx within the Loomis and LPO Block using DNA analysis of lynx hair. DNR also participated in an interagency effort with the Wildlife Conservation Society, USFS, and USFWS to survey lynx using the same technique in northeastern Washington, which included portions of the Little Pend Oreille Block.

5.3 Evaluation

This Lynx Plan will be evaluated every five years, or more frequently by mutual agreement between DNR, USFWS and WDFW. The purpose of these evaluations is to reflect upon five years of monitoring data and experience in carrying out forest management activities pursuant to guidance contained in this plan, as well as to incorporate new information on lynx habitat relationships or forest biology that may have arisen. Any changes to this plan that may be prompted by these evaluations will be made by mutual agreement between DNR, USFWS and WDFW.

DNR's Land Management Division will coordinate the Lynx Plan evaluations. Northeast Region staff will provide monitoring data and data on the management activities as well as technical support to prepare the evaluations.

In order to plan and conduct effective evaluations, it is essential that WDFW and USFWS provide DNR with timely information on changes in lynx conservation in Washington State. This information includes, but is not limited to, changes in the species conservation status; changes in Lynx Analysis Unit boundaries, known travel corridors, and known lynx den sites, etc.

Appendix 1 - Implementation Monitoring Report for the Period 1996-2004

Since the adoption of DNR's Lynx Habitat Management Plan in November 1996 (WDNR 1996a), DNR's Northeast Region biologists, foresters, and managers have continued to work together to ensure that the Lynx Plan is faithfully applied to DNR-managed lands within the lynx's range. Implementation monitoring included three major components, as outlined in the 1996 Lynx Plan: 1) reporting of forest management activities, 2) field checks of a sample of management activities to verify reporting, and 3) updating of landscape-level (Lynx Analysis Unit (LAU)) lynx habitat conditions. This appendix describes the results of implementation monitoring conducted from November 1, 1996 through June 30, 2004.

1. Implementation Planning

Planning activities associated with implementing the Lynx Plan occurred in six major areas: staff training, travel route identification, denning habitat designation, timber sale considerations, management changes for the Loomis State Forest, and negotiations regarding the "take avoidance" agreement with USFWS (USFWS letter dated 26 April 2002).

1.1 LYNX PLAN TRAINING

In January 1997, a training session was conducted to introduce DNR's northeast region staff to the guidelines contained in the Lynx Plan. The goals of the training were to familiarize participants with the different categories of lynx habitat, to delineate where lynx range occurs and when the plan is to be applied, and to introduce and discuss how the guidelines in the plan should be implemented. Twenty-eight DNR foresters and region staff completed the training. In addition, four biologists from WDFW (Region 1) attended. DNR foresters working on management activities within lynx range were asked to consult with the region wildlife biologist on all sales to ensure compliance with the lynx plan, and to complete denning habitat searches adjacent to sale areas. Summary checklists were revised in 2004 to assist DNR staff with future Lynx Plan implementation. (The lynx habitat implementation list is presented in Appendix 6.)

1.2 TRAVEL ROUTE IDENTIFICATION

Travel routes were reassessed in 2002 to accommodate changes in Lynx Analysis Unit (LAU) boundaries associated with the Washington State Lynx Recovery Plan (Stinson 2001). Travel routes were identified from USGS quads and digitized into GIS (see Figures 6-10 in the 2006 Lynx Plan). For DNR planning staff and managers, travel routes are available as a GIS data layer residing in the DNR corporate database. Travel route locations will be accessible to foresters for timber sale planning as a layer within the DNR State Uplands Viewing Tool in 2007.

1.3 DENNING HABITAT IDENTIFICATION

On the Loomis State Forest, designations of Denning Habitat have been completed in all sections to meet the denning dispersion guideline of 2 sites per square mile (see also "field checks" below). Larger blocks of denning habitat have also been designated to fulfill the requirements of protecting 10 percent of each LAU as Denning Habitat (see LAU guideline #1 in Chapter 4 of the Lynx Plan). Some of these are within the Loomis Landscape Plan's late successional forest blocks (25 percent of the subalpine fir and Douglas fir zones) distributed across the forest. A map of designated Denning Habitat in the Loomis State Forest has been created (see Figure 14 in the 2006 Lynx Plan) and will be maintained as a corporate GIS data layer. The Denning Habitat layer will be subject to changes over time as a result of improved forest inventory through field verification, and forest stand development.

Because little harvest activity has taken place in the Little Pend Oreille (LPO) block, searches for Denning Habitat have not been prioritized in the LPO. Thus, for most areas, the sites that are needed to meet the denning dispersal guideline have not been identified. However, a woody debris/potential den site checklist in the Lynx Monitoring Plan (WDNR 1997) was followed by contract crews during an extensive inventory of timber resources on the LPO during the summer of 1997. Preliminary field verification to identify suitable Denning habitat in the LPO occurred in the fall of 2004. The final denning designation for this area will be available in summer of 2006.

Lynx Denning Habitat locations will be accessible to foresters for timber sale planning as a layer within DNR's State Uplands Viewing Tool. For DNR planning staff and managers, Denning Habitat will be available as a GIS data layer residing in the DNR corporate data base.

1.4 HABITAT CONSIDERATIONS IN TIMBER SALES

Permanent travel routes have been identified and are incorporated into all timber sale boundaries. In addition, travel corridors are incorporated into sale design to allow movement of lynx throughout the sale area. Individual harvest units are evaluated for size, shape, and adjacency. Searches are also made of each sale area to ensure that the best Denning Habitat remains available to lynx. Every time a proposed sale enters a new section, the section is evaluated for potential Denning Habitat. Aerial photographs and inventory maps are inspected to locate the older stands (which are most likely to produce good Denning Habitat). Following this evaluation, actual field searches are conducted and the highest quality in the section is designated as Denning Habitat. If the best Denning Habitat available is within a proposed timber harvest unit, the sale will be modified to retain the Denning Habitat.

1.5 LOOMIS STATE FOREST PLANNING ACTIVITIES

The Board of Natural Resources approved the transfer of 24,677 acres of the Loomis State Forest from the Common School trust to conservation status in January 2000. The parcels transferred into conservation status are managed under the laws covering Natural Resource Conservation Areas (NRCAs). DNR's management plan for this NRCA was developed in 2003 (WDNR 2003). The remaining 110,000 acres of the Loomis State Forest are managed under the Loomis State Forest Landscape Plan (WDNR 1996b). This plan is being updated to reflect the changes in watersheds and ownership. Watershed analyses were conducted in the South Fork Toats Coulee and Sinlahekin Watershed Administrative Units (WAUs) and will be completed in 2006.

1.6 NEGOTIATIONS WITH USFWS FOR "TAKE AVOIDANCE" LETTER

During negotiations with USFWS to acquire an Agreement Letter to avoid the incidental take of lynx (2000-2002), DNR implemented interim measures that included 1) no addition of groomed or designated snowmobile trails or play areas, 2) no harvest of potential Denning Habitat during the lynx denning season, and 3) no pre-commercial thinning of high quality lynx Forage Habitat.

2. Forest Management Activities

Three types of forest management activities took place in the area covered by the Lynx Plan during the period 1996-2004: timber sales, other silvicultural activities, and road construction and management.

2.1 TIMBER SALES

Timber sales occurring within Lynx Management Zones (LMZ) during the reporting period are detailed in Table A1.1 (for Loomis State Forest), Table A1.2 (for Little Pend Oreille block), and Table A1.3 (for other areas). Most reforestation efforts on these timber sales will be by-hand planting, although some natural regeneration will also occur. Regeneration surveys will be conducted on all regeneration units approximately two years after harvest to ensure compliance with State Forest Practice standards. Following harvest, a complete forest inventory is planned at approximately two to six years for partial-cut units and 12-15 years for regeneration units as part of DNR's Forest Resource Inventory and Planning and Tracking systems.

2.2 OTHER SILVICULTURAL ACTIVITIES

Three types of silvicultural activities occurred in lynx habitat during the reporting period: pre-commercial thinning, broadcast burning, and. planting. Pre-commercial thinning was allowed under the Lynx Plan until DNR implemented its voluntary moratorium in April 2000, when lynx were federally listed. Two pre-commercial thinnings occurred on the Loomis State Forest in 1997 (Table A1.4). In 1999, four units totaling approximately 300 acres were pre-commercially thinned in Loomis. All stands were identified as Travel Habitat at the time. However, it is likely that they supported some level of hare use given their high tree densities. For example, the Crazy Cow unit was sampled in the fall prior to thinning and had relatively high pellet densities (15.4 pellets per plot). The thinning treatment was to "remove all surplus conifer trees more than two feet in height," reducing the tree density from 1200 trees per acre to 300 trees per acre. Cut trees were left on the ground. Over the summer of 1999, the rate of pellet accumulation on the site was the highest of 31 sites sampled on Loomis. Because the largest trees were retained, it was not surprising that treatment did not affect canopy cover (Wilcoxon signed rank (WSR) Z=-0.92, p=0.36). Horizontal cover above 1 m was affected (WSR Z=-2.20, p=0.028), decreasing almost 20 percent after treatment and becoming more variable (pre-thin mean=65.8 percent, 95 percent CI= 56.4-75.1 percent; post-thin mean=46.3 percent, 95 percent CI= 31.8-60.7 percent). As of 2002, there were still substantial numbers of hare pellets (9.2 pellets per plot), but rank had declined to fifth of the 31 study sites. DNR will continue to monitor this site.

In spring 1999, approximately 89 acres of harvested units on the Loomis were broadcast burned (Table A1.4). Burning is done to ensure that the sites reach their regeneration and forage habitat potential by reducing large amounts of slash that resulted from the lop-and-scatter process, stimulating the release of lodgepole pine seeds, releasing nutrients back onto the site, and improving the seedbed.

Table A1.1
Timber sales conducted within Lynx Range on the Loomis State Forest from November 1995 through June 2004

Timber Sale / LAU #	Date Sold	Status	Type of Harvest	Acres	Starting Habitat Category	Ending Habitat Category
Bugged Out *Central / #322*	11/95*	Complete 1997	Partial-cut (100-179 tpa) Partial-cut (11-99tpa)	148 59	Travel Travel	Non-Lynx Non-Lynx
Beetle juice *North / #302*	4/96*	Complete 1997	Partial-cut (11-99 tpa) Partial-cut (>180 tpa) Regeneration	43 300 210	Travel Travel Travel	Non-lynx Travel Non-lynx
W. Rabbit *Central / #322*	6/96*	Complete 1997	Partial-cut (11-99 tpa) Partial-cut (100-179 tpa) Partial-cut (>180 tpa) Regeneration	160 27 42 179	Travel Travel Travel Travel	Non-lynx Non-lynx Travel Non-lynx
Hope *South / #356*	5/96*	Complete 1997	Regeneration	63	Travel	Non-lynx
Lucky Foot *South / #356*	7/96	Complete 1997	Partial-cut (>180 tpa)	105	Travel	Travel
Chute *South / #356*	4/97*	Complete 1998	Partial-cut/ Regeneration Partial-cut (>180 tpa)	213 41	Travel Travel	Non-lynx Travel
Swamp Dog *South / #356*	1/98	Complete 1998	Partial-cut (11-99 tpa) Partial-cut (>180tpa) Regeneration	166 22 95	Travel Travel Travel	Non-lynx Travel Non-lynx
Big Rock *North / #302*	8/96*	Complete 1999	Partial-cut (0-99 tpa)1 Partial-cut (100-179 tpa) Partial-cut (>180 tpa)	362 123 75	Travel Travel Travel	Non-lynx Non-lynx Travel
Chow *Central / #322*	3/97*	Complete 1999	Partial-cut (0-99 tpa)1 Partial-cut (100-179 tpa) Partial-cut (>180 tpa)	307 87 65	Travel Travel Travel	Non-lynx Non-lynx Travel
Squeaky Clean *Central / #322*	12/97	Complete 1999	Partial-cut (0-99 tpa) Partial-cut (100-179 tpa) Partial-cut (>180 tpa)	173 132 10	Travel Travel Travel	Non-lynx Non-lynx Travel
Hilltop Basin *Central / #322*	10/99	Complete 1999	Partial-cut (0-99 tpa)	150	Travel	Non-lynx

tpa = trees per acre
*Forest practice application submitted prior to 1996 Lynx Plan adoption

Table A1.1 – continued

Timber Sale / LAU #	Date Sold	Status	Type of Harvest	Acres	Starting Habitat Category	Ending Habitat Category
Wickiup *South / #356*	10/98	Complete 1999	Partial-cut (0-99 tpa) Partial-cut (>180)	3 536	Travel Travel	Non-lynx Travel
Crazy Beetle *North / #302*	7/96*	Complete 2000	Partial-cut/Regenerat. Partial-cut (>180 tpa)	203 100	Travel Travel	Non-lynx Travel
Padded Paws *South +Central*	9/98	Complete 2000	Partial-cut (11-99 tpa) Partial-cut (>180 tpa)	382 47	Travel Travel	Non-lynx Travel
Nine Lives *North / #302*	1/99	Complete 2000	Partial-cut (0-179 tpa) Partial-cut (>180)	284 83	Travel Travel	Non-lynx Travel
Cougar Fork *Central / #322*	8/99	Complete 2000	Partial-cut (0-179 tpa) Partial-cut (>180)	368 10	Travel Travel	Non-lynx Travel
48 Deg. 45 Min. *Central / #322*	8/99	Complete 2000	Partial-cut (0-179 tpa) Partial-cut (>180)	332 40	Travel Travel	Non-lynx Travel
Timothy *South / #356*	9/97	Complete 2001	Partial-cut/ Regener. Partial-cut (>180 tpa)	368 84	Travel Travel	Non-lynx Travel
Top Dog *South / #356*	2/98	Complete 2001	Partial-cut (11-99 tpa) Partial-cut (100-179 tpa) Partial-cut (>180 tpa)	252 49 85	Travel Travel Travel	Non-lynx Non-lynx Travel
Monte Carlo *Central / #322*	3/01	Complete 2003	Partial-cut/Regeneration Partial-cut (>180 tpa)	183 86	Travel	Non-lynx Travel
Woodpile *South / #356*	2/01	Complete 2001	Partial-cut/Regeneration	166	Travel	Non-lynx
Tillman Mtn. *Central / #322*	2/01	Complete 2002	Partial-cut/Regen. Partial-cut (>180 tpa)	215 16	Travel	Non-lynx Travel
Bear Claw *Central / #322*	5/03	Complete 2004	Regeneration	336	Travel	Non-lynx
Chopaka *North / #302*	6/02	In progress 2004	Regeneration	330	Travel	Non-lynx
Chilson *South / #356*	6/02	In progress	Regeneration	262	Travel	Non-lynx
Cougar Mountain *South / #356*	06/04	No Activity	Regeneration	218	Travel	Non-lynx

tpa = trees per acre
*Forest practice application submitted prior to 1996 Lynx Plan adoption

Table A1.2
Timber sales conducted within Lynx Range on the Little Pend Oreille Block (LPO) from February 1995 through June 2004

Timber Sale / LAU #	Date Sold	Status	Type of Harvest	Acres	Starting Habitat Category	Ending Habitat Category
Sherry Divide *LAU 218 / 219*	2/95*	Harvested	Partial-cut	265	Travel	Mixed - Travel/Non-lynx
Sherry Basin *LAU # 219*	10/95*	Complete 1997	Partial-cut	700	Travel	Mixed - Travel/Non-lynx
Trading Post *LAU # 219*	9/97	Complete 2000	Partial-cut	188	Travel	Mixed - Travel/Non-lynx

*Forest practice application submitted prior to 1996 Lynx Plan adoption

Table A1.3
Timber sales conducted within Lynx Range outside of the Loomis State Forest and LPO from November 1996 through June 2004

Timber Sale	Date Sold	Status	Type of Harvest	Acres	Starting Habitat Category	Ending Habitat Category
Hoppit Pole	5/97	Complete 1997	Pole Sale	26	Travel	Travel
Skookum Root Rot	4/00	Complete 2001	Partial-cut/ Shelterwood	159	Travel	Mixed - Travel/Non-lynx
Stinger	5/00	Complete 2002	Partial-cut/ Shelterwood	185	Travel	Non-lynx
Crick	1/00	Complete 2001	Partial-cut/ Regeneration	205	Travel	Non-lynx
Twin	6/01	Complete 2003	Partial-cut/ Regeneration	328	Travel	Non-lynx
Last Byers Pole	3/02	Complete 2003	Pole Sale	30[1]	Travel	Travel
North Baldy	5/02	Complete 2003	Regeneration	95	Travel	Non-lynx
Belshazzar Ridge	2/03	Complete 2004	Regeneration	125	Travel	Non-lynx
Long Alec	3/03	In-progress 2004	Regeneration	313	Travel	Non-lynx
Swan	10/03	In progress 2004	Regeneration	41	Travel	Non-lynx
Seco	6/03	In Progress 2004	Regeneration	213	Travel	Non-lynx
Pend Oreille Pole	05/04	No Activity	Pole	70	Non-lynx	Non-lynx

[1]Total sale area was 111 acres but only 30 were within a Lynx Analysis Unit

Table A1.4
Pre-commercial thinning and broadcast burning conducted in the Loomis State Forest and LPO from November 1996 through June 2004

Year	Type of Activity	Timber Sale	Unit/Details	Acres	Habitat Change
1997	broadcast burn	Keep Cool Bugkill	1 2 3 4	22 33 34 23	Non-lynx to non-lynx
1997	Pre-commercial thinning	3 Forks	Retained >360 tpa	134	Travel to travel
		East 9 Mile	Retained >360 tpa	343	Travel to travel
1998	broadcast burn	W. Rabbit	2 5 7 10	17 11 9 8	Non-lynx to non-lynx
		Beetlejuice	6 7 8	20 25 12	Non-lynx to non-lynx
		Scattered Bugs	1 2 3	6 11 6	Non-lynx to non-lynx
1999	Pre-commercial thinning	3 Bucks	900 - 1,100 to 303 tpa	120	Travel to travel
		Branch Creek	1,100 - 1,300 to 303 tpa	22	Travel to travel
		Chopaka 2	1,300 - 1,700 to 538 tpa	18	Travel to travel
		Crazy Cow	1,100 - 1,300 to 303 tpa	140	Travel to travel
	broadcast burn	Sherry Basin	1	80	Non-lynx to non-lynx
		Beetlejuice	9	39	Non-lynx to non-lynx
2000	broadcast burn	Swamp Dog	4	29	Non-lynx to non-lynx
2004	broadcast burn	Chopaka	1	38	Non-lynx to non-lynx

From November 1996 through June 2004, planting activities occurring within DNR's lynx habitat included 2,056 acres on the Loomis State Forest, 461 acres on the LPO and 573 acres outside the two blocks. They are conducted to assure rapid regeneration and establishment of forage habitat (Table A1.5).

Table A1.5
Planting activities conducted from November 1996 through June 2004

Timber Sale	Location	Acres
Crazy Beetle Bug	Loomis (North LAU)	14
Bugged Out Bugkill	Loomis (Central LAU)	95
Cougar Fork	Loomis (Central LAU)	185
Padded Paws	Loomis (Central LAU)	56
Squeaky Clean	Loomis (Central LAU)	25
Swamp Dog	Loomis (Central LAU)	52
Top Dog	Loomis (Central LAU)	242
Hilltop Basin	Loomis (Central LAU)	69
Monte Carlo	Loomis (Central LAU)	118
Tillman Mountain	Loomis (Central LAU)	143
Timothy	Loomis (South LAU)	95
Woodpile	Loomis (South LAU)	53
Chow	Loomis (Central LAU)	95
Hare Again	Loomis (Central LAU)	128
Jumping Bugs	Loomis (Central LAU)	49
Keep Cool	Loomis (Central LAU)	196
Scattered Bug	Loomis (North LAU)	99
Nine Lives	Loomis (North LAU)	23
Beetlejuice	Loomis (North LAU)	217
W. Rabbit	Loomis (Central LAU)	202
Trading Post	Little Pend Oreille Block	178
Sherry Divide	Little Pend Oreille Block	268
Sherry Basin	Little Pend Oreille Block	15
Twin	other	328
Crick	other	245

2.3 ROAD CONSTRUCTION AND MANAGEMENT

DNR's road management plan for the Loomis Forest was re-evaluated in 1997 to reflect more accurately current status and future road building activities. Following on-the-ground field inspections of portions of the Loomis road system, it was determined that a significant portion of roads that were classified as "open" to public access were actually impassible to vehicles. Many of these roads were either blocked by tank-traps or boulders, or were overgrown. At the same time, other roads, which served little management function, were identified for potential closure. A review of the "potential" road system contained in the initial Loomis State Forest Landscape Plan (WDNR 1996b) also indicated that actual road building on the forest would be far less than anticipated. The Loomis Plan only indicated where road locations were best suited if every acre of the forest were to be harvested over the next 80-year cycle. Actual timber harvesting feasibility and other on-the-ground constraints were not considered. An estimate of potential road building and a cap on total road building was developed and incorporated into the plan for road management under the Loomis State Forest Landscape Plan (WDNR 1996b).

Road management in the Loomis State Forest has two planned phases. Phase 1, implemented in 1998, was to reclaim all roads that were not passable to meet state Forest Practice standards for abandoned roads. All roads that had potential for closure or abandonment were surveyed. The length of each road was measured with a hip chain, and data on the type of work needed to close the road were recorded. This included information such as timber condition behind the potential closure, drainage conditions, potential culvert removal, amount of brush and tree regeneration on the road, and other potential resource issues. Following the survey, a road abandonment plan and Forest Practice Application were submitted to the Forest Practices Division for approval. Fifty-nine miles of roads were approved for abandonment and closed to state standards in 1998, 5.6 in 1999, 0.42 in 2001, and 0.94 in 2003. In Phase 2 of the road management plan, an additional 70 miles (approximate) of open roads will be abandoned. Revised road density estimates based on the road management plan and 1997 evaluation are provided in Table A1.6.

Table A1.6
Road densities by LAU in the Loomis State Forest estimated for 1997 and for the future.

LAU #	1997 Open Road Density and length in miles	1997 Total Road Density and length in miles	Future Open Road Density and length in miles	Future Total Road Density and length in miles
North	0.73 mi/mi^2 31.6 mi	1.38 mi/mi^2 59.9 mi	0.49 mi/mi^2 21.1 mi	1.99 mi/mi^2 86.0 mi
Central	1.35 mi/mi^2 71.4 mi	1.81 mi/mi^2 95.7 mi	1.06 mi/mi^2 56.0 mi	2.05 mi/mi^2 108.0 mi
South	1.27 mi/mi^2 61.3 mi	1.55 mi/mi^2 75.1 mi	0.90 mi/mi^2 43.5 mi	1.79 mi/mi^2 86.4 mi

Also in 1997, DNR entered into a joint cooperative road management agreement for the Loomis State Forest with WDFW (WDNR 1998). All new roads currently being constructed will be closed to public access (vehicle), and procedures for closure and enforcement responsibilities are identified in the interagency agreement. Any non-agency vehicle on official business behind locked gates will be required to have a special vehicle access permit. No others will be permitted. To implement this procedure, a new lock system was implemented in 1998. Keys cannot be duplicated and are inventoried such that personnel must sign keys out before use.

New Forest Practice rules were adopted in early 2000 (WAC 222-24-010). These rules require road maintenance and abandonment plans to be completed by all large landowners. These are required for all Watershed Administrative Units (WAUs) regardless of the presence of endangered species. DNR has completed road maintenance and abandonment plans for the Loomis State Forest and LPO. These plans will be updated annually.

Table A1.7
Completed road construction and re-construction within lynx range

Year	Timber Sale	Miles of Road Construction	Miles of Road Re-construction
1997	Sherry Basin	2.36	0.57
	Lucky Foot	0.97	0.02
	W. Rabbit	2.41	1.22
	Hope	0.38	0
	Beetlejuice	2.79	3.21
	Bugged Out	2.08	0.13
1998	Crazy Beetle	3.52	2.09
	Big Rock	6.21	0.09
	Sherry Divide	1.07	0
	Chow	5.62	0.06
	Chute	4.05	0
	Squeaky Clean	2.12	4.69
	Swamp Dog	4.81	0
	Padded Paws	2.72	2.47
1999	Timothy	4.44	0
	Top Dog	4.67	0.91
	Wikiup	0.44	6.24
	Nine Lives	2.98	1.16
	Cougar Fork	2.24	1.20
	48 deg. 45 min.	4.11	0
	Hilltop	2.72	2.20
2000	Trading Post	0.47	0.66
	Monte Carlo	2.66	0
	Skookum Root Rot	0.78	1.83

Table A1.7 – continued

Year	Timber Sale	Miles of Road Construction	Miles of Road Re-construction
2001	Woodpile	2.24	0.10
	Tillman	1.65	1.27
	Stinger (Arcadia)	2.30	0.42
	Crick (North Columbia)	0.39	2.88
	Last Byers Pole	0	3.33
	Twin (North Columbia)	0.72	1.15
	Chopaka	0	1.1
2002	Chilson	0.32	3.94
	Juniper	0.2	0
	North Baldy	0.62	0.63
	Long Alec	0.2	1.6
	Bear Claw	1.7	2.1
2003	Belshazzar Ridge	0	1.47
	Last Byers Pole	0	0.076

All road locations in DNR lynx habitat are reviewed and designed to minimize the amount of necessary construction. On Loomis State Forest, open road mileage is limited to no more than 1.5 miles per square mile and the total road mileage (open + restricted) to no more than 2.5 miles per square mile as a result of the Loomis lawsuit settlement agreement. The current plan for the Loomis State Forest is to maintain the open road density near 1 mile per square mile. In 1998, new gates were installed on the Rabbit Basin road and on the system that accesses the Chow timber sale area. The gate on the Sinlahekin road was replaced with a stronger version. Miles of new road construction and re-construction completed in conjunction with harvested timber sales since adoption of the plan are provided in Table A1.7.

In future implementation reports, construction of new roads will be counted towards the 15 percent conversion to Temporary Non-lynx Areas per decade and will be reported as the area converted, not only as a list of road mileage built.

3. Field Verification of Lynx Plan Implementation at the Stand Level

All timber sales within lynx range were visited by a DNR biologist and some were visited by WDFW staff. No departures from the Lynx Plan were noted by region biologists in the sales designed under the Lynx Plan, aside from travel corridor changes noted below. Although no major sales were harvested in 1997 that were implemented under the Lynx Plan, all sales met guidelines contained in the plan, with the exception of travel corridors being 300 feet in width versus 330 feet.

Some travel routes were altered during timber sale planning:

- In 1997, two portions of the permanent travel route network shown in the Lynx Plan were modified, following field inspections, to more accurately reflect features of the landscape where lynx would potentially travel. The first was in the southwestern quarter of T38N R24E. The travel route was moved from a mid-slope location to follow Chickadee creek and an adjoining tributary.
- In sections 13 and 18 of T38N R23E and T38N R24E, travel routes were modified to follow directly along the ridge to the South Fork Toats Coulee creek and to fill in a gap in the travel route along the creek that was inadvertently left out. These modifications have been digitized into GIS and are currently in the Northeast region database.
- In 1998, one travel route in T38N R25E was modified to better coincide with features of the landscape. The travel routes, which lie northeast and southwest of Wickiup creek, were extended along the ridgelines to meet the travel route along Wickiup creek instead of cutting across section 31.
- In 2001, associated with the North Baldy 12 timber sale, a travel corridor along the southeastern edge of the sale area was extended for the length of the sale area to maintain east-west connectivity. The cover provided by the corridor will be especially critical considering the non-lynx habitat adjacent and south of the sale area. Given the insect-caused mortality at this site, natural vegetation along the corridor may not always contain the required 180 trees per acre for travel cover. Nevertheless, the sale will minimize cover losses through minimal disturbance to the corridor.
- Also in 2001, one of two parallel sets of travel corridors associated with the Belshazzar timber sale was removed. The retained north-south corridors followed true ridgelines whereas the east-west corridors were redundant.

Denning and late successional forest (LSF) habitat searches were conducted within all three Loomis LAU's during the summers of 1998-2000. The purpose of these searches was to identify the best available Denning Habitat within each section of the forest. Two Denning Habitat patches (minimum of 10 acres per section) have been designated for every section within lynx range on the Loomis, outside of the Natural Resource Conservation Area (NRCA) transfer area. In addition, a photo interpretation and ground-truthing exercise helped identify larger blocks that have the potential for Denning Habitat designation, in order to reach the goal of 10 percent per LAU. Approximately 1,200 forest inventory plots were completed in 1998 within these areas. By 2000, 9,059 acres of Denning Habitat were designated across Loomis State Forest. Although most of the Denning Habitat is also designated as late successional forest, a few non-LSF patches were designated as Denning Habitat depending on the abundance of down wood and availability within a section. A few patches of LSF habitat that were not classified as Denning Habitat were also designated for protection. A total of 2,310 acres have been designated as small patches of late successional forest habitat.

Denning Habitat was preliminarily identified from DNR's forest inventory data for the Little Pend Oreille block (LPO) in 2002 and field verified during the fall of 2004. Additional Denning Habitat has been designated to meet dispersal requirements in each section and to meet the 10 percent per LAU requirement. This data layer will be digitized and available in the GIS database by the summer of 2006.

Some temporary travel corridors between harvested units are managed to remove dead and dying lodgepole pine. Tree densities remaining in these "M-units" varies depending on species present and other environmental factors. The 1996 Lynx Plan specifies that at least 180 tpa (445 trees per ha) will be retained following harvest to qualify as Travel Habitat. Inventory plots were placed in M-units following harvest to ensure compliance with this guideline. A minimum of 5 plots or one plot for every 5 acres (whichever was greater) were randomly placed within each unit. All plots were 1/10 acre (37.28 feet or 12 m radius) in size. In 1999 and 2000, conifer trees 8 feet (2.4 m) tall and greater, deciduous trees >5 inches (12.7 cm) dbh, and dead conifers >5 inches (12.7 cm) dbh were counted separately. All of the "M-units" surveyed exceeded the minimum 180 trees /acre requirement (Table A1.8) and thus remained in Travel Habitat.

Table A1.8
Density of trees retained in managed travel corridors on the Loomis State Forest, by timber sale.

Year	Timber Sale/Unit	Size (ac)	Live Conifers/acre	Dead Conifers/acre	Deciduous Trees/acre	Total Trees/acre
1999	Chow Lodgepole: M-1	19	302	84	6 live	392
	M-2	8	246	52	2 live	300
	M-3	7	274	160	14 live, 4 dead	452
	M-4	3	228	72	none	300
	M-5	7	352	140	none	492
	M-7	11	160	106	14 live, 4 dead	284
	M-8	5	306	86	4 live, 2 dead	404
	Beetle Juice Bug Kill: M-1	71	336	30	none	366
	M-2	19	272	46	2 live	320
	M-3	10	472	98	84 live, 20 dead	674
	M-4	29	412	144	none	556
	Jumpin Bugs Lodgepole: M-1	11	204	84	14 live, 14 dead	316
	Squeaky Clean Lodgepole: M-1	6	178	86	none	264
	M-2	4	322	82	none	404
	Hare Again: M-1	7	440	54	none	494
	M-2	9	397	108	none	505
	Swamp Dog Lodgepole: M-1	22	852	138	none	990

Table A1.8 – continued

Year	Timber Sale/Unit	Size (ac)	Live Conifers/acre	Dead Conifers/acre	Deciduous Trees/acre	Total Trees/acre
1999 cont.	Scattered Bugs Bugkill: M-1	11	340	42	none	382
	M-2	8	544	58	none	602
	W. Rabbit Bugkill: M-1	3	412	144	none	556
	M-2	10	472	98	none	570
	M-3	7	660	106	none	766
	M-4	22	926	138	none	1064
	Chute Lodgepole: M-1	7	338	48	none	386
	M-2	34	442	122	none	564
2000	Nine Lives: M-1	27	260	56	none	316
	M-2	12	376	36	none	412
	M-3	3	270	56	none	326
	M-4	41	281	26	none	307
	Crazy Beetle: M-2	19	250	42	none	292
	M-4	10	882	470	none	1,352
	M-5	36	338	112	none	450
	Cougar Fork: M-1	21	236	38	none	280
	M-2	4	322	82	none	404
	Timothy Lodgepole: M-5	7	408	98	none	506
	M-8	3	344	64	2	410
	48 Degrees 45 Minutes: M-1	28	250	26	none	276

In 1999 and 2000, regeneration surveys were conducted in several old timber harvest units within Loomis to determine if the growth of young trees is sufficient for these areas to be reclassified from Temporary Non-lynx Areas to either Travel Habitat or Forage Habitat. Plots were only placed in units that were harvested at least 10 years prior to the survey. Plots were randomly distributed within a unit at a density of one plot for every 5 acres (2 ha). Within each 1/100th acre plot all live coniferous trees greater than 8 feet (2.5 m) in height were counted. All of the plots within a unit were averaged to get a total tree count per acre. Horizontal cover was measured using a four-quadrant cover board at 45 feet (15 m) from the plot center in the four cardinal directions. Cover values from the 3 - 6 feet (1 – 2 m) height interval on the cover board were used to determine percentage of horizontal cover, as specified in the 1996 Lynx Plan (Forage Habitat definition) and assuming an average 3 feet (1 m) of snow depth. Overhead cover was determined at each plot center using a densiometer. In 1999, all of the units sampled were found to meet either the minimum requirements for inclusion as lynx Travel Habitat (>180 tpa >8 feet or 445 trees/ha > 2.4 m) or the minimum horizontal cover requirement (>40 percent horizontal cover) to be included as lynx Forage Habitat (Table A1.9a). Of the units sampled in 2000, 1,286 out of 1,291 acres in two LAUs were determined to qualify as Forage Habitat (Table A1.9b.).

Table A1.9a
Results of the 1999 regeneration / lynx habitat surveys by Loomis LAU

LAU #	Unit No.	Unit Size (acres)	Location (Section-Town-Range)	Year Harvested	Trees/Acre ≥8' tall	Horizontal Cover %	Overhead Cover %
North	1	3	3-39-24	1985	650	56	69
#302	2	10	1-39-24	1987	1,350	51	40
	3	20	1-39-24	1987	425	44	16
	4	20	25-40-24	1976	300	56	28
	5	120	11-39-24	1985	1,281	64	46
	6	4	1-39-24	1970	2,433	62	56
	7	3	12-39-24	1984	850	56	43
	Total	180					
Central	1	5	14-38-24	1986	1,150	74	61
#322	2	13	27-39-24	1988	960	83	76
	3	12	4-38-24	1984	1,575	84	52
	4	63	34-39-24	1985	913	67	21
	5	10	15-38-24	1986	1,267	78	60
	6	55	13-38-24	1984	579	41	82
	7	6	5-38-24	1986	1,800	84	55
	8	6	33-39-24	1988	1,067	60	58
	9	50	9-38-24	1986	825	56	47
	Total	220					
South #356	1	55	28-37-24	1989	218	37	43

Table A1.9b
Results of the 2000 regeneration/lynx habitat surveys by Loomis LAU

LAU #	Unit No.	Unit Size (acres)	Location (Section-Town-Range)	Year Harvested	Trees/Acre ≥8' tall	Horizontal Cover %	Overhead Cover %
Central	1	46	2-38-24	1986	1,312	61	29
#322	2	50	25-38-24	1987	1,307	59	45
	3	5	3-38-24	1987	200	31	21
	4	50	25-38-24	1987	540	62	24
	5	200	3,10,11-38-24	1987	1,067	54	31
	6	300	22,23-38-24	1986/87	1,282	60	20
	Total	651					
South #356	1	640	25-37-24	1984	419	58	46

4. Results from Implementation Monitoring at the Landscape Level

Changes in the proportions of the major habitat categories for the period 1996-2004 were calculated for each LAU within the Loomis State Forest (Table A1.10). Habitat changes were calculated by subtracting all harvested acres in each habitat category from the totals established in the 1996 Lynx Plan (WDNR 1996a, Appendix C). The greatest change between lynx and non-lynx habitat occurred in Loomis Central LAU (2,592 acres or 1,050 ha of Travel Habitat changed to Temporary Non-lynx Habitat) and the least change occurred in Loomis South LAU (110 acres or 45 ha of Travel Habitat changed to Temporary Non-lynx Habitat). The number of acres of identified Forage Habitat and Denning Habitat increased for all LAUs but the LPO Block, where no field checks of Forage Habitat occurred. The total amount of Temporary Non-lynx Habitat created from Forested Habitat between November, 1996 and June 30, 2004 was: LAU North 1,359 acres (6 percent), LAU Central 2,928 acres (9 percent), LAU South 590 acres (3 percent), and LPO block 547 acres (4 percent).

Table A1.10
Changes in the landscape-level habitat conditions from 1996 to 2004 within the Loomis State Forest and the Little Pend Oreille Block.

	Open Area (acres)	Temporary Non-lynx (acres)	Forage (acres)	Travel (acres)	Denning (acres)
LAU North					
1996	3,018	1,956 (9%*)	52 (0%)	18,218 (82%)	1,906 (9%)
1997	3,018	2,494	52	17,680	1,906
1998	3,018	2,494	52	17,680	1,906
1999	3,018	2,799	232	17,195	1,906
2000	3,018	3,083	232	16,330	2,487
2001	3,018	3,083	232	16,330	2,487
2002	3,018	3,315	232	16,098	2,487
2003	3,018	3,315	232	16,098	2,487
2004	3,018	3,315 (15%*)	232 (1%)	16,098 (73%)	2,487 (11%)
Change for the period 1996-2004		**+ 6%**	**+1%**	**- 9%**	**+ 2%**
LAU Central					
1996	2,696	5,172 (17%*)	0	24,994 (81%)	839 (3%)
1997	2,696	6,142	0	24,024	839
1998	2,696	6,403	0	23,763	839
1999	2,696	7,032	220	22,914	839
2000	2,696	7,463	871	19,539	3,132
2001	2,696	7,764	871	19,238	3,132
2002	2,696	7,764	871	19,238	3,132
2003	2,696	8,100	871	18,902	3,132
2004	2,696	8,100 (26%*)	871 (3%)	18,902 (61%)	3,132 (10%)
Change for the period 1996-2004		**+ 9%**	**+ 3%**	**- 20%**	**+ 7%**
LAU South					
1996	4,300	3,495 (13%*)	504 (2%)	21,493 (81%)	921 (3%)
1997	4,300	3,558	504	21,430	921
1998	4,300	3,763	504	21,225	921
1999	4,300	3,711	504	21,277	921
2000	4,300	3,071	1,144	18,758	3,440
2001	4,300	3,605	1,144	18,224	3,440
2002	4,300	3,867	1,144	17,962	3,440
2003	4,300	3,867	1,144	17,962	3,440
6/30/2004	4,300	4,085 (16%*)	1,144 (4%)	17,744 (67%)	3,440 (13%)
Change for the period 1996-2004		**+ 3%**	**+ 2%**	**- 14 %**	**+ 10%**

* Percentage of the lynx habitat matrix' total area (Temporary non lynx + Travel + Forage +Denning habitat)

Table A1.10 – continued

LPO Block					
1996	469	2,039 (13%*)	381 (3%)	12,158 (80%)	700 (5%)
1997	469	2,492	381	11,675	700
1998	469	2,492	381	11,675	700
1999	469	2,492	381	11,675	700
2000	469	2,586	381	11,581	700
2001	469	2,586	381	10,881	1,400
2002	469	2,586	381	10,881	1,400
2003	469	2,586	381	10,881	1,400
2004	469	2,586 (17%*)	381 (3%)	10,881 (70%)	1,400 (10%)
Change for the period 1996-2004		**+ 4%**	**0%**	**- 10%**	**+ 5%**

Appendix 2 - Effectiveness Monitoring Report: Evaluating Snowshoe Hare Use of Northeastern Washington Forest Types 1997-2002

1. Introduction

The objective of effectiveness monitoring is to determine whether applying the guidance contained in the Lynx Habitat Management Plan results in anticipated habitat conditions. Effectiveness monitoring of the 1996 Lynx Plan consisted of two major components: 1) evaluating the suitability of the designated forest stands as Forage, Travel and/or Denning habitat, and 2) assessing snowshoe hare habitat use. Results of the effectiveness monitoring conducted from 1996 through 2002 are presented below. Results of the snowshoe hare pellet study were applied to develop a new definition of lynx Forage Habitat.

For land managers operating in the range of snowshoe hare, understanding the distribution of snowshoe hare in forested habitats is a first step in managing habitat for forest carnivores, especially lynx. The category of "lynx forage habitat," habitat that supports high densities of snowshoe hare, plays a key role in DNR's Lynx Plan. A study designed to evaluate snowshoe hare habitat use within lynx habitat range was conducted as part of the effectiveness monitoring of the 1996 Lynx Plan. This is a first step in the effort to expand our understanding of where snowshoe hare occur along a forest successional gradient, and it will enable DNR to make more educated decisions about lynx habitat management.

Objectives and summary of the snowshoe hare habitat relationship study are presented in Sections 2 and 3 below. A detailed description of the study design, statistical methods, data analyses results, and discussion are presented in Sections 4 through 6. The process of developing a new lynx forage habitat definition and discussion of the definition are presented in Section 7 of this Appendix.

2. Objectives

This study had two main objectives:

1. To expand the knowledge of snowshoe hare habitat use in forests of northeastern Washington.

2. To develop a new definition of lynx forage habitat based on information about snowshoe hare habitat use.

The following were the working hypotheses:

1. Hare pellet densities would be higher in Loomis State Forest than in the Little Pend Oreille block.

2. Forest stages with dense cover (young stands as well as older stands with understory) would have more pellets than stages with low cover.

3. Pellet densities would differ by ecosystem type or plant association, favoring lodgepole pine.

3. Summary

To evaluate snowshoe hare habitat use on DNR-managed lands within lynx range, a pellet study was conducted. Habitat occupancy by snowshoe hares was indexed by the number of fecal pellets per habitat. The number of pellets is known to be related to the abundance of snowshoe hares (Litvaitis et al. 1985a, Krebs et al. 1987, Krebs et al. 2001, Murray et al. 2002).

3.1 STUDY AREA AND METHODS

Hare pellets were sampled in different forest types and successional stages in two landscapes: Loomis State Forest (Loomis) and Little Pend Oreille Block (LPO). A total of 58 stands were sampled in Loomis and 32 stands were sampled in LPO. Sampling in the Loomis and LPO was originally stratified according to ecosystem type and age class from existing forest inventories. Three ecosystem types were recognized for each study area: wet subalpine fir, dry subalpine fir, and Douglas fir for Loomis; and western hemlock, western redcedar, and grand fir for LPO. Disturbance histories of the sites ranged from unmanaged to sites harvested within the last 30 years.

Within each surveyed stand, ten pellet plots were installed along a "U" shaped permanent transect 810 feet (270 m) long. Pellets were initially removed from the plots in the fall when transects were established. Pellets were then counted and removed in the spring and fall of each sample year, except in 2002, when pellets were counted in fall only. Detections of lynx alternative prey (grouse and squirrels) as well as deer and cattle were noted at any location along the transects.

The physical characteristics of the site recorded at each transect were slope, aspect and elevation. The species of vegetation browsed by hares (woody stems, needles, and forbs) within 3 feet (1 m) of the 12-inch (0.3 m) pellet plots was recorded in categories reflecting quantity of browse marks.

Standard forest structure measurements were also taken at four stations per transect, including tree height, diameter, tree densities by species and size class, snag height and diameter, etc. At each pellet plot (10 per transect), vegetation was sampled in three cover categories: 1) overhead (canopy), 2) ground, and 3) horizontal cover.

3.2 KEY FINDINGS OF THE HABITAT USE ANALYSES

1. Pellet densities in LPO ranged from 3.1 pellets/m^2 (in year 2000) to 4.7 pellets/m^2 (in 1999 and 2001). In Loomis the lowest density was 4.8 pellets/m^2 (in 1997) and the highest was 15.9 pellets/m^2 (in 1998). Translated into hare abundance these data result in 0.173-0.348 hares/ha on LPO and 0.3-0.7 hares/ha on Loomis (mean of all transects over all years studied). A minimum of 0.5 hares/ha is thought to be necessary to sustain lynx in northwestern Canada (Ruggiero et al. 2000).

2. Both the highest and lowest values of hare densities observed on Loomis and LPO are lower compared to northern hare populations where lynx have been studied, but similar to those reported from other southern areas.

3. The ten sites with highest pellet densities reflected what sites were available on the landscape. These were stands dominated by Douglas fir, lodgepole pine, Engelmann spruce, and subalpine fir.

4. Horizontal cover between 3-6 feet (1-2 m) was the most highly correlated habitat characteristics to mean pellet abundance on both study areas.

5. No clear stand age-pellet relationships were seen on LPO, the study area with available stand age data.

6. Sites with many pellets had more cover by shrubs and moss, more medium trees (1-5.5 inches dbh) and fewer large snags (>5.5 inches dbh).

7. Tree species significantly correlated with hare pellet abundance on LPO were grand fir, western redcedar, and western hemlock. Negative correlations were observed between pellets and larger lodgepole pine (5-15 inches dbh). On Loomis, pellet abundance correlated negatively with larger Engelmann spruce (5-15 inches dbh) and Douglas fir (25-30 inches dbh).

8. Multivariate analyses identified potential habitat variables, which can explain approximately 20 percent more variation in pellet densities than our best *a priori* model.

9. The average observations of browsed shrubs exceeded conifers, and overall browsed items were more diverse in LPO, where shrubs were broadly distributed. Shrubs and conifers were browsed similarly on Loomis.

10. Alternative lynx prey was well distributed on sites occupied by hares, from sites with few to many pellets. The presence of red squirrels and grouse were related to

the abundance of pellets on LPO but not Loomis. Ungulates were also well distributed on the sites, suggesting opportunities for browse competition.

11. Cattle presence was more common on Loomis than LPO; was negatively correlated with pellet abundance on Loomis; and was more frequent on sites with few rather than many pellets.

12. Multivariate analyses did not identify a relationship between a stand canopy multistory and hare pellet abundance.

3.3 DEVELOPMENT OF A NEW LYNX FORAGE HABITAT DEFINITION

1. The results of this study suggest that the definition of Forage Habitat used in the 1996 Lynx Plan (WADNR 1996a) was based upon sound habitat relationships.

2. However, the definition was inadequate in at least two ways. First, some types of older stands contribute to hare habitat and therefore should eventually be included as Forage Habitat. Second, the threshold value of 40 percent horizontal cover was too low, allowing many low-density hare sites to be included in the forage habitat category.

3. A revised forage habitat definition could be based on horizontal cover scores. The success in accurately classifying forage habitat using this variable was 87.5 percent for Loomis and 90.5 percent for LPO.

4. Forage Habitat is defined through horizontal cover above average snow level. The stand qualifies as forage habitat when it has no more than four zero scores (no cover) measured in 40 readings (four readings taken at each of the 10 sampling points on a transect within the 1.5-2.0 m range of a vegetation profile board viewed from 45 feet (15 m) in the four cardinal directions from the plot center.

5. The definition was based on a relatively small sample in LPO.

6. An additional variable, density of grand fir, was necessary to minimize the error when using the definition on LPO.

7. When applying the new forage habitat definition to both areas, DNR can anticipate that the highest risk of misclassification error will occur in older stands.

4. Methods

4.1 STUDY AREA

This study was conducted on two blocks of land managed by the Washington Department of Natural Resources that have been delineated as lynx habitat (WDW 1993, Stinson 2001).

- The larger block of habitat (32,167 ha), in the higher elevations of the Loomis State Forest (1220–2500 m), occurs within the Thompson Okanogan Highlands Ecoprovince. On the eastern edge of the Cascade mountains, the Loomis study area includes two major forest zones: Douglas fir (PSME) and subalpine fir (ABLA) (Williams and Lillybridge 1983). Many of the subalpine fir sites are currently occupied by lodgepole pine (PICO). Engelmann spruce (PIEN) and western larch (LAOC) are also common. Lynx were studied on parts of the Loomis study area in the mid-1980's (Brittell et al. 1989, Koehler 1990b) and reproducing lynx continue to be tracked there (M. Skatrud, pers. comm.).
- The second and smaller (6,145 ha) study area, the Little Pend Oreille Block (LPO), occurs in the mixed conifer zone of Shining Mountains Ecoprovince (Ruggiero et al. 1994). Mixed conifer forests of the LPO contain 10 primary coniferous species with western redcedar (THPL), western hemlock (TSHE), and grand fir (ABGR) plant associations being the most common (Williams et al. 1995). Elevations range from approximately 1,000 m to just over 1,350 m. The last lynx sighting in the area was in 1996 (Stinson 2001). Since then, one animal was videotaped there in the summer of 2004 (USFWS videotape).

Sampling on the Loomis and LPO was originally stratified according to ecosystem type and age class from existing forest inventories. Three ecosystem types were recognized for each study area: wet subalpine fir, dry subalpine fir, and Douglas fir for Loomis and western hemlock, western redcedar, and grand fir for LPO. Major plant associations within each type are listed in Table A2.1 (for an explanation of the abbreviations see Appendix 4). After field verification, sampled sites were regrouped according to the dominant species (Table A2.2) within the three size classes of tree data: large tree (>5.5 inches dbh), medium tree (1-5.5 inches dbh), and seedling (<1 inch dbh). On LPO, four groups were identified: ABGR, THPL, PICO and PSME. On Loomis, the groups were ABLA, PICO, PIEN, and PSME. Two age class stratifications were selected to ensure that relatively infrequently occurring young stands were sampled. "Recently disturbed stands" included those that had had harvest activity within the past 30 years. "Older stands" included all other forested management units. The type of disturbance, such as regeneration harvest versus commercial thinning, was not considered in this classification. At both study areas, final stand selection was constrained by accessibility, as parts of each study area remain unroaded.

Table A2.1
Major plant associations occurring within each ecosystem type by study area *

Loomis State Forest		
Wet Subalpine Fir	**Dry Subalpine Fir**	**Douglas fir**
ABLA2/RHAL ABLA2/LIBOL ABLA2/VACCI PIEN/EQUIS	ABLA2/CARU ABLA2/VASC-CARU ABLA2/VASC	PSME/ARUV PSME/VACCI PSME/CARU PSME-PIPO/AGIN PSME/SYAL
Little Pend Oreille Block		
Grand Fir	**Western Hemlock**	**Redcedar**
ABLA/VASC ABGR/LIBO	TSHE/CLUN ABLA/VASC	THPL/CLUN THPL/ATFI PSME/PHMA

* For an explanation of plant association abbreviations see Appendix 4.

4.2 FIELD METHODS

Pellet counts

Snowshoe hare habitat occupancy was indexed by the number of fecal pellets per habitat. The number of pellets is related to the abundance of snowshoe hares (Litvaitis et al. 1985a, Krebs et al. 1987, Krebs et al. 2001, Murray et al. 2002). Although this relationship has not been specifically confirmed in our study area, the broad success of pellet count methods for estimating relative abundance of hares and rabbits (Ångerbjorn 1983, Wood 1988) suggests that the technique is robust and appropriate for the indirect interpretation of habitat occupancy patterns at the scale of this study.

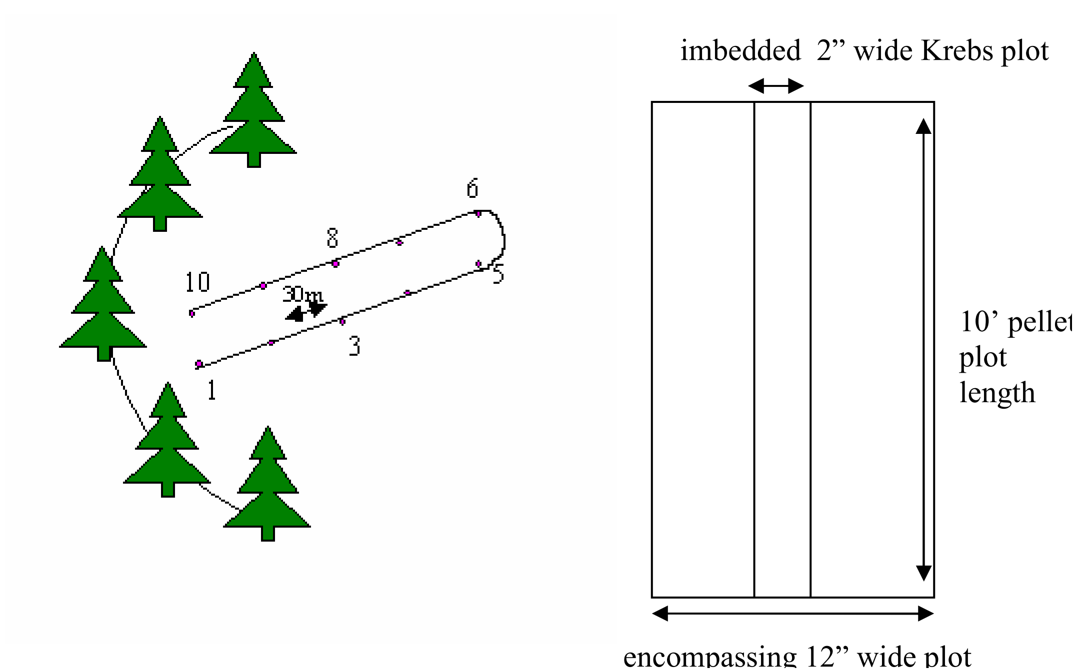
Table A2.2
Number of sampled stands on Loomis State Forest and Little Pend Oreille Block grouped by dominant tree species and disturbance regime

Age Classes	**LOOMIS STATE FOREST**				**LITTLE PEND OREILLE BLOCK**				
	ABLA	**PICO**	**PIEN**	**PSME**	**ABGR**	**PICO**	**PSME**	**THPL**	**Total**
Recently Disturbed	1	9	2	13	4	4	6	6	45
Older	4	7	11	11	3	3	4	2	45
Total	5	16	13	24	7	7	10	8	90

Within each surveyed stand, ten pellet plots were installed along an 810-foot (270 m) "U" shaped transect (Fig. A2.1a). Transects started approximately 120-feet (40 m) from the edge of each stand in the most homogenous region identified from an aerial photograph or orthophoto. Long, narrow pellet plots 2 inches x 10 feet (5 cm x 300 cm), also known as Krebs plots (Krebs et al. 1987, Krebs et al. 2001), were established every 90 feet (30 m) with random orientation. To improve the probability of encountering pellets in the suspected low-density study areas, pellets were also counted in larger 12 inches x 10 feet (30 cm x 300 cm) plots that centered on and overlapped the Krebs plots (Fig. 1b). Pellets were initially cleared off the plots in the fall of transect establishment. Pellets were then counted and removed in spring and fall of each sample year, except in 2002, when pellets were counted only in the fall.

Figure A2.1. Sampling design

a) layout of pellet transect within stand: 10 stations   b) pellet plot design at each station



The number of transects in each study area increased over the course of the study. Pellet transects were first installed in Loomis in 1997. Most of the stands (n=23 out of 29) were selected randomly. However, six were selected for their potential to be occupied by snowshoe hares to ensure that quality habitat would be represented in the data. Other random transects were installed over the next five years to gradually increase the sample size. Additionally, some transects were lost due to timber harvest. These were replaced in adjacent stands after harvest, resulting in 58 transects for Loomis by 2002. Within LPO, 30 transects were installed in 1998 and two were added in 2000. All sampled stands in both study areas were within a 20-minute walk from the nearest drivable road.

Physical Site Characteristics

At the first station of each transect, the slope, aspect and elevation were noted. The slope position was categorized as rolling, extreme concavity, shallow concavity, shallow convexity, extreme convexity, straight surface, or rolling/complex. Extreme convexity was only observed once in each study area and was lumped with shallow convexity for analysis.

Vegetation Sampling

At each station (10 per transect), vegetation was sampled in three cover categories: 1) overhead (canopy), 2) ground, and 3) horizontal cover. A vertical sighting tube (James and Shugart 1970, Noon 1981) was used to describe overhead and ground cover at 12 points per station, every 15 feet (5 m) from station center to 45 feet (15 m) in the four cardinal directions. Four categories of overhead cover were possible: open (no cover), conifer, broadleaf, or western larch. Seven categories of ground cover were recognized: grass/forb (including low shrubs), litter, moss, rock, soil, shrub (tall shrubs), and conifer. Horizontal cover was estimated using a 6-foot by 1-foot (2 m x 30.5 cm) cover board viewed at 45 feet (15 m) from four cardinal directions (Nudds 1977). Horizontal cover was scored at 50cm height intervals from ground level to 6 feet (2 m). Scores were measured on an ordinal scale ranging from 0 (no cover) to 5, representing 20 percent cover by each numerical category.

Standard forest structure measurements were also taken at four stations per transect (stations 2, 4, 7 and 9 on Fig. A2.1), including tree densities by species and size class in fixed (1/100 acre or 40.5 m^2) and variable plots. Seedlings were tallied by species on the fixed plot and heights were measured on a subset (first two of each species encountered as the observer turned clockwise starting from north). Medium trees (1-5.5 inches dbh, 2.5-14 cm) were tallied by diameter class and species on the fixed plots. Large trees and snags (>5.5 inches dbh, 14 cm) were tallied on the variable radius plots. Diameters of all large trees and snags were measured, and tree height, height to live crown, and crown radius were measured on a subset of the medium and large tallied trees (first two trees of each species encountered as the observer turned clockwise starting from north).

Snowshoe Hare Browse

The species of vegetation browsed by hares (woody stems, needles, and forbs) within 3 feet (1 m) of the larger 12-inch (0.3 m) pellet plots was recorded in three categories that reflect the quantity of browse marks: few (1-5 observed marks), some (6-10), or many (>10). Hare browse was recognized as those with 45-degree angle cuts and observers were instructed to only record data for those marks that they could confidently conclude as originating from hares. Data was averaged over years collected (1999 to 2001) for analysis. The percent of browse marks observed was weighted by the quantity of marks observed: few (no weight), some (marks multiplied by 3), or many (marks multiplied by 5).

Presence of Alternate Prey and Browse Competitors

Signs of grouse, squirrel, deer, and cattle presence within pellet plots were noted. Grouse and deer signs (absent, old, or new pellets) were recorded when they occurred within 3 feet (1 m) of the larger pellet plot (12 inches). Signs of squirrels included chewed cones, pellets, and middens (holes in piles of cone bracts/seeds). Signs of cattle included presence of animals, cow droppings, or tracks. Detections of deer, cattle, grouse, and squirrels were noted at any location along the transects. For analysis, the mean number of pellet plots with detections was averaged over the years data was collected per transect (cow, grouse and squirrel 1999-2002; ungulate 1999-2001).

4.3 DATA ANALYSIS

Estimation of Hare Density

Snowshoe hare pellet counts from spring and fall were summed to give an annual total. Mean counts per transect (stand) per year were calculated, excluding initial plot-clearing counts, and log-transformed to normalize the data. Hare densities were also calculated from mean hare-pellet counts in the 2"x10' Krebs plots using the EXCEL spreadsheet described in Krebs et al. (2001), for comparison to other areas. Counts from the larger (12"x10') plots and hare densities were highly correlated (Pearson's r=0.96), such that a minimum hare density suggested for lynx (0.5 hares/ha, Ruggiero et al. 2000) is represented by just under 10 pellets per 12"x10' plot. However, hare density results must be reviewed with caution because the computation was developed for hare densities in the Yukon: the equation may not be assumed accurate in low-density areas like Washington (Murray et al. 2002). For this reason, and because pellet data from the 12"x10' plots were closer to being normally distributed than hare densities, data from the 12"x10' plots were used for habitat analyses.

Estimation of Yearly Dynamics in Pellet Density

Yearly dynamics of hare pellet density were analyzed on a subset of transects that had been counted each year for the longest time possible. On Loomis, 21 transects were monitored from 1997 to 2002 and on LPO, 30 transects were monitored from 1998 to 2002. Mean hare-pellet counts from the 12"x10' plots per transect are used in the analyses and expressed as pellets/m^2 for each year studied to facilitate comparison to other study areas that may have used different plot sizes. The 12"x10' plot is similar in terms of area (1 foot or $0.93m^2$) to a 1 m^2 circular plot used and/or advocated in other studies (Koehler 1990a, Murray et al. 2002). Repeated measures ANOVA was employed for both pellet abundance (per m^2 per transect) and pellet presence (percentage plots with pellets per transect) because pellets were counted on the same sites every year.

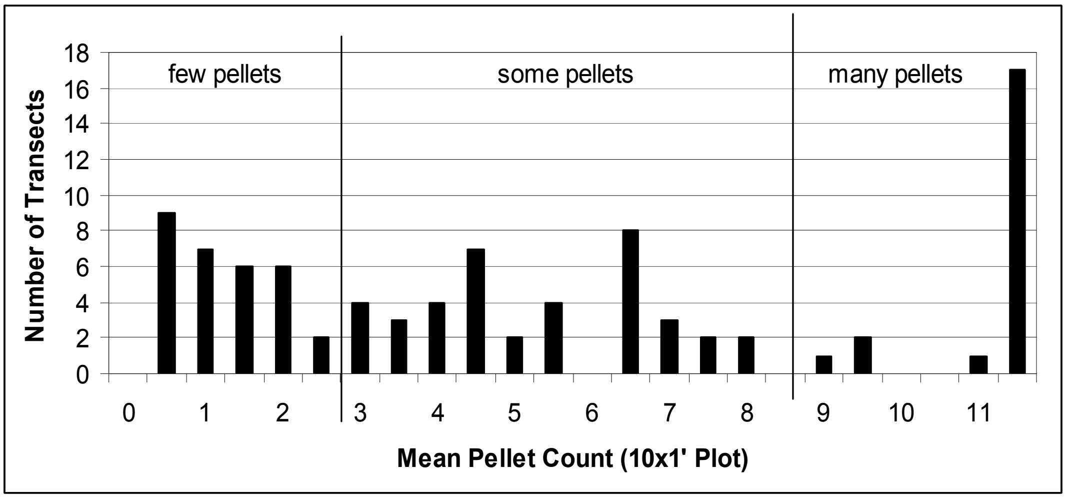
Analyses of Snowshoe Hare Habitat Relationships

Habitat variables were either log-transformed (count data) or arc-sin transformed (percentage cover data, using equation 14.5 from Zar (1984)). Analyses of hare habitat occupancy began with ANOVAs (pellet category, study area). Individual correlations were then calculated for comparison to hare habitat relationships reported in the literature or for specific questions of management interest. For example, uncorrected Spearman rank correlations of pellet density with conifer densities and heights were provided to give managers as much detail as possible about the occurrence of pellets in structurally different forests. Influence of the physical site characteristics on pellet densities was analyzed with Pearson correlations (pellets with slope, elevation), Mann-Whitney U tests (study area comparisons of slope, elevation), ANOVAs (pellets between slope configuration categories), and Raleigh's test (aspect).

Univariate analyses of pellet counts from the 12"x10' plots were used to identify key habitat variables and to provide detailed information to land managers. The count data was either log-transformed or grouped into three abundance categories, following observed breaks in the data while maintaining reasonably similar sample sizes in each category (Figure A2.2): few (<2.5 mean pellets/plot), some (2.5-7 pellets/plot), or many (>8 pellets/plot). The categories will help managers differentiate good from poor sites relative to what occurs on local sites, enabling them to select the best forage habitats available for meeting the landscape level forage habitat guidelines of the 1996 Lynx Plan. All sites categorized as having few pellets had less than 0.12 hares per hectare and 3 out of 21 sites categorized as having many pellets had at least 0.5 hares per ha.

Figure A2.2. Number of transects with a given mean pellet count, for both study areas, used to derive pellet categories

n=30 few, n=39 some, n=21 many



After redundant habitat variables (Spearman's $r^2 \geq 70\%$) were removed from the dataset, multivariate models for predicting pellet densities on the 12"x10' plots were developed in two steps. First, models based on the literature were developed. Second, step-wise regression procedures were used to develop an alternative set of candidate models. Residual plots and scatterplots were examined for meeting model assumptions (i.e. normality, colinearity) and for the presence of outliers (>4 SE). Akaike's Information Criteria (corrected for small sample size) were calculated to evaluate the *a priori* models (Burnham and Anderson 1998). The multivariate modeling procedures were repeated for 2"x10' Krebs' plots for comparison.

Analyses were performed with SPSS Systat software program (Wilkinson 1997). Probabilities were reported for correlations and pairwise comparisons in ANOVA, and correlations were adjusted by the Bonferroni method, unless otherwise noted. For parametric statistics, count variables were log-transformed and percent variables were transformed with arcsine (Zar 1984). The program ORIANA was used to analyze the distribution of pellets on sites according to aspect (Raleigh's test).

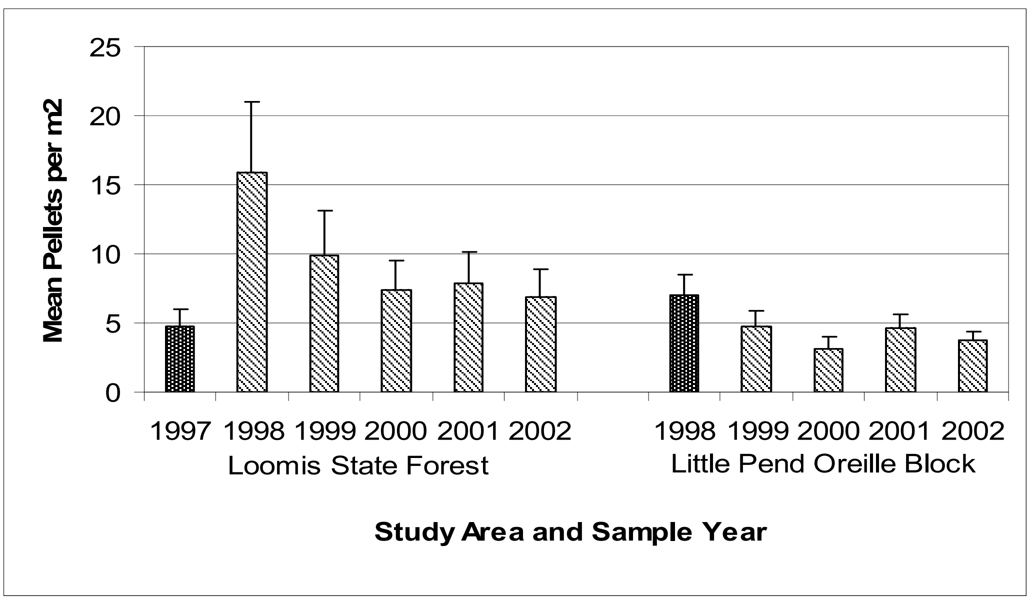
5. Results

5.1 HARE PELLET PRESENCE AND ABUNDANCE THROUGH TIME

Between 1997 and 2002, fluctuations in pellet densities on the study areas were of low amplitude (Figure A2.3). On Loomis (n=21), fluctuations in pellet densities showed higher amplitude in differences between years than the Little Pend Oreille block (LPO). The year of transect initiation (1997) should have been the highest year of pellet counts, but instead was the lowest (mean=4.8 pellets/m^2)—3.3 times lower than the highest year: 1998 (15.9 pellets/m^2). No individual transects had their highest counts in 1997, and none had their lowest counts in 1998. Presence of pellets on the plots followed a trend similar to abundance (Fig. 4), with 55 percent of the plots/transect having pellets in 1998. However, the lowest year (47.4 percent) was 2000 rather than 1997, and 2000 was the only year in which all transects had at least one pellet. Repeated ANOVA measures showed a largely quadratic change through time for the abundance of pellets/plot (df=5, F=6.143, p<0.0005), but no change for the presence of pellets/plot (df=5, F=0.849, p=0.518), with the increase from 1997 to 1998 and the decrease from 1998 to 1999.

Figure A2.3. Mean (standard error) pellets per square meter tallied in 12 inches x 10 feet plots at Loomis State Forest (n=21) and Little Pend Oreille Block (n=30)

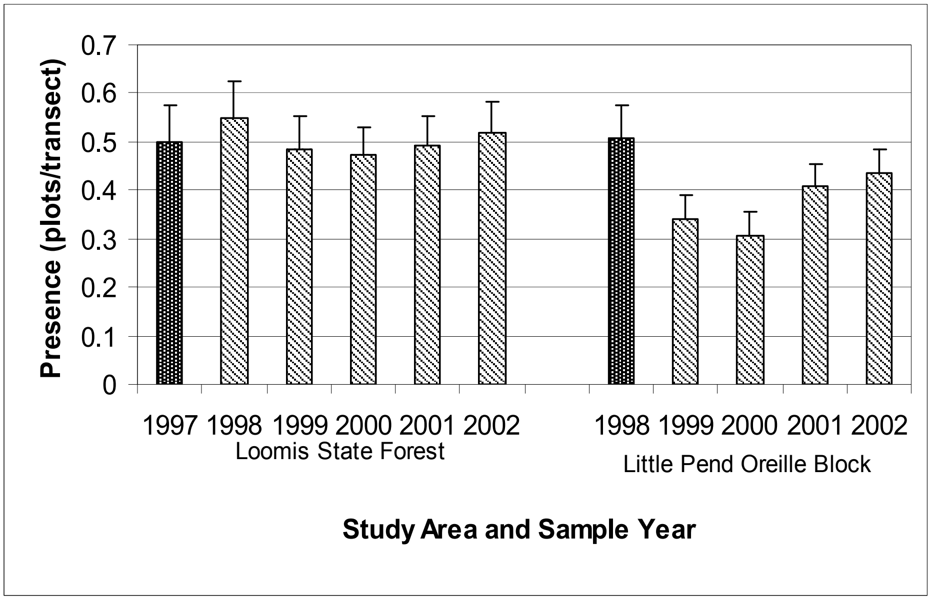
First bar in each time series represents the number of pellets present when transects were first established.



Between 1998 and 2002 on LPO (n=30), there was only a 1.5 fold difference between the lowest (2000, mean=3.1 pellets/m^2) and highest year (1999, mean=4.7 pellets/m^2, Fig. 3). On individual transects in 2000, mean pellet abundance was lowest at 15 sites and highest at one site. Presence of pellets within sites followed abundance (Fig. 4), with only 30 percent of plots per transect having pellets in 2000 compared to 44 percent in 2002. No pellets were found at any station on 6 out of 30 sites in 2000 compared to 1 out of 30 in 2001. Repeated ANOVA measures showed a largely quadratic change through time for both the abundance (df=4, F=2.882, p=0.026) and presence of pellets/plot (df=4, F=8.647, p<0.0005), with the increase from 2000 to 2001 significant in both cases and the decrease from 1999 to 2000 significant in pellet abundance. The decrease from 1998 to 1999 was expected given that the 1998 data represents initial counts (not time-standardized) compared to the annual accumulations represented by the other sampling years.

Figure A2.4. Mean (standard error) pellet presence in 12 inches x 10 feet plots at Loomis (n=21) and LPO (n=30).

First bar in each time series represents the number of pellets present when transects were first established.



Equations from Krebs et al. (2001) were used to estimate hare densities on Loomis and LPO from pellet densities within 2”x10’ plots. Over the years studied, hare densities ranged from 0.29-0.69 hares/ha on the Loomis (n=21) and from 0.18-0.35 hares/ha on the LPO (n=30, excluding initial counts in 1997 for Loomis and 1998 for LPO).

5.2 PREDICTING HARE PELLET DENSITIES FROM HABITAT CHARACTERISTICS

Comparison of Akaike weights for regression analyses on mean pellet densities using habitat variables of interest (Table A2.3) suggests that 51 percent of the variation in pellets in the 12”x10’ plots can be explained by five *a priori* variables (horizontal cover, study area, shrub cover, broadleaf canopy, number of trees with low height-to-live-crown; n=90, $F_{(5,84)}$=19.34, p<0.0005). Stepwise multiple regression on the larger suite of habitat variables suggested that a model with 12 variables could explain 70 percent of the variation in pellet abundance: horizontal cover, study area, mean dbh of large trees, number of large (>5.5”) spruce, number of pine seedlings (<1” dbh), number of subalpine fir seedlings, broadleaf canopy cover, number of large hemlock, ground cover of shrubs, ground cover of soil, mean height-to-live-crown of large trees, and number of large subalpine fir (listed in order of t-value; n=90, $F_{(12,77)}$=18.44, p<0.0005; Table A2.4).

> **a) Horizontal cover** had the strongest relation to pellet densities. There was little pattern in the relation of cover to pellets by forest type (Fig. A2.5). Our *a priori* hypothesis that total tree density would be strongly related to pellets was also confirmed (Fig. A2.6), but tree density was not retained in the higher performing models. Loomis had higher pellet densities than LPO, and was apparent in most models as either “study area” or “elevation” (Fig. A2.7).

b) Other cover variables (including broadleaf canopy, and soil and shrub ground cover) were represented in the models, yet showed little significant correlation to pellet density. Broadleaf canopy occurred on 22 out of 32 LPO sites and 30 out of 58 Loomis sites (Fig. A2.8). However, conifer and open canopy cover categories were better able to discriminate good from poor sites in univariate analyses (Table A2.3). Soil cover was slightly more common on Loomis (38 out of 58) than LPO (17 out of 32) and was absent on many of the high density pellet transects. Shrub cover (Fig. A2.9) occurred on 31 percent of transects in both LPO and Loomis, but was more strongly related to pellets on LPO (r=0.402) than Loomis (r=0.089). Forb/grass, litter, and moss cover had stronger relationships to pellet densities than shrub or soil cover (Table A2.3).

c) Characteristics of large trees (>5.5 inches dbh) also contributed to prediction of pellet densities, including mean diameters, numbers of certain species, presence, and height to live crown. All but one stand had large trees (89 out of 90 stands). Generally, a negative relation of tree diameter to pellet density was seen (Fig. A2.10 and Fig. A2.11). Pellet densities were expected to be higher when the height to live crown of large trees was shorter, but the relationship in the data was not apparent (Fig. A2.12) and was not detected in univariate analyses (Table A2.4). Presence of large trees (number of plots with large trees), reflecting the patchiness of tree distribution in a stand, was related to pellets but driven by young sites with high pellet densities and few large trees.

d) Tree species also contributed to a prediction of pellet densities in the form of medium trees (1-5.5 inches dbh) and seedlings (<1 inch dbh, < 7 feet tall). Medium subalpine fir and grand fir (Fig. A2.16) with diameters of 1-5.5 inches were not significantly related to pellets, but their occurrence differed by study area. In univariate analyses for LPO, medium grand fir and cedar were positively related to pellets, and subalpine fir was negatively related to pellets. Pine seedlings showed a generally negative relation to pellets (Fig. A2.17), and subalpine fir, no relation to pellets (Fig. A2.18), but mean seedling height was related to pellets in univariate analyses (Table A2.4). The negative relationship between large Engelmann spruce (Fig. A2.13, Table A2.8) and pellets was not expected.

Table A2.3
Two-way ANOVA results for Habitat structure variables between study areas (LSF= Loomis, LPO= Little Pend Oreille) and pellet categories (f=few, s=some, m=many).

Post-hoc test results reported when $p \leq 0.05$ (n=90).

Variable	Study Area			Pellet Category			Interaction of Site and Pellet Category		
	$F_{(1, 84)}$	p	post-hoc	$F_{(2, 84)}$	p	post-hoc	$F_{(2, 84)}$	p	post-hoc
Ground Cover									
grass/forb	0.53	0.47	-----	9.98	<0.0005	m<f>s	4.70	0.012	LPO f > LPO s,m and LSF m,s,f
conifer	12.69	0.001	LPO>LSF	2.47	0.090	-----	0.22	0.81	-----
soil	3.96	0.050	LSF>LPO	1.53	0.22	-----	2.49	0.089	-----
litter	3.39	0.069	-----	4.66	0.012	f<s	1.27	0.29	-----
moss	3.02	0.086	-----	4.01	0.022	f<m	0.85	0.43	-----
rock	5.19	0.025	LSF>LPO	1.22	0.30	-----	0.41	0.66	-----
shrub	5.09	0.027	LPO>LSF	3.01	0.055	-----	2.54	0.085	-----
Horizontal Cover									
0-0.5m	17.59	<0.0005	LPO>LSF	0.76	0.49	-----	0.16	0.85	-----
0.5-1.0m	14.19	<0.0005	LPO>LSF	8.74	<0.0005	f<m	1.60	0.21	-----
1.0-1.5m	5.23	0.025	LPO>LSF	12.37	<0.0005	f<m>s	1.26	0.29	-----
1.5-2.0m	1.23	0.27	-----	12.79	<0.0005	m>s>f	1.18	0.31	-----
# Zeros 1.5-2 m	2.32	0.13	-----	15.02	<0.0005	f>s>m	0.24	0.79	-----
# Zeros 0-2.0m	9.94	0.002	LSF>LPO	15.88	<0.0005	f>s>m	0.52	0.60	-----
Overhead (Canopy) Cover									
broadleaf	4.59	0.035	LPO>LSF	0.33	0.72	-----	3.62	0.031	LPO m>LSF m
conifer	1.99	0.16	-----	3.55	0.033	f<s	0.88	0.42	-----
larch	5.67	0.019	LPO>LSF	1.27	0.29	-----	1.17	0.32	-----
open	4.36	0.040	LSF>LPO	2.46	0.091	-----	1.30	0.28	-----
conifer canopy + conifer ground	5.90	0.017	LPO>LSF	4.11	0.020	f<m	0.34	0.71	-----
open canopy – conifer cover	15.53	<0.0005	LSF>LPO	5.03	0.009	f>m	0.10	0.90	-----

Table A2.4
Two-way ANOVA results for Forest characteristics (tree data) between study areas (LSF= Loomis, LPO= Little Pend Oreille) and pellet categories (f=few, s=some, m=many).

Post-hoc test results reported when $p \leq 0.05$ (n=90).

Variable	Mean Pellet Category			Mean (SE)		
	$F_{(2, 87)}$	p	post-hoc	Few (n=30)	Some (n=38)	Many (n=22)
Seedlings (<1" dbh)						
Total # (# per plot)	0.493	0.612	-----	171.3 (32.6)	120.711 (20.417)	77.318 (13.358)
Mean height (inches)	3.158	0.047	m>s	2.438 (0.228)	1.877 (0.175)	2.716 (0.334)
Max height (inches)	2.275	0.09	-----	6.947 (0.448)	5.497 (0.449)	7.314 (0.869)
Medium Trees (1-5.5" dbh)						
Total # (# per plot)	13.737	<0.0005	m>f,s	9.200 (1.618)	15.605 (2.156)	55.091 (13.482)
Presence per plot (plots without trees)	3.090	0.051	m>f	0.367 (0.060)	0.263 (0.043)	0.170 (0.053)
Mean height (feet)	4.340	0.016	f<s	15.306 (1.429)	19.261 (1.103)	17.930 (1.131)
Height to live crown (feet)	1.569	0.214	-----	13.219 (5.362)	6.087 (0.849)	6.232 (1.133)
Crown radius (feet)	4.594	0.013	s>f	2.938 (0.243)	3.735 (0.198)	3.011 (0.188)
Large Trees (>5.5" dbh)						
Total # (trees per acre)	4.779	0.011	s>m	135.183 (13.253)	224.772 (25.781)	137.870 (24.597)
Mean height to live crown (feet)	2.394	0.097	-----	24.370 (1.944)	26.048 (2.026)	20.286 (2.294)
Mean height (feet)	4.934	0.009	f>m<s	77.212 (3.187)	73.929 (2.937)	60.124 (4.860)
# 25' height intervals	4.831	0.010	f>m	3.633 (0.182)	3.184 (0.159)	2.727 (0.256)
Mean DBH (inches)	5.095	0.008	f>m<s	13.427 (0.733)	12.682 (0.665)	10.270 (0.915)
Maximum DBH (inches)	4.397	0.015	f>m	23.927 (1.376)	22.868 (1.657)	17.986 (1.902)
Crown radius (feet)	4.029	0.021	f>m	8.793 (0.434)	7.847 (0.418)	6.966 (0.630)
Presence per plot (plots without trees)	6.829	0.002	f>m<s	0.167 (0.069)	0.263 (0.090)	0.818 (0.224)
# Snags (trees per acre)	3.861	0.029	f>m<s	14.614 (2.666)	29.807 (7.770)	5.315 (1.743)

Table A2.5
A set of candidate models (*a priori* above double line) for predicting pellet densities from habitat variables.

Habitat Variables Modeled	Adj. R	K	RSS	AICc	*Wi***
study area, total medium (1-5.5") trees	0.280	4	9.19	-196.9	0
study area, total (≥1") trees	0.312	4	8.77	-201.0	0
horizontal cover	0.388	3	7.89	-212.8	0
horizontal cover, study area	0.433	4	7.11	-220.0	0.020
horizontal cover, study area, shrub cover	0.451	5	6.13	-220.1	0.022
horizontal cover, study area, shrub cover, broadleaf canopy*	0.482	6	6.46	-224.1	0.15
horizontal cover, study area, shrub cover, broadleaf canopy, # trees with low height-to-live-crown	0.508	7	6.07	-227.4	0.80
horizontal cover, elevation, broadleaf canopy, large PIEN, moss cover	0.580	7	5.18		
horizontal cover, medium ABGR, medium ABLA, broadleaf canopy, forb/grass cover, large PIEN, pine seedlings, total trees, mean diameter large trees	0.652	11	4.09		
horizontal cover, study area, broadleaf canopy, large PIEN, TSHE seedlings, medium ABLA, medium ABGR, pine seedlings, large trees (>5.5"), large tree presence	0.672	12	3.79		
horizontal cover, study area, broadleaf canopy, pine seedlings, mean dbh large trees, large PIEN, ABLA seedlings, large TSHE, shrub cover, soil cover	0.677	12	3.74		
horizontal cover, study area, broadleaf canopy, pine seedlings, mean dbh large trees, large PIEN, ABLA seedlings, large TSHE, shrub cover, soil cover, mean HLC large trees, large ABLA	0.702	14	3.37		
horizontal cover, elevation, large tree presence, broadleaf canopy, total PICO, total large trees, large TSHE, large PIEN, mean diameter large trees, moss cover, medium LAOC, medium ABLA, medium ABGR	0.716	15	3.16		

*original hypothesis for canopy relation to pellets was conifer, but broadleaf proved to be a stronger canopy variable
** probability that the model is the best-approximating model among those considered

Table A2.6
Regression coefficients for predicting pellet density from habitat variables

***A priori* model**	y (log pellets)= -0.463 -0.655(deciduous canopy) + 1.472(horizontal cover) + 0.183(study area)+ 0.939(shrub cover) - 0.106(# trees with low height-to-live-crown)
Multivariate model	y (log pellets)= 0.327 + 0.395(study area) – 0.110(pine seedlings) -0.151(large PIEN) + 0.235(large TSHE) -0.888(mean DBH large trees) + 1.271 (horizontal cover) – 1.028(soil cover) + 1.106(shrub cover) – 0.778(broadleaf canopy) – 0.173(ABLA seed) + 0.111(large ABLA) + 0.250(mean HLC large trees)

Other species that entered the multivariate model were western hemlock and subalpine fir. Only seven stands (LPO) had large western hemlock, and these stands were likely to have generally higher pellet densities (Table A2.7). Large subalpine fir was present on 15 Loomis sites and 5 LPO sites and there was no clear trend with pellets (Figure A2.5; Tables A2.7 and A2.8). A positive relationship between lodgepole pine density and pellets was expected (Figure A2.5), but lodgepole pine did not play a significant role in the models.

Table A2.7
Spearman rank correlations (r_s) of conifer densities (#) and heights (ht) by size classes with pellet counts on LPO (n=32).

seedlings <1"dbh, medium trees 1-5.5"dbh, large trees >5.5"dbh

	ABGR	ABLA	LAOC	PICO	PIEN	PIMO	PIPO	PSME	THPL	TSHE
# seedlings	0.038	-0.096	-0.017	-0.760[d]	-0.176	-0.356[b]	-0.126	-0.368[b]	0.400[b]	0.255
seed ht	0. 070	-0.139	-0.047	-0.650[d]	-0.140	-0.410[b]	-0.126	-0.391[b]	0.449[b]	0.176
# med trees	0.351[b]	-0.322[a]	-0.007	-0.190	0.103	-----	-----	-0.104	0.529[c]	0.200
med tree ht	0.204	-0.323[a]	0.095	-0.167	0.126	-0.088	-----	0.071	0.292	0.208
# 6-10" dbh	0.483[c]	-0.090	-0.081	-0.399[b]	-0.208	-----	-0.215	0.268	0.180	0.407[b]
10-15"	0.057	-0.088	-0.100	-0.364[b]	-0.048	-----	-0.290	0.258	0.185	0.073
15-20"	0.144	-----	0.016	0.004	0.016	-----	0.121	0.153	0.395[b]	0.126
20-25"	0.126	0.146	-0.019	-----	-----	-----	-----	-0.121	0.135	-----
25-30"	-----	-----	-----	-0.146	-----	-----	-----	0.291	0.272	-----
large tree ht	0.172	-0.240	0.035	-0.122	0.204	-----	-0.363[b]	-0.015	0.051	0.149

a - trend at 0.05-0.10
b - significant at p=0.01-0.05
c - significant at p=0.005-0.01
d - significant at p<0.001 (UNCORRECTED p-values)

Table A2.8
Spearman rank correlations (r_s) of conifer densities (#) and heights (ht) by size classes, with pellet counts on Loomis (n=57)

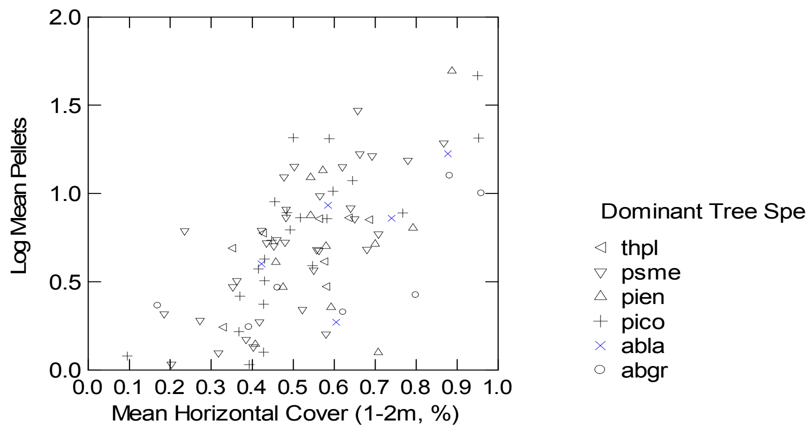
seedlings <1”dbh, medium trees 1-5.5”dbh, large trees >5.5”dbh

	ABLA	LAOC	PICO	PIEN	PIPO	PSME
# seedlings	0.187	0.053	0.102	0.105	-0.089	0.031
seed ht	0.008	-0.154	0.096	0.173	-0.013	-0.212
# med trees	0.136	0.101	0.176	0.130	0.154	-0.170
med tree ht	0.248[a]	0.115	-0.128	0.042	0.154	-0.167
# 6-10" dbh	0.102	0.007	-0.051	-0.294 [b]	0.154	-0.135
10-15"	-0.154	-0.027	-0.105	-0.265[b]	-0.016	-0.208
15-20"	-0.029	-0.131	0.193	-0.170	-0.016	-0.187
20-25"	-0.187	-0.182	-----	-0.065	-0.016	-0.177
25-30"	-----	-0.382[c]	-----	-0.127	-0.146	-0.234 [a]
large tree ht	-0.016	-0.089	0.016	-0.072	0.026	0.002

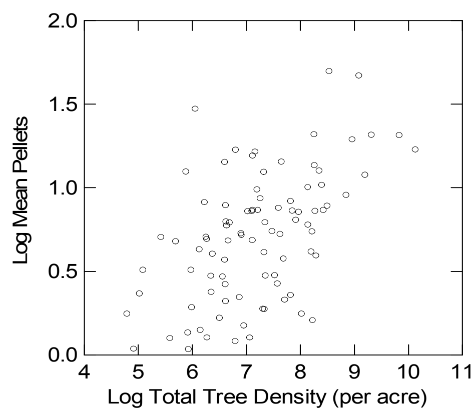
a - trend at 0.05-0.10
b - significant at p=0.01-0.05
c - significant at p=0.002-0.01 (UNCORRECTED p-values)

Figure A2.5. Relations of log mean pellets to habitat characteristics

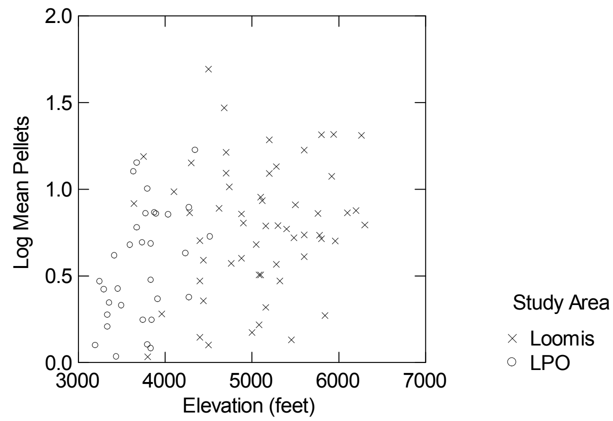
a) horizontal cover (1-2m, %), as categorized by dominant tree species



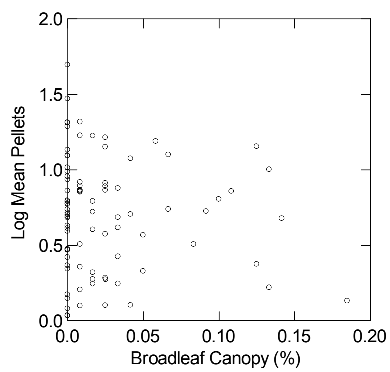
b) trees per acre (≥1” dbh)



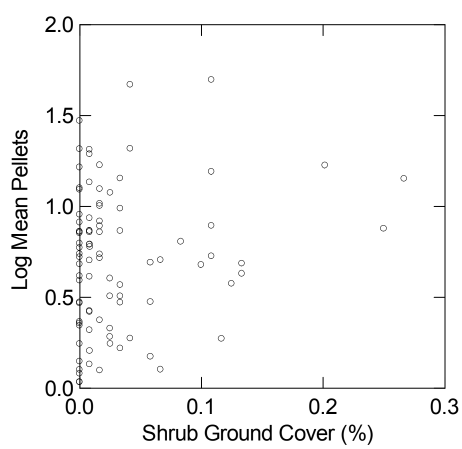
c) elevation (feet), by study area



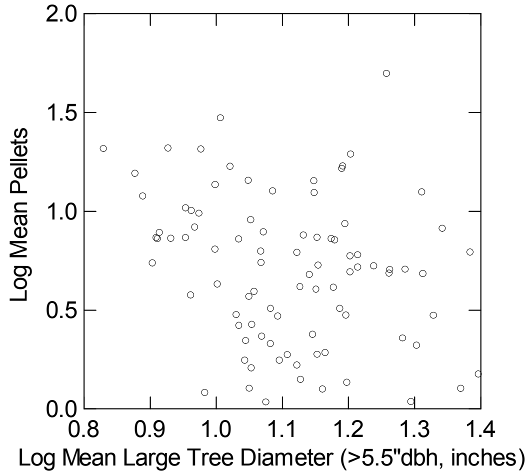
d) broadleaf canopy cover (%)



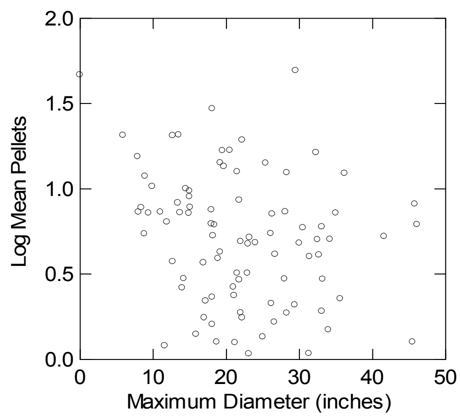
e) shrub ground cover (%)



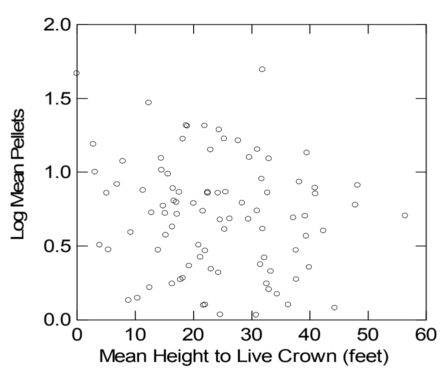
f) log mean large tree diameter (>5.5" dbh)



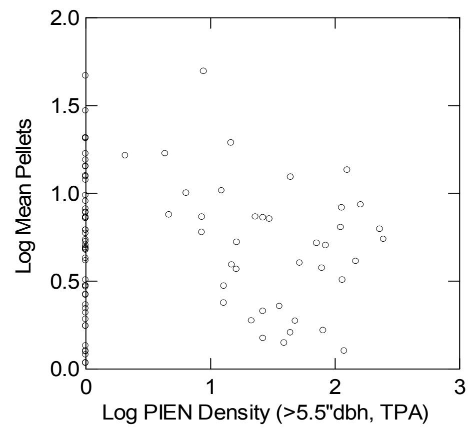
g) maximum large tree diameter (>5.5" dbh)



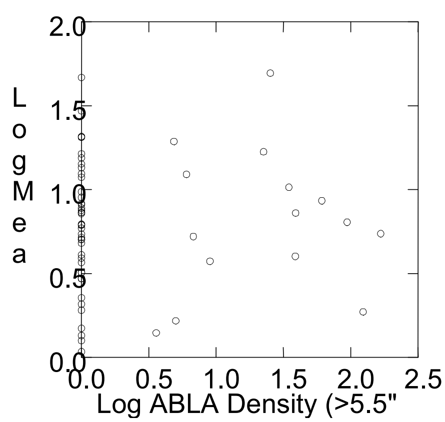
h) live crown (feet) of large trees (>5.5" dbh)



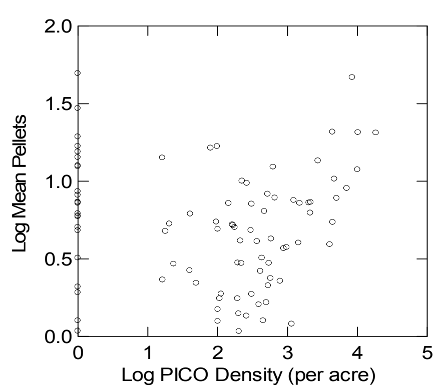
i) log mean Engelmann spruce trees (>5.5" dbh, tpa)



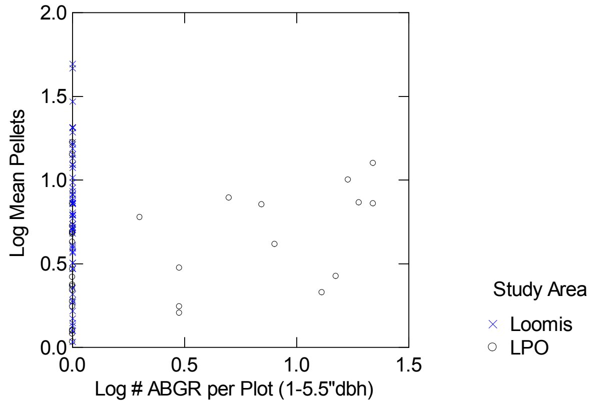
j) log mean subalpine fir trees (>5.5" dbh, tpa)



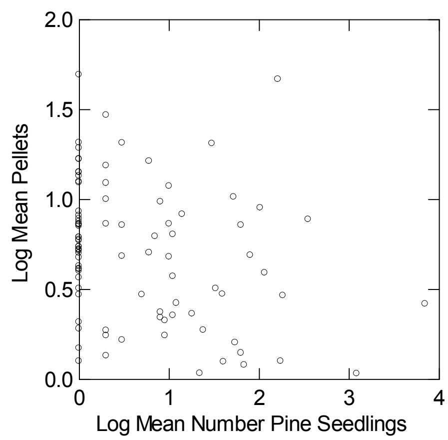
k) log lodgepole pine trees (>1" dbh, tpa)



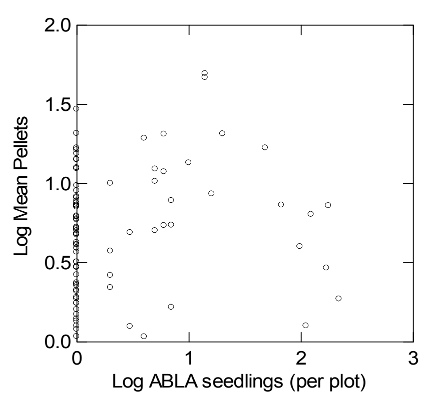
l) log medium grand fir trees (1-5.5" dbh, per plot)



m) log pine seedlings (<1" dbh, per plot)



n) log subalpine fir seedlings (<1" dbh, per plot



5.4 BROWSE

A list of all species browsed is provided in Table A2.9.

Sites with many pellets had more plots with mean hare-browse marks observed than sites with some or few pellets (n=90; site $F_{(1,84)}=6.148$, $p=0.015$; category $F_{(2,84)}=29.203$, $p<0.0005$; interaction $F_{(2,84)}=0.264$, $p=0.769$). The consistent presence of browse in plots for each of the three years sampled (n=78) differed by pellet category (few<some<many) and was greater in LPO than Loomis (site $F_{(1,72)}= 4.618$, $p=0.035$; category $F_{(2,72)}=22.342$, $p<0.0005$, interaction $F_{(2,72)}=0.012$, $p=0.988$). Mean observations of browsed shrubs exceeded conifers on LPO (Figure A2.6), where shrubs were more broadly distributed. On Loomis, where shrubs were less distributed, shrubs and conifers were similarly browsed.

Table A2.9
Flora observed with hare browse and frequency of observation summed over years surveyed by study area, Loomis and LPO.

Not weighted by amount of browse per species/plant.

Loomis State Forest			Little Pend Oreille Block		
Species Browsed	**Observed Frequency**	**% Total Observations**	**Species Browsed**	**Observed Frequency**	**% Total Observations**
PICO	283	0.16	Rosa spp.	213	0.20
VACCI	255	0.15	VACCI	127	0.12
PSME	222	0.13	THPL	115	0.11
PIEN	131	0.076	PAMY	104	0.098
ABLA	117	0.068	PSME	69	0.065
Ribes spp.	110	0.064	Mahonia spp.	47	0.044
Ledum spp.	90	0.052	Salix spp.	44	0.042
VASC	67	0.039	SPBEL	39	0.037
Salix spp.	60	0.035	PHCA	37	0.035
LAOC	53	0.031	Unknown	28	0.026
Lonicera spp.	51	0.030	CHUM	25	0.024
ALRU	39	0.023	ABGR	24	0.023
SPBEL	38	0.022	PICO	21	0.020
PAMY	35	0.020	PHMA	20	0.019
Lupinus spp.	24	0.014	Alnus spp.	15	0.015
SHCA	23	0.013	VASC	14	0.014
POTR	22	0.013	ALRU	14	0.014
Unknown	18		TSHE	12	
SPCA	14		SHCA	8	
ARUV	13		PIEN	8	
Rubus spp.	9		Lonicera spp.	7	
Rosa	7		LAOC	7	
PIPO	5		ABLA	7	
FRVI	5		HODI	6	
EPAN	5		SYAL	5	
SYAL	4		RUPA	5	
THOC	3		Rubus spp.	5	
RUPA	3		ARUV	5	
CHUM	3		LIBO	4	

Table A2.9. Continued

Loomis State Forest			Little Pend Oreille Block		
Species Browsed	**Observed Frequency**	**% Total Observations**	**Species Browsed**	**Observed Frequency**	**% Total Observations**
ACER	3		Acer spp.	4	
MEFE	2		PIPO	3	
CARU	2		PIMO	3	
SMRA	1		AMAL	3	
Sambucus spp.	1		SPCA	2	
PHCA	1		Ribes spp.	2	
PERA	1		Lupinus spp.	1	
Juniperus spp.	1		FRVI	1	
COCA	1		EPAN	1	
ASTR	1		COCA	1	
ARTI	1		Cirsium	1	
ARNICA	1				
AMAL	1				

Browsed species were more diverse on LPO than Loomis (Table A2.5), with only three categories (lodgepole pine, huckleberry species, and Douglas fir) accounting for 40-49 percent of browse observed by season on Loomis. Observed conifer browse differed among all three pellet categories, and sites with few pellets had less browse on shrubs than sites with many pellets (Table A2.6). Mean browse observations were correlated with mean pellets (r=0.703), conifer browse was correlated with total medium trees (r=0.532), and observations of browse on tall shrubs were correlated with shrub ground cover (r=0.469).

Figure A2.6. Mean (SE) browse marks observed by three hare browse categories between study areas (LPO, Loomis).

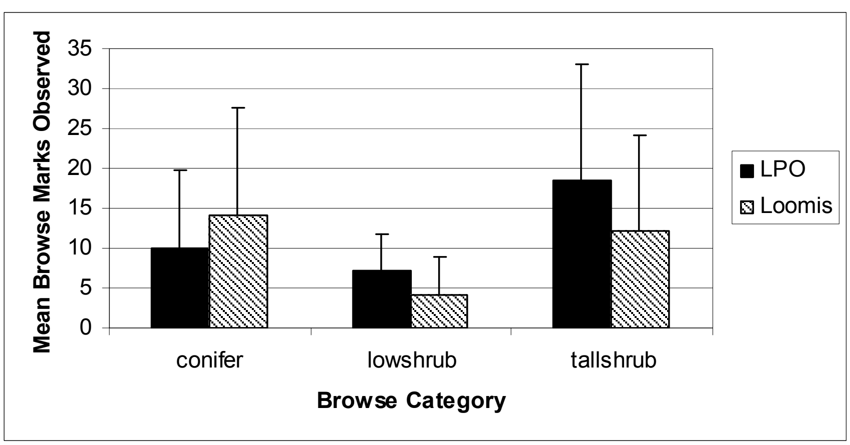


Table A2.10
Scoring browse for LPO and Loomis by season (1999-2001)

Percent of browse marks weighted by quantity of marks observed: few (x1), some (x3), many (x5)

Little Pend Oreille Block				Loomis State Forest			
Species	**Spring**	**Species**	**Fall**	**Species**	**Spring**	**Species**	**Fall**
Rosa sp.	14.3%	Rosa sp.	17.7%	Vaccinium	22.3%	PICO	18.3%
Vaccinium	13.2%	Vaccinium	12.0%	PICO	14.6%	Vaccinium	12.1%
THPL	9.7%	PAMY	7.3%	PSME	12.6%	PSME	10.1%
PSME	7.6%	PSME	5.3%	Ribes	7.2%	PIEN	7.3%
PAMY	7.4%	THPL	4.8%	ABLA	6.3%	Ribes	5.7%
oregon grape	4.0%	oregon grape	4.4%	Ledum	4.7%	Ledum	4.3%
phca	3.8%	phca	4.1%	PIEN	4.1%	ABLA	4.1%
Salix	3.3%	Salix	3.7%	LAOC	3.7%	Salix	3.1%
Alnus	3.3%	PICO	2.9%	Salix	3.6%	Lonicera	2.8%

Table A2.11
ANOVA results for browse observations between study areas and pellet categories (f=few, s=some, m=many).

Post-hoc test results reported when $p \leq 0.05$ (n=89).

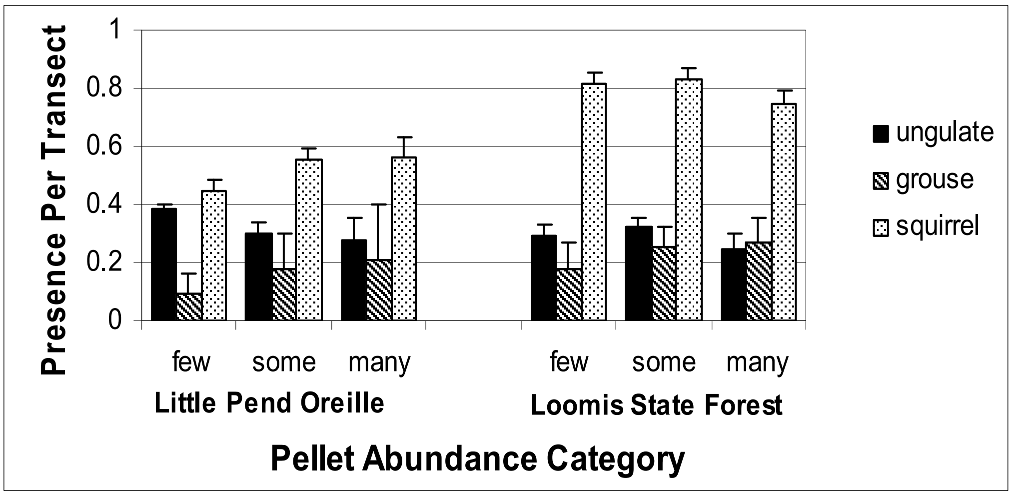
Variable	Study Area			Mean Pellet Category			Interaction of Site and Pellet Category		
	$F_{(1,83)}$	p=	post-hoc	$F_{(2,83)}$	p=	post-hoc	$F_{(2,83)}$	p=	post-hoc
Conifer browse	0.780	0.380	-----	24.960	0.000	f<s<m	1.541	0.220	-----
Low shrub browse	18.072	0.000	LPO>LSF	3.985	0.022	f<m	0.026	0.974	-----
Tall shrub browse	14.053	0.000	LPO>LSF	8.409	0.000	f<s, f<m	1.837	0.166	-----

5.5 ASSOCIATIONS WITH OTHER LYNX PREY

Red Squirrels

The mean presence of red squirrels was correlated with snowshoe hare pellets on LPO (r=0.404, p=0.022, n=32; Fig. A2.20) but not Loomis (r=-0.183, p=0.169, n=58). There was a trend for higher squirrel presence in older stands (Loomis higher, site $F_{(1,86)}=49.700$, $p<0.0005$; category, $F_{(1,86)}=3.521$, p=0.064; interaction, $F_{(1,86)}=0.287$, p=0.593). On Loomis, squirrel presence was significantly correlated with height (r=0.637), maximum diameter (r=0.557), mean diameter (r=0.532), and mean height-to-live-crown of large trees (r=0.466), and negatively with density of medium ponderosa pine (r=-0.496). On LPO, squirrel presence was correlated with conifer canopy cover (r=0.701), large grand fir (r=0.664), litter cover (r=0.628), and density of medium western redcedar (r=0.614), moss cover (r=0.601), and density of large western redcedar (r=0.574), and negatively with forb cover (r=-0.684).

Figure A2.7. Mean (SE) presence of ungulate, grouse and squirrel sign by hare pellet category (few, some, many) and between study areas (LPO, Loomis)



Squirrel presence was correlated with snowshoe hare pellets in spring (r=0.369, p=0.001, n=90), but not fall (r=0.122, p=0.759, n=90). Over the years studied, squirrels were detected at least once in the fall on all transects (n=32 LPO, n=58 Loomis), but not detected in spring on 4 LPO sites and 8 Loomis sites. On Loomis, squirrel sign was present or squirrels were detected on each transect in fall 2000 and nearly every site in 1999 (49 of 50), 2001 (56 of 58), and 2002 (54 of 56). In spring, squirrel sign was less distributed, such that 18 percent of sites in 1999, 6 percent in 2000, and 44 percent in 2001 lacked squirrel sign.

Grouse

Grouse were detected on all but 9 transects in each study area (23 out of 32 LPO, 49 out of 58 Loomis). The presence of grouse was correlated with snowshoe hare pellets on LPO (r=0.389, p=0.028, n=32; Fig. 20) but not on Loomis (r=0.209, p= 0.116, n=58). Grouse sign was more common on Loomis, with a trend for more sign on older stands (site $F_{(1,86)}$=5.263, p=0.024; age $F_{(1,86)}$=3.468, p=0.066; interaction $F_{(1,86)}$=0.563, p=0.455). On Loomis, grouse presence was positively correlated with large lodgepole pine trees (r=0.497), canopy cover divided by mean dbh of large trees (r=0.593) and negatively with the crown radius of large trees (r=-0.446) and mean diameter of large trees (r=-0.463). On LPO, grouse presence was correlated with litter (r=0.591), density of medium cedar trees (r=0.576), and forb cover (r=-0.590).

Ungulates

Ungulates were detected on all transects of LPO and 56 out of 58 Loomis transects. The presence of ungulates was inversely correlated with the abundance of snowshoe hare pellets on LPO (r=-0.420, p= 0.017, p=32) but not Loomis (r=-0.146, p=0.273, n=58; Fig. 20). Ungulate presence did not differ by study area or disturbance history in a multiple ANOVA (site, $F_{(1,86)}$=0.762, p=0.385; age, $F_{(1,86)}$=2.9463, p=0.090; interaction, $F_{(1,86)}$=0.2169, p=0.588). On Loomis, no correlations between ungulate sign and pellets were significant, but the highest ranking correlations were elevation (r=-0.305), conifer canopy cover (r=-0.303), crown radius of medium trees (r=0.387) and total zero scores (0.360). On LPO, deer presence was correlated with large ponderosa pine (r=0.700) and forb/grass cover (r=0.626).

Cattle

Cows were detected with higher frequency on Loomis (50 of 58) than LPO (8 of 32), Figure A2.8). The presence of cows was negatively correlated with the abundance of snowshoe hare pellets on Loomis (r=-0.393, p= 0.002, n=58) and nearly so on LPO (r= -0.335, p=0.061, n=32). Cow presence was greater on Loomis than LPO and there was a trend for more presence in younger stands (site, $F_{(1,86)}$=19.056, p<0.0005; age, $F_{(1,86)}$=3.715, p=0.057; interaction, $F_{(1,86)}$=2.467, p=0.120). On Loomis, cow presence was positively correlated with soil (r=0.637) and total zero scores in horizontal cover (r=0.493), and negatively correlated with seedling density (r=-0.523) and conifer canopy (with conifer ground cover included when canopy was otherwise scored as open, r=-0.564). On LPO, cow presence was significantly correlated with Engelmann spruce seedling density (r=0.627), and not significant but high ranking in relation to open canopy cover (r=0.481), forb cover (r=0.461), and large tree height deviation (r=0.455). It correlated negatively to elevation (r=-0.481).

Grass presence negatively correlated with the abundance of snowshoe hare pellets on LPO (r= -0.242, p= 0.068, n=32) and nearly so on Loomis (r= -0.396, p= 0.025, n=58; Fig. 21). Grass was slightly more frequent on Loomis than LPO, and more frequent on younger than older transects (site $F_{(1,86)}$=3.569, p=0.062; age $F_{(1,86)}$= 16.264, p<0.0005; interaction $F_{(1,86)}$= 2.883, p=0.093), potentially explaining the co-occurrence of cows with sites that have few pellets (i.e. early regenerating stands) and indicating potential for trampling to occur (seedlings).

The percent of young stands with high average cow presence (>31 percent average cow sign per transect, n=15 of 58) on Loomis was 44 percent (11 out of 25). More of the high cow presence sites were in younger (11 of 15) than older stands, in PSME (11 of 13) rather than PICO types (2 of 8), and had few (8 of 15) or some (5 of 15) pellets. Cow presence was detected for four consecutive years (1999-2002) on 29 percent (17 of 58) of the Loomis transects. Cow presence was highest in 1999 (Fig. 22) and most negatively correlated (r=-0.626, p=0.007 uncorrected) to pellet presence. Cow presence was still negatively correlated to pellet presence in 2000 (r=-0.559, p=0.02 uncorrected), but not in 2001 or 2002.

Figure A2.8. Mean presence (standard error) of cattle sign observed along pellet transects, by snowshoe hare pellet abundance categories (few, some, many) and between study areas (LPO, Loomis).

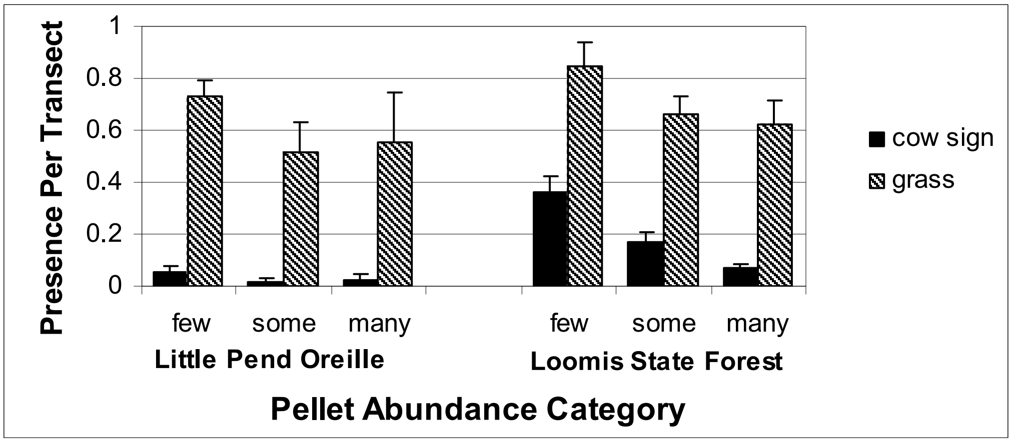
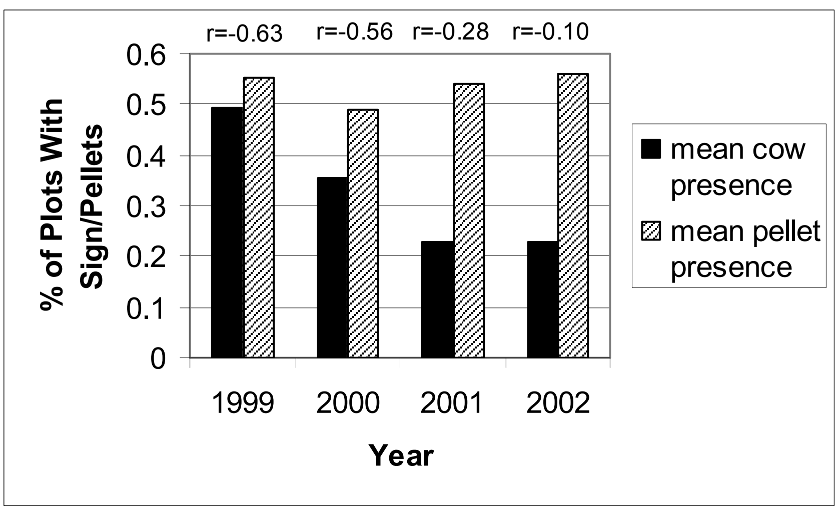


Figure A2.9. Mean presence (plots/transect) of cattle sign and snowshoe hare pellets observed along 17 pellet transects, by year sampled on Loomis

The uncorrected correlation between pellet and cow presence is given for each year.



6. Discussion

6.1 PATTERNS THROUGH TIME

Between 1998 and 2002, small fluctuations in pellet densities on the study areas (1.5x LPO, 3.3x Loomis) were similar to those expected of southern or montane snowshoe hare populations (Hodges 2000, Murray 2000). Likewise, Koehler (1990a) observed 1.5 fold differences on pellet plots in Washington and Malloy (2000) observed 2.4-4.7 fold differences from 1986-1998 on four individual transects in Montana. Fluctuations in cyclic populations can reach well over 10 hares/ha (25 hare/acre, Keith 1990).

Both the highest and lowest values of hare densities observed on Loomis and LPO are lower than northern hare populations where lynx have been studied, but similar to those reported from other southern areas (Table A2.12). The densities provided here should be viewed with caution because the equations used to extrapolate hare densities from pellet densities were generated from a different study area (Krebs et al. 1987, Krebs et al. 2001). The low year (2000) of pellet densities and presence observed on LPO and Loomis was similarly observed in the Kootenai National Forest, Montana, in a 1998-2001 Yaak hare study (J. Weaver, pers. comm.). The lower hare densities on LPO compared to Loomis were expected, given the historical presence of lynx and casual observations of snowshoe hare signs between areas.

Table A2.12
Hare densities derived from pellet counts within 2 inches x 10 feet "Krebs" plots (Krebs et al. 1987, Krebs et al. 2001).

Estimated Hare Densities/ha	Area	Author
High 0.69, low 0.29	North-central WA, means from 5 years	This study
High 0.35, low 0.18	Northeastern WA, means from 4 years	
Peak 7.5, low 0.8-1.3	Teslin Plateau, Yukon, means from 8 years	Slough and Mowat 1996
Peak 7-9, low 0.4-1.0	Great Slave Plain, Northwest Territories, means from 5 yrs	Poole 1994
High 0.47, low 0.01	southern BC, means from one year	Apps 2000
0.57 on intensive study plots, 0.14 on extensive study area	Northern Idaho, means from 2 years	Murray et al. 2002

Although pellet presence did not significantly change over time on Loomis, hare pellets were found in 68 percent of the habitats sampled in the low years as high years on LPO. The correlation of pellets to horizontal cover jumped from 44 percent before the 2000 low to 66 percent during the low, suggesting that hares were surviving in areas of denser cover. Keith (1966) concluded that intrapopulation movements during a hare decline resulted in changes in distribution of hares, such that they occupied 72 percent of habitats occupied during the peak. Fuller and Heisey (1986) observed an increase in presence of pellets in all cover types, with an increase in pellets in north-central Minnesota. It may be that the occurrence of hares follows a cyclic pattern in LPO. Radio telemetry would be the ideal choice for evaluating potential hare survival and movements associated with density changes. It would also be interesting to see if hare pellets are again found in more habitats in this study as (or if) hare populations increase again.

Why was a similar or even stronger pattern of habitat abandonment not observed on Loomis, where the change in pellet abundance between years was greater than LPO? With no change in hare pellet presence over the time studied, hares appear to be reliably available in most habitat types on Loomis. The mean total zero scores were much higher on Loomis (18.0) than LPO (12.8), suggesting that cover on Loomis sites was patchier within a stand. Thus, hare response to a low population density may have been to move/survive in denser cover within a stand rather than between stands.

For Washington forest managers, the similarity of pellet numbers among years suggests that habitat relationships can be reliably derived from pellet counts averaged over years sampled. However, habitat relationships derived from only one year's pellet data should be interpreted with caution because there may be some differences in low or high hare years, particularly on LPO.

6.2 PATTERNS WITH STAND AGE AND TYPE

Hare pellets were broadly distributed across age and plant associations on both study areas, with high pellet densities occurring in lodgepole pine, spruce/fir, Douglas fir, and grand fir types. Although lodgepole pine stands were the most frequently represented in the group of stands with highest pellet counts in this study, and pellets were related to high lodgepole pine density, high pellet densities and evidence of successful reproduction (observations of leverets) additionally occurred within mature PSME/CARU, ABLA2/VASC, and PSME/VACA stands. On LPO, the relationship of pellets to plant association was similarly indiscernible in a hare pellet study to the south (Thomas et al. 1998), yet three plant associations common to LPO sites were ranked in the same order (PSME/PHMA> THPL/CLUN> TSHE/CLUN, Table A2.13. For an explanation of the abbreviations see Appendix 4). In other western hare studies, lodgepole pine has clearly been identified as a preferred snowshoe hare habitat type (Koehler et al. 1979, Malloy 2000, McKelvey et al. 2000).

Table A2.13
Comparison of plant association rankings (highest rank listed first) by hare pellet counts between two northeastern Washington studies.

Associations shared by studies are in bold.

Thomas et al. 1998*	LPO (this study) **
THPL/VAME	THPL/ATFI
PSME/PHMA	ABGR/CLUN
ABLA2/CLUN	PIAL/ABLA
THPL/CLUN	ABLA/VASC
TSHE/MEFE	ABGR/LIBO
TSHE/CLUN	**PSME/PHMA**
ABLA2/TRCA3 and TSHE/GYDR	**THPL/CLUN**
ABGR/PHMA	**TSHE/CLUN**
THPL/ARNU3	

*derived from figure 7 in Thomas et al. 1998, an area to the south of LPO;
**from DNR inventory plot nearest to transect

The few conclusions of hare pellet relationships to stand age or plant association in this study may also result from the range of studied transects. For example, regenerating forests in the suitable age range for snowshoe hare (20-40 years) were scarce on Loomis. Outside of Loomis, younger sites such as those resulting from a 1970's burn had much higher hare pellet densities than most sites on Loomis (Okanogan National Forest, DNR unpublished data). Hare avoidance of the earliest forest successional stages has been observed across the species' range (Keith 1990, Hodges 2000). In this study, low hare occupancy of the earliest successional stages was suggested by the higher forb/grass cover and lower litter, shrub, and moss cover and greater abundance of pine seedlings on sites with fewer pellets. Buskirk et al. (2000) described potential hare habitat characteristics of old forests as including brushy understories, maximum tree diameters, and dense coniferous understories. In this study, there was little evidence for hare preference of gap-phase forests. Older sites on Loomis were likely to have more pellets if they had a closed conifer canopy cover by small diameter trees, particularly lodgepole pine, with relatively low heights-to-live–crown. These older sites were also likely to have fewer pellets if there was a diversity of large trees present (particularly western larch and Englemann spruce), and if the large trees were tall and had large diameters, as would be expected in gap-phase forests, although snowshoe hare occupancy of older forests was clearly documented. On LPO, older sites were more likely to have higher hare pellet densities if they had closed overstories to the point of much litter accumulation, yet still having horizontal cover and conifer cover, especially regenerating western redcedar in the form of medium trees and seedlings.

6.3 PATTERNS WITH SPECIFIC HABITAT CHARACTERISTICS

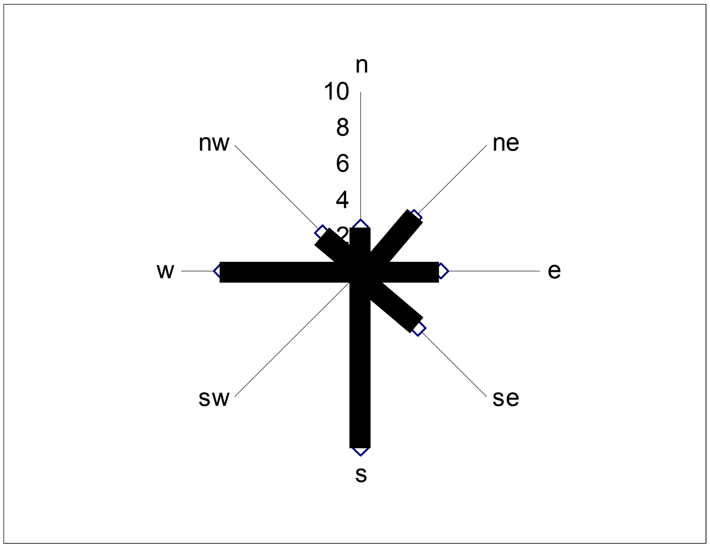
The predominance of horizontal cover as a descriptor of hare habitat that was found in this study has been observed in other areas of the snowshoe hare's range. Cover densities >40 percent within 3-5 feet (1-1.5m) explained 85 percent of winter hare habitat use in northern Utah (Wolfe et al. 1982), and cover densities >60 percent within 7 feet (1-2m) of the ground were used intensively in Maine (Litvaitis et al. 1985b). In Idaho, Wirsing et al. (2002) found low hare densities in study areas with less than 40 percent horizontal cover. “Refuges” with cover densities of 75 percent (up to 12 feet or 4 m tall) were used by hares in winter near Fairbanks, Alaska (Wolff 1980). Cover 3-10 feet (1-3 m) above ground in the form of 50-60% conifer foliage cover values was identified as the single most important factor influencing snowshoe hare distribution in New Brunswick (Parker 1986). Likewise, the correlation of shrubs with pellets on LPO was r=0.48 (p=0.005, n=32), similar to north-central Minnesota, where Pietz and Tester (1983) found r=0.52 (p=0.02, n=12) in jack pine/spruce.

The disassociation of older sites with large spruce on the Loomis study area has not been reported elsewhere. Hodges (2000) reported a field survey in which forest managers ranked habitats they thought were most likely to contain hares. In Washington and Oregon, lodgepole pine and Douglas fir ranked highest, but in the intermountain west, spruce/fir and lodgepole ranked highest. Spruce forests are also high ranking in hare use within northeastern states (New York: Rogowitz 1988; Maine: Monthey 1986, Litvaitis et al. 1985b), New Brunswick (Parker 1984), Colorado (Dolbeer and Clark 1975), and northern Utah (Wolfe et al. 1982). Young spruce stands in this study supported high hare pellet densities, and Engelmann spruce itself was frequently browsed. Older spruce stands on north-northeastern aspects may have had lower pellet densities than other aspects, suggesting that the microclimate on these sites was perhaps too cold and/or wet to support high hare densities (Figure A2.9).

It is possible that other forest structural characteristics not measured in this study are critical to hares. For example, field observations suggested that woody debris cover could be important to hares in the absence of dense vegetative cover. However, a preliminary analysis of the relationship between pellet abundance and woody debris cover and cover by specific species of vegetation on a subset of Loomis transects did not reveal any strong associations (Appendix 8). Likewise, large-scale habitat factors such as patch size and amount of disturbed habitat in a given area (Thomas et al.1998) may influence hare pellet densities. New England cottontails had lower survival where there were larger amounts of disturbed habitat within 0.5km of a habitat patch, large perimeter to edge ratios of habitat patches, and greater amounts of coniferous forest within 1km of a habitat patch (Brown and Litvaitis 1995).

Figure A2.9. Mean hare-pellet densities on older Loomis transects with large Engelmann spruce trees, grouped by aspect (n=22 sites).

Bar length corresponds to mean pellet densities, scale on northern axis.



Although aspect and topography may influence the distribution of snowshoe hares (Litvaitis et al. 1985b, MacCracken et al. 1988), little evidence for this occurred in this study. The model results indicated that neither slope, aspect, nor slope configuration appeared to be related to hare pellet occurrence. Elevation did correlate with pellets on LPO, indicating that perhaps elevation is more important in some areas (marginal hare/lynx habitat) than others. South of LPO at mean elevations of 1,220 m, Thomas et al. (1998) also found a positive correlation between elevation and hare pellet densities. It is possible that measuring the physical characteristics at each plot rather than at the scale of the site may reveal more relationships.

6.4 PATTERNS WITH ALTERNATIVE PREY

This study employed a simple methodology to describe the presence of squirrels within sites occupied by snowshoe hares. The large seasonal discrepancy in squirrel detection suggests that future use of the index should be carefully planned to occur during the same season. The results here should be used to aid future study designs.

This study confirms that red squirrels, a principal alternative prey for lynx, occupy older forests. On Loomis, squirrel sign was associated with old forest characteristics that were negatively related to hare pellets (large diameters, crown radii, height-to-live-crowns, large Engelmann spruce and Douglas fir). However, squirrels were broadly distributed throughout sites occupied by hares, including young seral stages and especially in the fall. High occupancy in the fall is presumably driven by dispersing animals. Young lodgepole pine stands may be temporarily attractive to squirrels because lodgepole pine produces cones at an early age (<10 years), dense stands allow squirrels to travel easily between tree canopies without touching the ground, and cone serotiny may not be expressed for many years (30-60 years, Lotan and Perry 1983). However, dispersing animals in young seral stages may be more vulnerable to lynx than squirrels in older stands given that escape habitat is shorter (young trees) and there is less sight distance to detect predators. In British Columbia, red squirrel use of juvenile lodgepole pine forest was comparable to mature forests, varying with cone crop fluctuations (Sullivan and Moses 1986, Ransome and Sullilvan 1997). On LPO, the presence of red squirrel sign was positively correlated with snowshoe hare pellets and conifer canopy. These results contrast with Buskirk et al. (2000), who asserted that red squirrels are absent from sapling-stage forests used by snowshoe hare. Stand thinning, an important concern for decreasing vegetative cover needed for snowshoe hare, has also proven to be detrimental to red squirrel densities (Sullivan et al. 1996) and may therefore also be an important consideration for managers of lynx habitat.

On LPO, pellets and grouse sign were related. On both LPO and Loomis, detection of grouse sign was correlated with habitat features that were also related to pellets. These data indicate that grouse should be available to lynx when lynx are hunting snowshoe hares.

6.5 PATTERNS WITH BROWSE USE

Deciduous woody species are routinely reported as the most common winter food of snowshoe hares, with conifers also used extensively, and herbaceous vegetation important during the summer (Keith 1990). In this study, broadleaf woody species were browsed more frequently where they were more available (LPO vs. Loomis) and sites with many hare pellets were more likely to have browsed shrubs than sites with few hare pellets. Similar to this study, Thomas et al. (1998) also observed that Douglas fir, rose, and huckleberry were important browse species in the LPO area. However, two other important browse species in the Thomas et al. (1998) study location, lodgepole pine and serviceberry, were less important in LPO. The list of browsed plants observed in this study (Table A2.9) expands the reported food plant list for the western region as summarized by Hodges (2000). The simple method of browse determination used in this study should be discontinued in favor of a more rigorous design to answer further, specific questions.

6.6 PATTERNS WITH PRESENCE OF CATTLE SIGN

This study employed a simple methodology to look for a relationship between cattle presence and hare habitat occupancy. The results discussed here must be considered as exploratory, as information that could be used to develop hypotheses in a future rigorous study design.

The relationships between cattle sign, grass, horizontal cover (zero scores), and open canopies suggest that cattle are largely occupying areas in the earliest stages of succession or more open forest types than generally preferred by hares. However, the relationship between pellets and cattle sign that changed from negative correlation, during years when the most cow sign was observed, to no correlation, during years of lower cow sign confirms a potential for interaction when cattle densities are relatively high. Likewise, higher animal stocking rates on Loomis compared to LPO led to higher detections of cattle sign and a significant overall negative correlation with pellets on Loomis.

This study could not evaluate changes in hare habitat that may have been caused by cattle, which a treatment study (grazed vs. ungrazed) would have been able to detect. For example, McClean and Clark (1980) advised, “Overstocking by lodgepole pine on some sites may be reduced by temporarily grazing an area heavily." The rate of "overstocking" reported, 5,600-6,100 trees /hectare, is within the range preferred by hares (Koehler 1990a). Given the pattern of cattle occurring in the earliest successional stages, it is possible that some sites on Loomis have not reached their naturally stocked potential due to the heavy presence of cattle. Grazing may also retard the growth of lodgepole pine stands compared with ungrazed stands (McClean and Clark 1980). The slow return of some recently harvested sites to hare habitat status could be exacerbated by heavy cattle presence.

6.7 CONCLUSION

This study identified potential habitat variables that can explain approximately 20 percent more variation in pellet densities than our best *a priori* model. Although the multivariate models give us insight into hare habitat relationships, applying such a model to the task of defining hare habitat on the ground is relatively data intensive. Detailed habitat data is not currently available for DNR-managed lynx habitat. If possible, simplifying the definition of hare forage habitat to something with one or two relatively easy-to-measure variables should facilitate implementation. Section 7 below examines this possibility.

7. Defining Forage Habitat

What kinds of habitat should be included as Forage Habitat for lynx? Most stands, with the exception of non-lynx habitats, probably have some role as forage habitat for lynx. Lynx can hunt in a variety of habitats from dense young forests to mature forests by using a combination of ambush and sit-and-wait strategies (Murray et al. 1995). Where timber is managed in lynx range, it would be helpful to define a subset of habitats that stand out as important prey areas for lynx. Forage habitats thus defined could be planned for and managed through time. DNR's 1996 Lynx Plan started with a simple definition of forage habitat as 40 percent cover for 1 meter above mean snow depth. The literature suggested that this was a starting point where hares would use regenerating stands (Wolfe et al. 1982). Literature concerning hare and lynx use of mature stands was equivocal. Therefore, lynx forage habitat was restricted to young stands in the 1996 Lynx Plan (WDNR 1996a). Determining hare use of older stand types on Loomis and LPO was a specific concern for the 1997-2002 effectiveness monitoring effort. The intent of the 1996 Lynx Plan was to eventually include all ages and types of forests that typically supported higher densities of hares in the definition of lynx Forage Habitat.

7.1 SETTING A PELLET DENSITY THRESHOLD FOR THE FORAGE HABITAT DEFINITION

To classify a site as Forage Habitat or not, a pellet density threshold must be set for the Forage Habitat definition. Although we lack lynx hunting data to identify the specific number of hares or pellets that should define habitat, hypotheses state a minimum hare density of 0.5 hares/ha to sustain lynx in northwestern Canada (Ruggiero et al. 2000). The numbers of pellets counted on the 12"x10' plots in this study are highly correlated to hare densities computed from the 2"x10' Krebs' plots imbedded within them (r=0.96), such that the minimum hare density suggested for lynx (0.5 hares/ha) is represented by just under 10 pellets per 12"x10' plot (Figure A2.10). The proportion of transects with ≥9 mean pellets/plot was 16 out of 58 (27 percent) on Loomis and 4 out of 32 (15 percent) on LPO. Because some stands were specifically included in the sample due to their potential to have high pellet densities, the incidence of good pellet sites in the landscape is probably lower. All but two of the 20 transects with ≥9 mean pellets/plot had hare densities of ≥0.5 hares/ha on their imbedded Krebs' plots.

7.2 APPLYING THE FORAGE HABITAT DEFINITION FROM THE 1996 LYNX PLAN

As predicted by the literature and identified in the multivariate habitat models, horizontal cover is an important variable for predicting snowshoe hare densities. Specifically, horizontal cover from 3 to 6 feet (1-2 m) was more correlated to mean pellet counts than cover at other height intervals. However, most of the studied transects (86 percent Loomis, 75 percent LPO) had mean horizontal covers of 40 percent or more between 3 and 6 feet (1 – 2 m) from the ground, and therefore would be classified as Forage Habitat according to the 1996 Lynx Plan (WDNR 1996a) (Figure A2.11).

Although all 20 high-pellet sites would be recognized as Forage Habitat if the 1996 Lynx Plan definition is applied (Table A2.14), 74 percent of the sites recognized as Forage Habitat would be sites with lower pellet densities, including 7 out of 16 transects with means of <1 pellet/plot. With a definition of 60 percent horizontal cover, approximately half of the sites recognized as habitat would have high pellet densities, but 35 percent of high-pellet sites would be excluded.

Figure A2.10. Relation of hare pellet densities in 12"x10' plots to hare densities calculated from imbedded Krebs plots.

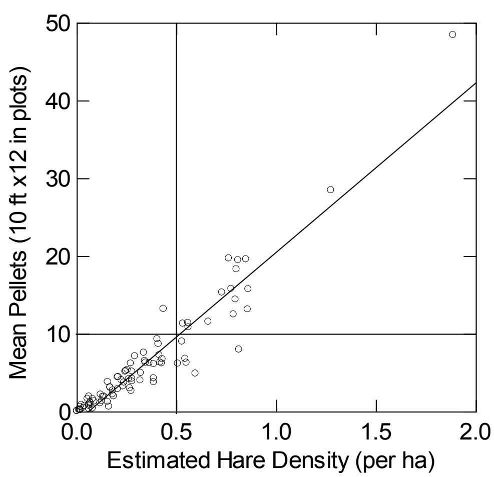


Figure A2.11. Relation of log mean pellets to mean horizontal cover (LPO, Loomis).

Note that all but 2 plots with log pellets ≥1.00 had 0.5 hares per ha or more as calculated from their imbedded 2”x10’ Krebs’ plots.

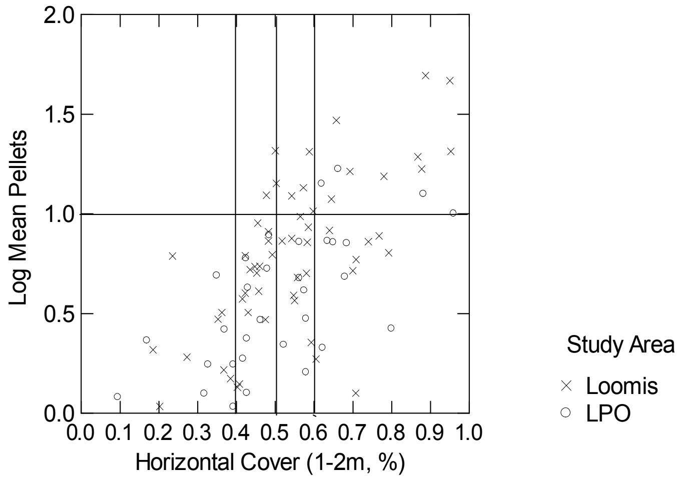


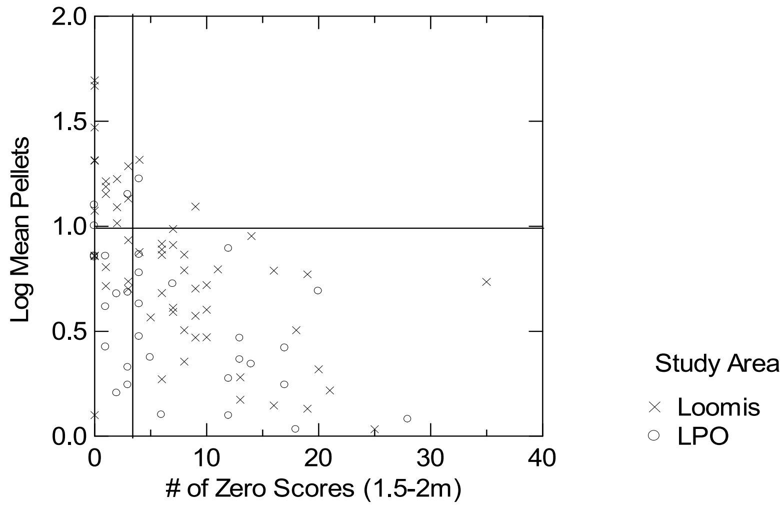
Table A2.14
Classification of transects as Forage Habitat by percent of horizontal cover and number of zero scores.

Horizontal Cover	Total number of sites classified as forage habitat	High hare pellet sites		Lower hare pellet sites	
		Classified as high	low	Classified as low	high
40% from 1-2m	76/90	20	0	14	56
50% from 1-2m	49/90	19	1	41	29
60% from 1-2m	26/90	14	6	57	13
<10 zero scores from 0-2m	41/90	19	1	48	22
<4 zero scores from 1.5-2.0m	48/90	18	2	50	20

A middle definition of 50 percent horizontal cover results in the best compromise for misclassification (lacking only one good site), but 41 percent of the 70 low-pellet sites would still be considered forage habitat.

An alternative to the percent horizontal cover Forage Habitat definition is one based on the number of zero scores counted at specific height intervals. Horizontal cover was scored at 50 cm height intervals from ground level to 2.0m. Scores were measured on an ordinal scale ranging from 0 (no cover) to 5, representing 20 percent cover by each numerical category. Scores of zero reflect the patchiness of available cover (horizontal cover continuity) and are highly related to pellet densities (Fig. A2.12).

Figure A2.12. Relationship of log mean pellets to mean horizontal cover as indicated by zero scores (LPO, Loomis).



A Forage Habitat definition based on the number of zero scores counted from 1.5-2.0 m (less than 4 in 40 readings per transect) has the least classification error of the definitions considered in Table A2.14 (22 out of 90 sites). Basing the definition of forage habitat on zero scores might have the added benefit of being more consistent between observers than cover percentages, because it is easier to recognize “zero cover.”

EXPANDING THE 1996 LYNX PLAN TO INCLUDE MATURE FORESTS AS LYNX FORAGE HABITAT

Results of the pellet study showed that pellet densities were similar between the two age class stratifications (recently disturbed, older) of the studied transects (df=90, $F_{(1,89)}$= 1.562, p=2.15), affirming that it is valid to include old stands as Forage Habitat. Although stand age did not come out as an important characteristic in the previous chapter’s multivariate analyses of Forage Habitat, many of the individual model components are related to stand age, such as mean diameter of large trees, scarcity of pine seedlings, density of large Engelmann spruce, and density of large western hemlock.

The correlation of pellets to horizontal cover (1-2m, %) is substantially lower in older than in younger Loomis stands (older r=0.22, younger r=0.90). The discrepancy between age classes suggests that a singular Forage Habitat definition based on horizontal cover alone will be less accurate for older stands on Loomis. On LPO, there is less difference in the correlation of horizontal cover and pellets between age classes (older r=0.73, younger r=0.58). Breaking down sites by the age of dominant species (vs. sale dates, which is what the “age class” classification is derived from) reveals the strongest correlations for sites whose primary species are less than 30 years old, but also a steadily high correlation through the available data range (Table A2.15). A similar table cannot be derived for Loomis because the earliest recorded sale date is 1974 and the youngest primary species in the database is 70.

Table A2.15
Correlation of mean hare-pellets per transect to horizontal cover (1-2m) for LPO by age of priority species

From DNR’s FRIS database

Age of Priority Species	N	Pearson R for pellets vs. cover
<20 years	3	0.83
30	6	0.87
40	10	0.63
50	14	0.52
60	20	0.64
70	24	0.69
80	25	0.70
all	32	0.62

PATTERNS IN MISCLASSIFICATION USING A DEFINITION BASED ON HORIZONTAL COVER

The previous sections highlighted possible success with a revised horizontal-cover-based Forage Habitat definition, but identified mature forests, especially on Loomis, as having a high potential for misclassification. Table A2.16 sorts the classification errors by cover type and stand age for both the 50 percent horizontal cover definition and the >4 zero score definition. Error rates were proportionally higher on LPO using either the 50 percent cover definition (29 percent misclassified on Loomis, 37 percent LPO) or zero score definition (15 percent Loomis, 34 percent LPO), indicating that both Forage Habitat definitions will be more accurate on Loomis. Within Loomis, misclassification was most common in older stands, particularly those dominated by Engelmann spruce or subalpine fir. On LPO, misclassification occurred in both recently disturbed and older stands under both habitat definitions, and no clear pattern emerged with respect to cover type. These patterns of misclassification match what would be predicted from the correlations with horizontal cover.

Table A2.16 Age and cover type of transect sites in Loomis State Forest and Little Pend Oreille Block

Numbers in parentheses indicate the number of sites per category that had fewer pellets than indicated by their measured horizontal cover. Numbers with stars (*) indicate the number of sites per category that had more pellets than indicated by their measured horizontal cover.

Age Classes	LOOMIS STATE FOREST				LITTLE PEND OREILLE BLOCK				
	ABLA	PICO	PIEN	PSME	ABGR	PICO	PSME	THPL	Total
Recently Disturbed Sites									
Available	1	9	2	13	4	4	6	6	45
Misclassified under 50% cover definition	(1)	(1)		(3)	(1)		(3)	(3)	12
Misclassified under <4 zero scores definition					(1)		(2)	(2)	5
Older Sites									
Available	4	7	11	11	3	3	4	2	45
Misclassified under 50% cover definition	(2)	(1)	(8)	1*	(1)		(2)	(2)	16, 1*
Misclassified under <4 zero scores definition	(2)	1*	(5)	1*	(2)		(2), 1*	(1)	12, 3*

Another variable identified in the univariate analysis as potentially important to predicting pellet densities from habitat characteristics on LPO is the presence of large grand fir (Table A2.7). Requiring that LPO Forage Habitat stands have at least 30 large (>5.5 inches) grand fir trees per acre in addition to <4 zero scores reduces error to one missed habitat site and only three sites with less pellets than predicted by cover, all older sites (two grand fir and one redcedar). This definition change reduces classification error on LPO to 12 percent (4 out of 32), and results in a conclusion, consistent with the data from Loomis, that error is more frequent in older stands.

CONCLUSION

This study has demonstrated that the definition of Forage Habitat used in the 1996 Lynx Plan is based upon a sound habitat relationship (horizontal cover at 1-2m above ground). However, the definition is inadequate in at least two ways. First, some types of older stands do contribute hare habitat and therefore should eventually be included as lynx Forage Habitat. Second, the threshold value of 40 percent cover is too low, allowing too many low-density hare sites to be called Forage Habitat. A new approach that is relatively reliable and simple to identify in the field is desirable.

The analysis in this chapter highlighted the potential for a definition based on horizontal cover scores (zero scores) to have the least error in classifying Forage Habitat sites (12.5 percent Loomis, 9.5 percent LPO). An additional variable, density of grand fir, is necessary to minimize error on LPO. However, DNR is advised to continue testing the Forage Habitat definition. Especially on LPO, the definition is based on relatively small samples (only four good pellet sites were found). In such small samples, differences between habitat/not-habitat are likely to be artifacts of particular sites rather than large-scale trends. For example, there is no reported biological association between the presence of large grand fir and the occurrence of snowshoe hare. In applying the new Forage Habitat definitions to both study areas, DNR can anticipate misclassification error in older forests, especially within older Engelmann spruce dominated forests in Loomis, and may wish to sample pellets directly in these stand types to determine Forage Habitat status rather than, or in addition to, sampling horizontal cover.

The next step for DNR would be to identify new study sites based on the horizontal cover and grand fir predictions, and determine whether the expected pellet densities exist. Also, DNR could add new random samples on both study areas to make sure other stand types that may be of use to hares are not missed, and then develop new models and definitions for the sites. If new models generated from new data sets employ similar variables, confidence in the model results and subsequent Forage Habitat definitions will increase.

Appendix 3 - Lynx habitat as quantified in the literature

Alberta (50 mi^2 or 130 km^2)

Brand et al. (1976)

Densities of 2 - 3 lynx/100 km2 were reported from a study area described as: "33 percent improved pasture and cropland; 33 percent aspen and poplar forest; 15 percent spruce bog; 8 percent bog with scattered black spruce, tamarack, bog birch, and willow; 7 percent brush and regenerating (post-fire) aspen, poplar, and willow; 2 percent marsh with cattail and bulrush; and 2 percent open water." (Snow tracking study)

Cape Breton Island, Nova Scotia (21.3 mi^2 or <58 km^2)

Parker et al. (1981)

"Optimum lynx habitat on the highlands of Cape Breton Island (Nova Scotia) was represented by a mosaic of approximately 50 percent mature conifer, 30 percent mature mixed, 12 percent successional (~20 years following cutting), and approximately 8 percent peat bogs, alder swales, and small streams and ponds. We suggest that the amount of successional habitat could have been increased to 20-25 percent at the expense of the mature mixed type." The authors do not give percent of open habitat, but from a table in the article, home ranges never had more than 15 percent recent (≥ 4 yr old clearcuts). (Three lynx collared, references to previous snow tracking results.)

Ontario (39,376 mi^2 or 107,000 km^2)

Quinn and Thompson (1987)

Between "Boreal Mixed Wood" (27 percent of forest in early successional stages, with 160 ha average clearcut size) and "True Boreal" forests (17 percent early successional, 560 ha avg. size), there were no differences in productivity of lynx or trapping mortality, but the authors speculated that the carrying capacity of Boreal Mixed Wood (southern) forests may have been relatively higher.

Kenai Peninsula, Alaska (92 mi^2 or 250 km^2)

Kesterson (1988)

The study area contained: 34.3 percent mature spruce-hardwood forest (80+ yrs.), 61.4 percent midsuccessional forest burned in 1947 (38-40 yrs.), and 4.3 percent early successional forests (8-11 yrs.). Remnant stands of mature forest occurred throughout the 1947 burn (~13 acres), and mature and midsuccessional stands occurred within the early successional areas. "Over 87 percent of the relocations occurred within the midsuccessional 1947 burn, which occupied 61.4 percent of the study area. Twenty-four of 101 relocations in mature forest occurred around female den sites... lynx significantly selected midsuccessional forest within the study area and neglected habitats consisting of large expanses of crushed or mature forest." (Twenty-nine lynx captured.)

Washington (448 mi^2 or 1,161 km^2)

Brittell et al. (1989)

Habitat categories within lynx home ranges were not significantly different from those available in the study area; however, "lynx avoid xeric south and west aspects presumably due to the little cover and prey." Smaller lynx home ranges were positively correlated with regenerating forests, mid-elevations, and moderate to low slopes. The study area and average lynx home ranges contained: 59-65 percent forested stands with high canopy closure (>66 percent closed), 20-22 percent forested with medium canopy closure (33-66 percent closed), and 14-21 percent non-forest. (Twenty five lynx captured, snow tracking indicated others present.)

Washington (693 mi^2 or 1,795 km^2)

Koehler (1990a)

Lynx "used lodgepole pine and Engelmann spruce/subalpine fir forest cover types in greater proportion than expected and xeric lowland types less than expected." Lowland grassland and ponderosa pine (0.3-3.0 percent range, 15.2 percent study area), Douglas fir/western larch/quaking aspen (12.8 percent, 7.8-17.2 percent, 27.5 percent), Engelmann spruce/subalpine fir (25 percent, 15.8-33.8 percent, 20.6 percent), lodgepole pine (57.3 percent, 46.7-65.8 percent, 31.8 percent), and alpine meadow (3.2 percent, 1.3-5.9 percent, 5 percent). Lodgepole pine >44yr. covered >80 percent of the study area; lodgepole <21years covered <11 percent, mainly in 2.5 acre (1ha) plots resulting from lightning and windthrow. (Seven lynx radio collared, two kittens ear-tagged, 19 lynx (including four kittens) known to occupy 247mi^2 (640 km^2) of the study area (6.7 adult lynx/100mi^2, 2.6 adults/100 km^2)).

Kenai Peninsula, Alaska

Bailey (1992)

"In general, habitat practices that increase food/cover for hares will benefit lynx and large blocks of good hare/lynx habitat will be better than smaller, separated blocks of good hare/lynx habitat. Your mixture of habitat types for lynx appear reasonable except perhaps for non-foraging or travel habitat. Because lynx are opportunistic, they will take prey anywhere it occurs. Areas of high and low density prey densities better describe lynx habitat in our area, but perhaps good lynx habitat in your area is separated by mountain valleys and developed areas... Our non-lynx habitat only includes lakes and open bogs and roughly approximates about 30 percent of lynx habitat and home ranges... In mountainous/benchland habitat, conditions appear more like a climax community where hare/lynx numbers are lower but fluctuate less than lowland successional boreal forest. These habitats appear more dependent on hares using alders and willow communities situated in small drainages and slopes/ridges and interspersed with conifers at/near timberline."

Kluane, southwestern Yukon (68 mi^2 or 175 km^2)
Murray et al. (1994)

The study area contained: 36 percent open spruce, 25 percent very open spruce, 16 percent closed spruce, 2 percent very closed spruce, 10 percent shrub, 6 percent deciduous, 5 percent open. Lynx avoided shrub and open habitats during all years, and selected very closed spruce during low density lynx years (although use was always low: <11 percent). In all years, open spruce was most heavily used (35-43 percent). (Ten to fifty lynx in the larger Kluane Project area (135mi2 or 350km2).)

Mackenzie Bison Sanctuary, Northwest Territories (112 mi^2 or 290 km^2)
Poole et al. (1996)

Landscapes and home ranges used by lynx had high proportions of dense coniferous and dense deciduous forests. Other habitat classes, including open black spruce forests and wetland-lake bed complexes, had lower selection indices. "Much of the dense coniferrous habitat resulted from 20-60 year old burns where young conifer and deadfall from fire-killed trees combined to produce dense understory vegetation." Preferred habitat types made up at least 50 percent of the study area. At least 19 percent of the study area was shrub, meadow, or water. Another 12 percent was unclassified. Lynx relocation areas had means of 21-22 percent unforested habitat types, and the mean of unforested habitat in lynx home ranges was 29-28 percent. (Twenty seven lynx radio-collared.)

Teslin Plateau, Southern Yukon (128 mi^2 or 304 km^2)
Mowat and Slough (2003)

Wildfire burned more than 70 percent of the study area 30-35 years prior to the study resulting in 9.8 percent mature spruce/pine (80-year old), 10.8 percent alpine fir, 5.2 percent riparian willow and 74.2 percent immature forest. "Lynx showed strong preference for regenerating habitats (86 percent of the locations) over mature white spruce and alpine-subalpine." (Over 100 lynx captured.)

Appendix 4 – Common and Scientific Names of Plants and Animals Used in the Text

PLANTS (listed in alphabetical order of the common name)

Common Name	Abbreviation	Scientific Name
alder species	ALNUS	*Alnus* spp.
alderleaf buckthorn	RHAL	*Rhamnus alnifolia*
balsam fir	ABBA	*Abies balsamea*
blackberry	RUBUS	*Rubus spp.*
black spruce	PIMA	*Picea mariana*
blueberry, huckleberry	VACCI	*Vaccinium* spp.
russet buffaloberry	SHCA	*Shepherdia canadensis*
bunchberry	COCA	*Cornus canadensis*
cattail	TYPHA	*Typha* spp.
coastal sand verbena	ABLA2	*Abronia latifolia*
common ladyfern	ATFI	*Athyrium filix-femina*
common snowberry	SYAL	*Symphoricarpos albus*
currant species	RIBES	*Ribes* spp.
Douglas fir	PSME	*Pseudotsuga menzeisii*
dwarf blueberry	VACA	*Vaccinium caespitosum*
elderberry species	SAMBU	*Sambucus* spp.
Engelmann spruce	PIEN	*Picea engelmanni*
false azalea	MEFE	*Menziesia ferruginea*
false Solomon's seal	SMRA	*Smilacina racemosa*
falsebox	PAMY	*Pachistema myrsinites*
fireweed	EPAN	*Epilobium angustifolium*
glossyleaf manzanita	ARNU3	*Arctostaphylos nummularia*
grand fir	ABGR	*Abies grandis*
grouseberry	VASC	*Vaccinium scoparium*
hemlock species	TSUGA	*Tsuga* spp.
honeysuckle	LONIC	*Lonicera* spp.
horsetail	EQUIS	*Equisetum* spp.
jack pine	PIBA2	*Pinus banksiana*

Common Name	Abbreviation	Scientific Name
juniper	JUNIP	*Juniperus* spp.
Kinickinnick	ARUV	*Arctostaphylos uva-ursi*
labrador tea	LEDUM	*Ledum* spp.
Lodgepole pine	PICO	*Pinus contorta*
longtube twinflower	LIBOL	*Linnaea borealis*
lupine species	LUPIN	*Lupinus* spp.
maple	ACER	*Acer* spp.
pecan spray	HODI	*Holodiscus discolor*
Oregon grape	MANE	*Mahonia* spp.
pacific ninebark	PHCA11	*Physocarpus capitatus,*
pine species	PINUS	*Pinus* spp.
pine grass	CARU	*Calamagrostis rubescens*
ponderosa pine	PIPO	*Pinus ponderosa*
prince's pine	CHUM	*Chimpaphila umbellata*
poplar		*Populus* spp.
quaking aspen	POTR	*Populus tremuloides*
red alder	ALRU2	*Alnus rubra*
red spruce	PIRU	*Picea rubens*
rose species	ROSA5	*Rosa* spp.
sagebrush	ARTI	*Artemesia tridentata*
service berry	AMAL	*Amalanchier alnifolia*
sickletop lousewort	PERA	*Pedicularis racemosa*
spirea	SPBEL	*Spiraea betulifolia*
spruce species	PICEA	*Picea* spp.
strawberry	FRVI	*Fragaria virginiana*
subalpine fir	ABLA	*Abies lasiocarpa*
tamarack	LALA	*Larix laricina*
thimbleberry	RUPA	*Rubus parviflorus*
thistle	CIRSI	*Cirsium spp.*
trapper's tea	LEGL	*Ledum glandulosum*
twinflower	LIBO3	*Linnaea borealis*
western hemlock	TSHE	*Tsuga heterophylla*
western larch	LAOC	*Larix occidentalis*
western meadowrue	THOC	*Thalictrum occidentale*
western oakfern	GYDR	*Gymnocarpium dryopteris*
western redcedar	THPL	*Thuja plicata*
white pine	PIMO	*Pinus monticola*
white spruce	PIGL	*Picea gluaca*
white-bark pine	PIAL	*Pinus albicaulis*
willow species	SALIX	*Salix* spp.

ANIMALS (listed in alphabetical order of the common name)

Common Name	**Scientific Name**
black tailed jackrabbit	*Lepus californicus*
bobcat	*Lynx rufus*
caribou	*Rangifer tarandus*
Columbian ground squirrel	*Spermophilus columbianus*
cougar	*Felis concolor*
coyote	*Canis latrans*
Dall sheep	*Ovis dalli dalli*
deer	*Cervus* spp.
domestic cow	*Bos taurus*
domestic sheep	*Ovis aries*
European lynx	*Lynx lynx*
golden eagle	*Aquila chrysaetos*
ground squirrel	*Spermophilus* spp.
grouse	*Bonasa* spp.
hoary marmot	*Marmota caligata*
human	*Homo sapiens*
lynx	*Lynx canadensis*
marten	*Martes americana*
moose	*Alces alces*
mountain beaver	*Aplodontia rufa*
New England cottontail	*Sylvilagus transitionalis*
northern red-backed	*Clethrionomys rutilus*
northern spotted owl	*Strix occidentalis*
ptarmigan	*Lagopus* spp.
rabbit	*Sylvilagus* spp.
raven	*Corvus* spp.
red fox	*Vulpes vulpes*
red squirrel	*Tamiasciurus hudsonicus*
snowshoe hare	*Lepus americanus*
white-tailed deer	*Odocoileus virginianus*

Appendix 5 – Lynx Habitat Guidelines Checklist

Ecoprovince

✓ The sale does not include a designated lynx travel route. (GO TO LMZ)

The sale area includes a designated lynx travel route. (PROCEED)

- ☐ The sale maintains at least 330 feet of forested habitat along the travel route, unless the route crosses an Open Area.
- ☐ The edge of the forested zone along the travel corridor follows the contour of the landscape.
- ☐ Vegetative cover is maintained along the route, as appropriate for site. (GO TO LMZ)

Lynx Management Zone (LMZ)

✓ The sale maintains connectivity within the zone. (GO TO LAU)

Lynx Analysis Unit (LAU)

✓ The sale occurs outside the areas listed below. (GO TO ECOLOGICAL COMMUNITY)

The sale occurs within LAUs of Loomis or the Little Pend Oreille (LAU 18). (PROCEED)

- ☐ The sale does not contribute to >30 percent Temporary Non-lynx Areas within the LAU.

- ☐ Looking back 10 years from the date of the proposed sale and including the sale area, no more than 15 percent of the forested lynx habitat in a LAU has been converted to Temporary Non-lynx Areas in a 10-year period.

- ☐ The sale does not contribute to more than 10 percent of a LAU being managed at the lower levels of forested habitat (180 tpa, >8' tall).

- ☐ Looking back 10 years from the date of the proposed sale and including the sale area, no more than 5 percent of the forested lynx habitat in a LAU has been converted to the minimum forested habitat condition (180 tpa, >8' tall) within a 10 year period.

- ☐ The sale does not decrease Denning Habitat below 10 percent of the LAU.

- ☐ The sale maintains the connection between Forage Habitat and forested habitat.

- The sale maintains ≥50 percent of the area surrounding Denning Habitat as forested habitat.

- The sale incorporates road design/closure measures to minimize human or other disturbance.

(GO TO ECOLOGICAL COMMUNITY)

Ecological Community

- The sale design promotes swift vegetative regeneration and snowshoe hare/lynx recolonization through unit size, shape, composition, and regeneration techniques.

- If the sale involves pre-commercial thinning, self-pruning processes in the stand have excluded most limbs within 2' of average snow pack, or the sale area either occurs under an approved research program or within the white pine seed orchard.

- The sale area has been screened for denning habitat and timing restriction applied as necessary.

- The sale has been surveyed for den sites, so there are ≥2 per square mile section. (END)

Appendix 6 – Lynx Habitat Implementation Checklist

For use on any proposal conducted within Lynx Range on DNR-managed lands. The following report form should be submitted to the Management Forester at sale or contract handoff for any proposal that occurs within areas identified in the Lynx Plan.

1) Name of proposal:
____

2) Location: ___________________________(Legal)
3) LAU Name/Number(s):____
4) Type of Activity: Timber Sale, Silvicultural Activity, and/or Road Construction (Circle One)
5) Number of Units/Size (acres):____
____

Fill in the Following only if proposal is a Timber Sale or Silvicultural Activity:

6) Type of harvest or silvicultural activity:____
7) Reforestation: (Natural/Artificial—describe) __________________________________

8) Identify the number of acres that are even-aged vs. the number of acres with 180+ trees per acre remaining following harvest: ____________ Even-aged Acres (Clearcut, Shelterwood, Seed Tree)
____________ 180+ trees per acre remaining after logging
9) Will a timing restriction be applied (yes/no)? ________________________
10) Effect of Harvest or Silvicultural Activity on forest structure and lynx habitat: how will existing stand(s) be altered? Show forage, denning and travel corridors on an attached prospectus map:________
____
____

Fill in the Following for any type of activity:

11) Was a departure made from the lynx plan? ____________ (Yes/No)
12) Summarize how the lynx plan was used in development of the proposal. Explain why departures were necessary, if applicable:
____
____
____

Fill in the Following for Roads:

13) Miles or Stations of new construction: _____________ (Miles/Stations)

14) Miles or Stations of reconstruction: _______________ (Miles/Stations)
15) Miles or Stations of abandonment: _______________ (Miles/Stations)
16) Miles of Active road: ___________________________________ Miles of Inactive road:___________________
17) Does the proposed road have road closures? _____ (Yes/No) Road Number(s):________

18) Summarize how the lynx plan guidance was applied to the design of the new road:
____
____

Appendix 7 – Lynx Denning Concerns for Timber Harvest in Lynx Range

DNR's Denning Habitat strategy has three components: area, dispersion, and season. The strategy is based on identifying the "best available" habitat for denning, and thus designation as denning habitat is dynamic throughout the life of the plan.

DNR's denning area strategy addresses the quantity of habitat available within a Lynx Analysis Unit (LAU) by maintaining a minimum of 10 percent of the lynx habitat as denning habitat in the four LAUs in which DNR manages at least 20 percent of the habitat (Loomis SF and LPO Block). The 10 percent minimum follows recommendations by WDFW (1996) and is within the ranges historically occurring within the Methow River Basin (Table 4.2 in the 2006 Lynx Plan). Denning Habitat designated to meet the 10 percent minimum area requirement is selected according to the following criteria:

1) Stands with known den sites.

2) Late seral stands of spruce/fir or similar mesic association with denning structure on northerly aspects.

3) Late seral stands with denning structure on mesic associations with other aspects.

4) Late seral stands with denning structure on other associations.

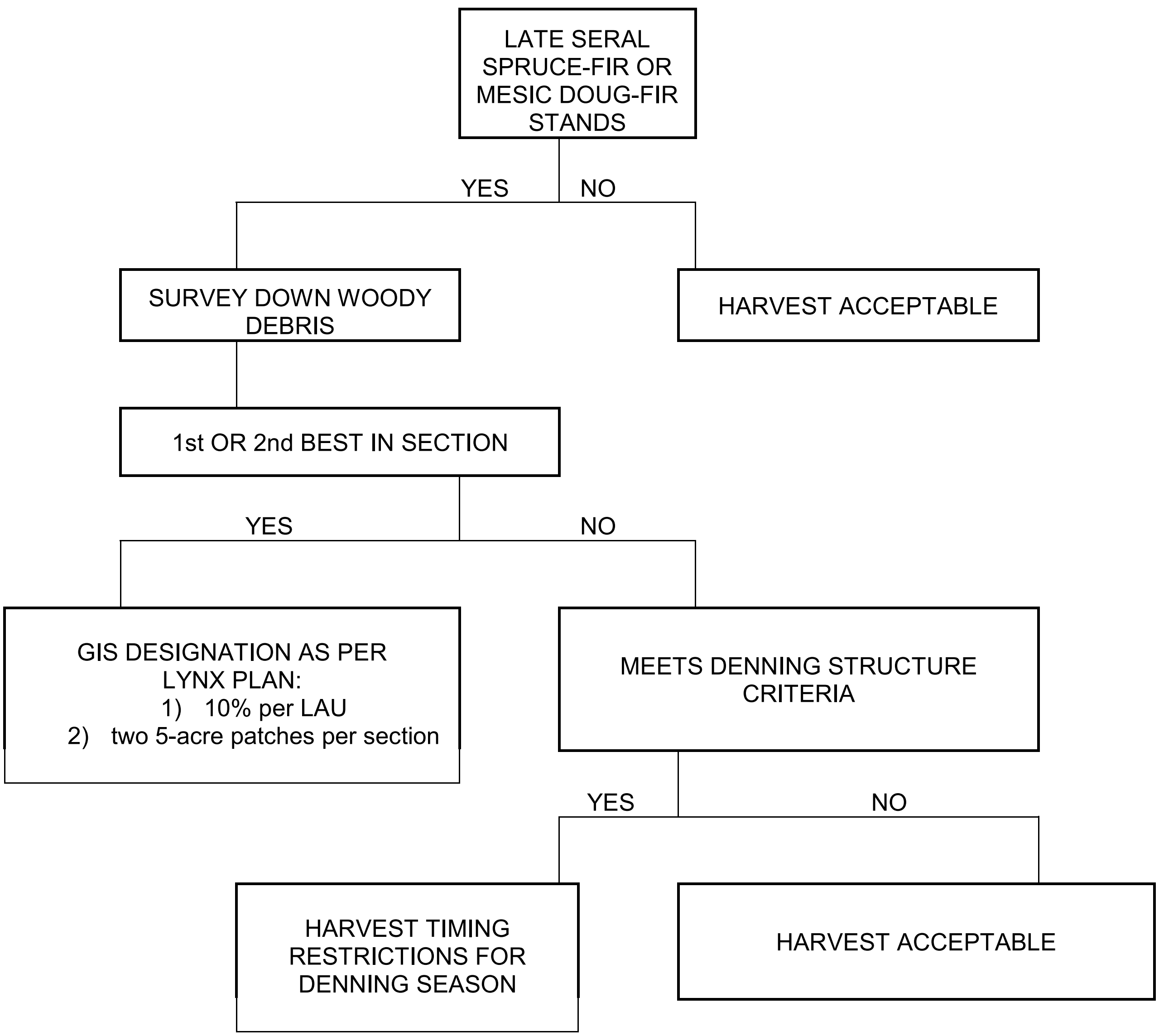
Denning Habitat area has been surveyed and designated in the three Loomis LAUs, and in the Little Pend Oreille Block. Should some of the 10 percent be compromised by fire, pathogens, or other unforeseen events, new Denning Habitat can be added as indicated in the attached flowchart.

Denning structure includes deadfall with large-end diameters of 6 inches or greater, layered such that there is an average of >0.8 logs/yard over a 150 foot transect that are 1-4 feet off the ground. Deadfall includes upturned rootwads. Woody debris should cover the majority (75 percent) of a 5 acre patch. Examples of preferred denning structure conditions are depicted in the Lynx Habitat Field Reference Notebook (ILC 1999). According to the "best available" strategy, denning habitat will still be identified if site conditions do not match this definition, as indicated in the selection criteria. DNR recognizes the role of windthrow in providing material for future denning sites. In areas where denning habitat is scarce, sites with insect and/or disease mortality or other potential to provide future denning will be considered for denning habitat designation.

DNR's denning dispersion strategy of at least two 5-acre sites with denning structure per section (square mile) distributes denning habitat throughout the plan area. Dispersion is believed to be important to lynx. Dispersion of den sites also minimizes the chance that all denning habitat will be eliminated during a fire event, as does selection of sites with northerly aspects and low slope positions. In the case of a large fire or other catastrophic event (640 acres or more where 40 percent of the trees or volume die or are at risk of dying within 12 months of the event), designated denning habitat will still encompass the best available per section; that is, patches ≥5 acres with standing trees, snags, and woody debris will be maintained for denning habitat recruitment.

DNR′s seasonal strategy includes avoiding the harvest of denning habitat during the denning season. The denning season for lynx is May 1 - July 30.

Lynx denning concerns for timber harvest in lynx recovery area (USFWS, 2002)



Appendix 8 – Additional fieldwork conducted on the snowshoe hare pellet transects to describe the vegetative characteristics associated with hare habitat occupancy

Field observations suggested that some additional vegetation variables might help explain hare habitat use. For example, it appeared that woody debris might contribute an important cover component to hare habitat where cover by vegetation was lower. In 2001, data on cover by woody debris and specific vegetation was collected for 26 Loomis transects. Methodology and data summaries are provided here for hypothesis formation and potential guidance for future study.

Methods

Woody debris (by species) and vegetative cover were measured along a 150 feet (50 m) sampling transect at stations 2, 4, 7, and 9. The cover sampling transect was placed at a random angle and the slope of the transect was recorded. Small diameter debris (1-2.9 inches or 2.5-7.5 cm) was tallied if it intersected the transect between 0-3 feet (0-1m) along the length of the transect. Heights were noted for the first three pieces of debris encountered. Debris 3 inches (8 cm) or larger was tallied along the entire length of the transect (0-50m). Details noted for each piece where it intersected the transect included: 1) whether the piece was rotten or sound, 2) species, 3) height, 4) diameter, and 5) whether the piece was elevated from the ground. When pieces were rotten, original diameters were estimated. Relationships between pellets and woody debris cover were investigated through correlations by tallying pieces by size class, averaging heights and diameters, and considering the decay class of wood.

For vegetative cover, the species of vegetation directly intercepting the transect was noted along the distance of the transect from 0-6 feet (0 to 2 m) above the ground. In many cases, multiple species overlapped as layers in the forest understory. The average height (up to 2m) and distance covered were noted for each occurrence of species of vegetation. Relationships between pellets and vegetative cover were investigated by summarizing the total cover by species or groups of species and averaging heights.

Correlations and one-way ANOVAs were used to explore relationships between pellets and vegetation cover. Probabilities were not adjusted for multiple correlations because of the exploratory nature of this analysis, designed to guide future hypotheses and research questions.

Results

The only woody debris characteristic that was different between pellet categories was the mean height of non-elevated wood (Table A8.1). Comparing sites with low to high horizontal cover, it appeared that pellets on sites with low cover were most highly correlated with the height of 1-3 inches (2.5-7.5 cm) material on site and negative to the diameter of non-elevated woody debris (Table A8.2). On sites with high cover, pellets were most highly correlated with the mean diameter of larger woody debris on site, especially that which was non-elevated. The strongest negative correlation observed was between pellets and the height of non-elevated wood. There were no significant relationships between vegetative cover and pellets.

Table A8.1
One-way ANOVA results for woody debris characteristics (tree data) between pellet categories (f=few, s=some, m=many)

Post-hoc test results reported when $p \leq 0.05$ (n=26).

Variable	**Mean Pellet Category**		
	$F_{(2, 23)}$	**p**	**post-hoc**
Mean height of non-elevated wood	5.037	0.015	s>f<m
Mean height of elevated wood	1.285	0.296	_____
Mean diameter of wood 3” or greater	0.603	0.556	_____
Diameter of non-elevated wood	0.975	0.392	_____
Diameter of elevated wood	0.769	0.475	_____
Tally of 1-3” wood	0.283	0.756	_____
Mean height of 1-3” wood	1.058	0.363	_____
Number of non-elevated wood	0.281	0.758	_____
Number of elevated wood	1.733	0.199	_____
Number of rotten 3” or greater	1.440	0.258	_____
Number of sound 3” or greater	2.335	0.121	_____

Table A8.2. Correlation coefficients between pellets and woody debris for sites with relatively low (n=13) and high (n=11) horizontal cover

Woody Debris Characteristic	Pearson's R- low cover	Woody Debris Characteristic	Pearson's R- high cover
Mean diameter of elevated wood	-0.555	Mean height of non-elevated wood	-0.675
Mean diameter of sound 3" or greater	-0.444	Number of sound 3" or greater	-0.269
Mean height of non-elevated wood	-0.404	Number of elevated wood	-0.183
Mean height of elevated wood	-0.289	Tally of 1-3" wood	-0.12
Number of sound 3" or greater	-0.091	Mean height of elevated wood	-0.061
Number of non-elevated wood	-0.089	Height of 1-3" wood	-0.049
Tally of 1-3" wood	-0.002	Number of rotten 3" or greater	0.063
Number of elevated wood	0.232	Diameter of elevated wood	0.543
Number of rotten 3" or greater	0.321	Mean diameter of sound 3" or greater	0.777
Height of 1-3" wood	0.608	Diameter of non-elevated wood	0.789

Table A8.3. One-way ANOVA results for vegetation cover characteristics between pellet categories

Variable	Mean Pellet Category	
	$F_{(2, 23)}$	p
Mean height 1	0.139	0.871
Mean height 2	0.047	0.954
Mean height 3	1.075	0.358
Conifer cover	0.661	0.526
Herb cover	1.160	0.331
Grass cover	0.610	0.552
Low shrub cover	0.326	0.726
Tall shrub cover	1.609	0.231
ABLA cover	1.036	0.371
CARU cover	0.570	0.574
LIBOL cover	0.917	0.414
Lupine cover	0.859	0.437
PAMY cover	0.363	0.700
PIEN cover	1.599	0.224
PSME cover	0.305	0.740
Vaccinium cover	0.432	0.654

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