DOES CANADA LYNX TRAPPER HARVEST TRACK POPULATION CYCLES?
A REVIEW OF DATA FROM 1973 TO 2016 IN ONTARIO'S SIXTEEN
NORTHERN FOREST DISTRICTS

by

Rachel Sweezey

Source: Jeff Lepore 2019

Faculty of Natural Resources Management

Lakehead University

Thunder Bay, Ontario

April 2019

DOES CANADA LYNX TRAPPER HARVEST TRACK POPULATION CYCLES?
A REVIEW OF DATA FROM 1973 TO 2016 IN ONTARIO'S SIXTEEN
NORTHERN FOREST DISTRICTS

by

Rachel Sweezey

0645054

An Undergraduate Thesis submitted in partial fulfilment of the requirements for the
degree of Honours Bachelor of Environmental Management with a Specialization in
Wildlife Conservation and Management

Faculty of Natural Resources Management

Lakehead University

April 26, 2019

_____   _____
Major Advisor   Second Reader

LIBRARY RIGHTS STATEMENT

In presenting this thesis in partial fulfillment of the requirements for the HBEM degree at Lakehead University in Thunder Bay, I agree that the University will make it freely available for inspection.

This thesis is made available by my authority solely for the purpose of private study and research and may not be copied or reproduced in whole or in part (except as permitted by the Copyright Laws) without my written authority.

Signature: _____

Date: _____ Apr 26 /19 _____

A CAUTION TO THE READER

This HBEM thesis has been through a semi-formal process of review and comment by at least two faculty members. It is made available for loan by the Faculty of Natural Resources Management for the purpose of advancing the practice of professional and scientific forestry.

The reader should be aware that opinions and conclusions expressed in this document are those of the student and do not necessarily reflect the opinions of the thesis supervisor, the faculty or Lakehead University.

ABSTRACT

The Canada lynx (*Lynx canadensis*) has been widely studied for its strong interaction with the snowshoe hare (*Lepus americanus*), and the lynx exhibits a slightly lagged, 10-year population cycle dependent on the hare cycle. Trapper return data from 1973 to 2016 was obtained from the Ontario Ministry of Natural Resources and Forestry sorted by return year and district, corresponding to 16 northern forest districts. The objectives of this study were: 1) to organize trapper return data to show the number of Canada lynx caught and reported in each district from 1973 to 2016; 2) to quantify and qualify the cycles inherent in the database; and 3) to discuss biases in the trapper return database in terms of its ability to reflect peaks in lynx abundance. Numbers of pelt returns do not suggest synchrony of the lynx cycle across Northern Ontario, but modal peak years were identified, which consistently had larger returns of lynx pelts than corresponding low years at the midpoint from the previous peak year. This trend was significant across all forest districts. Return data does provide support for the refugium model that predicts for more southerly forest districts, where the snowshoe hare occurs at lower densities than in more northerly forest districts, dampened cycle peaks. However, behaviour of trappers and other biases may have an influence on interpretations in this thesis.

Keywords: Boreal Forest, Canada lynx, Great Lakes-St. Lawrence Forest, *Lepus americanus*, *Lynx canadensis*, Northern Ontario, population cycles, refugium model, snowshoe hare, synchrony.

CONTENTS

TABLES

FIGURES

ACKNOWLEDGEMENTS

Through the process of writing this thesis, I have received a great deal of support and assistance. First, I thank my supervisor, Dr. Brian McLaren, whose expertise was very helpful in developing my thesis topic, as well as carrying out the study and assisting me with the statistical analysis in particular.

I acknowledge my second reader, Neil Dawson, from the Northwest Biodiversity and Monitoring office of the Ontario Ministry of Natural Resources and Forestry for his wonderful collaboration. Neil helped greatly with the development of my topic and provided me with the raw dataset of trapper return data as well as district maps that I was able to conduct my thesis on.

In addition, I thank a couple of Lakehead NRM professors for their roles and contributions. Mr. Tomislav Sapic helped me in creating a map overlaying the district boundaries with the forest region boundaries, and Dr. Kevin Crowe provided the basis for writing skills that were required in writing this thesis.

INTRODUCTION AND OBJECTIVES

The Canada lynx (*Lynx canadensis*) is a species that has been widely studied for its strong interaction with the snowshoe hare (*Lepus americanus*). Lynx follow the same 10-year population cycle as the snowshoe hare, and its dependency on this prey species denotes high vulnerability to trapping (Elton and Nicholson 1942). The species was overharvested by trappers from the 19th and into the 20th century, due to poor management and lack of knowledge surrounding their life history (Quinn and Parker 1987). Since then, a better understanding of lynx population cycles has allowed for the recovery of the species. Currently, the Canada lynx is not at risk in Canada, but has remained a threatened species in the United States since 2000, and the species was placed under review for a status downgrade in early 2018 (USFWS 2018). Further study of the lynx-hare population cycle may lead to a better understanding of the Canada lynx and improved management practices for trapping.

The Canada lynx is one of only three wild cat (Felidae) species currently found in North America (Koehler and Aubry 1994). Ranging across the northern part of the continent, the lynx prefers Boreal Forest habitats and tends to avoid disturbed areas (Kurta 1995). The Canada lynx is a specialist predator of the snowshoe hare, and the species has corresponding adaptations (Stenseth et al. 1997). Long hind legs and disproportionately large feet allow a lynx to chase down a hare in deep snow (Quinn and Parker 1987). This characteristic is what separates the Canada lynx from the bobcat (*Lynx rufus*), whose range is notably limited by snow depth (Quinn and Parker 1987).

The Canada lynx also has carnassial teeth, which are characteristically feline and help to bite through the neck of prey (Kurta 1995). Snowshoe hare comprises 65-85% of the lynx diet and one lynx individual can eat 170 hares in a year (OFMF 2016). While the lynx does consume other prey, its dependency on snowshoe hare populations is what drives populations to follow a slightly lagged, 10-year cycle (Brand et al. 1976, Quinn and Parker 1987). Reproduction is also dependent on food availability and in low hare years, a female lynx has fewer young and kit survival rates are lower (Brand and Keith 1979). Overall, it is clear that the snowshoe hare is the primary driver in the life cycle of the Canada lynx.

The pattern of snowshoe hare and Canada lynx cycles was first determined from Hudson's Bay Company records harvests, which found that the two species have the same cycle time with a slight lag (Elton and Nicholson 1942, Krebs et al. 2001). Keith et al. (1984) determined that hare populations are driven by food supply and predation. The initial population decline is due to an abundant hare population causing a decline in preferred food availability, leading to lower litter size and survival rates. The next stage of hare decline is a result of adult malnutrition from the scarce and unpalatable food that remains in the habitat. The final stage in the population decline is due to predation, primarily by the Canada lynx. A study by Krebs et al. (2017) suggested that declines in hare populations are almost entirely caused by predation. Directly, predation has an obvious effect on hare mortality; however, fear of predation produces chronic stress in breeding females and indirectly causes lower reproductive rates. Lynx numbers follow the hare cycle, usually with a one-year lag (OFMF 2016). When hare populations collapse near the end of the 10-year cycle, it does not take long for lynx populations to

collapse. The difference is that lynx numbers fail primarily owing to the reduced litter size and low survival rates of young, in addition to starvation (Brand and Keith 1979). This knowledge suggests that the two species follow a predator-prey-forage cycle with a time delay or lag in predator response (Brand et al. 1976).

Finally, a model of snowshoe hare cycles originated by Wolff (1980) predicted that extremes in cyclic population dynamics in the southern margins of the boreal forest are prevented by source-sink dynamics (Griffin and Mills 2002). In the northern range, high quality habitat tends to be more continuous, allowing hare numbers to reach the extreme peaks observed in the 10-year cycle. However, habitat fragmentation and mixed forest is more prevalent in the southern range, where only smaller metapopulations of hares occur during declines and when populations are low. Southern hare cycles appear to be stabilized by discontinuous forests, facultative hare predators, and the presence of other hare species (Wolff 1980). A study by Wirsing et al. (2002) found that, in their southern range, snowshoe hare survival rates were so uniformly low that it was likely that hare populations were supported by immigrant hares from elsewhere. Studies on snowshoe hare, however, are localized and few studies – if any – have investigated a possible dampening of lynx cycles in the southern limit of their range as a response to any difference in the behavior of snowshoe hare.

The Canada lynx is a commonly harvested species for its fur (OMNRF 2018). The most popular trapping method is by leghold trap set near a scent post to attract the lynx. This type of trap must be checked at least once a day, as per Ontario regulations, but several daily checks ensures minimal suffering (OFMF 2018a, Quinn and Parker 1987). In the spring of 2018, lynx pelts averaged about CAD $80 at the North American

Fur Auctions (NAFA), and the most expensive sold for CAD $281.60 (NAFA 2018). As with other trapped species, lynx numbers trapped each year must be reported by Ontario trappers in a mandatory season-end harvest report that is submitted to the Ontario Fur Managers Federation (OFMF). The collection of these reports, or returns, allows trends to be sorted to indicate at what stage the population is in the 10-year cycle (OFMF 2018b, OMNRF 2018). Quotas for the next year are based on trapper returns and are adjusted each year to avoid overharvest during declining years when the population is most vulnerable (Quinn and Parker 1987, OFMF 2016, OMNRF 2018).

The first objective of this thesis was to organize trapper return data obtained from the OMNRF to show the number of Canada lynx caught in each Northern Ontario forest district from 1973 to 2016 in order to quantify and qualify the cycles inherent in the database. A second objective was to discuss biases in the trapper return database in terms of its ability to reflect peaks in lynx abundance. It was expected that lynx harvest cycles would be lower in amplitude in the southern part of their range, where boreal mixedwood and Great Lakes-St. Lawrence transitional forests create fragmented escape habitat for hares and consequently should produce dampened snowshoe hare cycles.

LITERATURE REVIEW

CANADA LYNX ECOLOGY

General

The Canada lynx (*Lynx canadensis*) is one of only three wild cat (Felidae) species currently found in North America (Koehler and Aubry 1994). Although some have considered it a conspecific of the Eurasian lynx (*Lynx lynx*), the Canada lynx does have notable size and prey selection differences, leading to species differentiation as a consensus in the literature (Quinn and Parker 1987, Tumlinson 1987). According to Tumlinson (1987), there are two recognized subspecies of the Canada lynx; *Lynx canadensis canadensis*, found in the mainland United States and Canada, and *Lynx canadensis subsolanus*, found only in Newfoundland.

Description/Appearance

The Canada lynx is a medium size feline with reddish to grey-brown fur, a short, black-tipped tail, and black ear tufts. Pelage is generally lighter in the winter; however, a rare, partial-albino variety also exists as a "blue lynx." The Canada lynx exhibits mild sexual dimorphism, with males typically being 15-25% larger than females. Long fur makes the lynx appear larger than its true size. A gradient has been found in body size with larger individuals inhabiting more northern areas (Quinn and Parker 1987).

Distribution/Range

Ranging across the northern part of North America, lynx prefer Boreal Forest habitat, and tend to avoid disturbed areas (Kurta 1995). Over the years, their distribution in Canada has remained mostly unchanged, and their northern boundary is limited only by the treeline. Comparatively, lynx distribution in the United States has been reduced. Their southern boundary is limited by snow depth, and it has been pushed further north by habitat fragmentation and alteration from expanding farmland and urban areas (McKelvey et al. 2000). Certain individuals and populations have exhibited large dispersal patterns, characterized by years of low prey availability. Movements greater than 800 km have been recorded for certain individuals (Ward and Krebs 1985).

Habitat

The Canada lynx inhabits areas of Boreal, Sub-Boreal, and Montane forests. Highest densities occur in spruce-, pine-, and balsam fir-dominated forests with some deciduous component (Quinn and Parker 1987). At the stand level, habitat preferences are driven by the occurrence of snowshoe hare (Hodges 2000). Kesterson (1988) found that lynx prefer older, regenerating stands (>20 years) and avoid younger stands, while potentially using habitat edges to hunt hares living in areas with extremely dense cover. Denning sites are generally hidden in dense vegetation or in areas with deadfall or roots that provide overhead protection (Kesterson 1988). Wildfire is a major habitat modifier in the Boreal Forest, and fire suppression has reduced habitat quality for the Canada lynx, especially towards the southern boundary of the ecoregion. Logging practices are

conducted to emulate wildfire, necessary in the creation of optimal, early successional

habitat for hare and lynx; however, modified logging also removes den site material for

lynx and is not a perfect solution (Mowat and Slough 2003).

Feeding

The Canada lynx is a specialist predator on the snowshoe hare and the species

shows corresponding adaptations (Stenseth et al. 1997). Lynx are able to effectively

chase down a hare in deep snow with help from their long hind legs and

disproportionately large feet (Quinn and Parker 1987, OFMF 2016). These

characteristics separate the Canada lynx from the bobcat (*Lynx rufus*), which has shorter

legs and smaller feet, and are therefore limited in geographic range by snow depth

(Quinn and Parker 1987). Carnassial teeth, which are characteristically feline, also help

the Canada lynx to bite through the neck of their prey (Kurta 1995). Sixty-five to eighty-

five percent of a lynx's diet is comprised of snowshoe hare and one individual lynx can

eat 170 hares per year (OFMF 2016). The Canada lynx is known to consume other prey,

including squirrels, mice, voles, beaver (*Castor canadensis*), muskrat (*Ondatra*

zibethicus), grouse, and other birds and mammals (Parker et al. 1983), although this

extended diet occurs mainly in low cycle years when the snowshoe hare is rare (Brand et

al. 1976).

Reproduction

The Canada lynx breeds from March to early April with gestation lasting 60-65

days, and kittens born late May to early June (Slough and Mowat 1996, Quinn and

Parker 1987). The Canada lynx's dependency on snowshoe hare populations is what

drives their own numbers in a slightly lagged, 10-year cycle (Brand et al. 1976, Quinn

and Parker 1987). Reproduction is highly dependent on food availability, and in low

hare years, a female lynx has fewer young with lower survival in the litter (Brand and

Keith 1979). Brand et al. (1976) found that during years of abundant snowshoe hare, the

average lynx litter size was 4-5 kittens with a survival rate of 50-83%. Comparatively,

during the cycle low in snowshoe hare, lynx recruitment fails for about two years as a

result of reduced birth rate following the hare decline and low kitten survival the

following year (Slough and Mowat 1996, Brand et al 1976). Typically, all lynx females

ovulate during high snowshoe hare years, but ovulation declines during a cycle low

(Quinn and Thompson 1987). After the cycle low, female lynx begin breeding again and

litter sizes increase (Brand and Keith 1979). Overall, the snowshoe hare is a clear

primary driver in the life cycle of the Canada lynx.

SNOWSHOE HARE ECOLOGY

General/Appearance

The snowshoe hare (*Lepus americanus*) is a member of the Leporidae family and

is one of the most common forest mammals in Canada (Banfield 1974). It ranges in size

from 380 to 505 mm in length (Bittner and Rongstad 1982) and is sexually dimorphic,

with females larger than males (Severaid 1942). Well known for its adaptations to a

snowy climate, the snowshoe hare has a grey-brown coat in the summer that changes to

almost pure white in the winter (Banfield 1974). Its large hindfeet (120-150 mm in length) are coated with stiff hairs, and they act as snowshoes, allowing the individual to travel over deep snow without sinking (Bittner and Rongstad 1982).

Feeding

Food sources for the snowshoe hare are largely dependent on season. During summer months, hares forage primarily on grasses, forbs, sedges, clover, dandelion, asters, strawberry, ferns, and horsetails. They may also choose to feed on young leaves of aspen, willow, and birch. In the winter, foraging shifts to the needles of most conifer species, as well as bark, twigs, and buds of woody plants, such as maples, willows, and poplars (Murray 2003, Bittner and Rongstad 1982). Unlike other Leporidae, the snowshoe hare occasionally eats meat by scavenging from carcasses of deer or other hares. A snowshoe hare typically only ventures into forest clearings to feed at night, remaining in dense cover during the day. Foraging home ranges average about 8 ha (Murray 2003).

Reproduction

Snowshoe hare breed from March to September (Murray 2003). Females may have up to four litters per year, each with an average of four leverets (Bittner and Rongstad 1982). Litter size and the number of litters per year vary with geographic location (Murray 2003). Females will hide their young under suitable cover, such as a log or shrub for most of the day. Providing minimal maternal care, the mother will rest

alone up to 250 m away, as an antipredator strategy, and return only once per day to nurse (Bittner and Rongstad 1982).

Range/Preferred Habitat

The snowshoe hare is found across Canada in every province and territory, inhabiting much of the country's boreal and montane regions. In the United States, the species is found in Alaska, the mountainous western states, and the southern reaches of the Boreal Forest (Banfield 1974). Preferring dense understory as cover, this species thrives in conifer-dominated and mixedwood stands with ages of 25 to 40 years. The snowshoe hare typically avoids human-disturbed areas but may occupy forest edge habitat (Bittner and Rongstad 1982, Murray 2003).

POPULATION CYCLES OF CANADA LYNX AND SNOWSHOE HARE

Snowshoe Hare Cycle

Fluctuations in snowshoe hare and Canada lynx abundances occur in roughly 10-year cycles (Elton and Nicholson 1942). This pattern was determined from Hudson's Bay Company harvest records, which found that lynx and hare pelt returns followed the same cycle time with a slight lag (Elton and Nicholson 1942, Krebs et al. 2001). Keith et al. (1984) determined that hare populations are driven by food supply and predation. The initial population decline is due to an abundant hare population that causes a decline in availability of its preferred food and consequently results in smaller litters and

decreased survival. The next stage of decline is due to malnutrition from the scarce and unpalatable food that remains. And the final decline is due to predation, primarily by the Canada lynx.

Krebs et al. (2001) found that snowshoe hare cycles are driven by both food availability and predation. Food quality was found to directly lower the body condition of the snowshoe hare, and overgrazing was found to indirectly lead to poor body condition as a result of chronic stress. Predation is another obvious driver of the cycle (Krebs et al. 2001). However, chronic stress from repeat encounters and unsuccessful attacks is proposed to have a negative effect on the reproductive output of breeding females during both peaks and lows in the snowshoe hare cycle (Boonstra et al. 1998). Disease and parasites do not have a significant effect on snowshoe hare reproductive, survival or mortality rates, and therefore are not considered as influential in creating the hare cycle (Keith et al. 1985, Sovell and Holmes 1996, Murray et al. 1997). Overall, predation is considered to be the primary cause of death for snowshoe hare, but other factors, such as food quality and quantity, affect body condition, by increasing parasite loads, chronic stress, and the likelihood of predation (Krebs et al. 2001). Krebs et al. (2017) suggested that snowshoe hare declines are caused almost entirely by predation. The Canada lynx has a direct effect on hare mortality through hunting and feeding. However, predation has the additional indirect effect of inducing the fear of predation as a chronic stress in breeding females and lowering hare reproductive rates.

Canada Lynx Cycle

Abundance in Canada lynx populations tracks the snowshoe hare cycle, typically with a one-year lag (OFMF 2016). When the population of snowshoe hare collapses near the end of the 10-year cycle, the resulting lynx population collapse happens shortly after. However, the lynx decline is primarily due to reduced litter sizes and low survival rates of young, as well as starvation, while snowshoe hare declines are predominantly a result of starvation (Brand and Keith 1979). Kitten mortality rates were at 65 to 95% for lynx born during the lynx population decline. During low years in the hare cycle, the Canada lynx shifts to alternative food sources, such as squirrels, ruffed grouse (*Bonasa umbellus*), other avian species, and some carrion. Despite the shift to other prey, Brand et al. (1976) also concluded from body fat measurements that average food consumption by the lynx was only at 80% of the minimum requirement to maintain body weight. This negative energy balance ultimately suggests a poorer body condition during low hare years, a contributing factor to lower reproductive rates and particularly high mortality rates of young lynx.

The Refugium Model

The refugium model is a concept often used in biogeography (Birks 2015). Simply put, it suggests that a population could survive during a period of unfavourable regional conditions, so long as local refugia are available (Birks and Willis 2008). It has its origins in descriptions by Gause (1934) and experiments by Huffaker (1958), who showed that persistence in predator-prey systems depends on the availability of refuges

for prey, themselves dependent on division of resources into a number of patches that allow prey to move about in space and stay one step ahead of the predators. The refugium model was first applied to lynx-hare cycles by Wolff (1980), who predicted that the extremes of cyclic population dynamics in the southern range of the snowshoe hare are prevented by source-sink dynamics (Griffin and Mills 2002). Hares avoid local extinction by seeking refuge in higher quality habitat patches. These refugia are often dense spruce or willow-alder thickets that provide the much-needed cover and protection from predators. In the northern range, high quality habitat is typically more continuous, allowing for snowshoe hare numbers to reach the extreme peaks observed in the 10-year cycle. Habitat fragmentation is more prevalent in the southern range, and refugia become crucial towards maintaining smaller metapopulations of the hare during a decline and a low population. Thus, snowshoe hare cycles are dampened in the south, where more stable populations are maintained by the refugia.

Wolff (1980) concluded that northern hare cycles are regulated by obligate snowshoe hare predators – such as the Canada lynx – that display their own cycle dependent on snowshoe hare densities, as well as by the mosaic of vegetation that creates suboptimal (low-quality) and optimal (refugium) habitats. However, southern hare cycles appear to be stabilized by discontinuous forests, facultative predators, and the presence of other hare species (Wolff 1980). Wirsing et al. (2002) reported that snowshoe hare survival rates in their southern range were so uniformly low that hare populations were likely supported by immigrant hares from other locations.

STUDIES USING TRAPPER HARVEST DATA

The Canada lynx is a furbearing species that is commonly harvested for pelts (OMNRF 2018). Fur trappers in Ontario are legally required to obtain a licence each season at a cost of CAD$39.55. The exception to this regulation is for farmers trapping on their own land. However, a trapping licence is mandatory for anyone selling pelts. The most recent open season for trapping lynx was from October 25, 2018 until the end of February 2019 in all wildlife management units (WMU) across Ontario (OFMF 2018a). The most popular trap is a certified leghold trap, which is set near a scent post to attract the lynx. This type of trap must be checked at least once per day, but several times daily is preferable to ensure minimal suffering (OFMF 2018a, Quinn and Parker 1987). Lynx pelts averaged CAD$80 at the North American Fur Auction (NAFA) in the spring of 2018, with the most expensive pelt being sold for CAD$281.60 (NAFA 2018).

Each year, a mandatory season-end harvest report must be submitted to the Ontario Fur Managers Federation (OFMF) detailing harvest numbers of each species – including lynx – as well as number of pelts sold and kept. The completion of this form is a requirement for license renewal the following year. The resulting database of trapper returns allows trends to be seen in the lynx numbers that indicate at what stage the lynx population is in the 10-year cycle (OFMF 2018b, OMNRF 2018). Trapper return data provides the basis for quotas the following year, which are adjusted each year to avoid overharvest during the most vulnerable declining years in a cycle (Quinn and Parker 1987, OFMF 2016, OFMF 2018a, OMNRF 2018).

MATERIALS AND METHODS

Trapper return data was obtained from the Ontario Ministry of Natural Resources and Forestry (OMNRF). The dataset included the number of Canada lynx harvested each year for all years available (1973 to 2016, with some gaps) in the Northwestern and Northeastern Regions, with forest districts and return year as qualifiers. The raw data included lynx numbers for 26 forest districts. In 1992, the boundaries of some OMNRF districts were changed, reducing the number of Northern Ontario districts to sixteen (Neil Dawson, pers. comm.). The district boundaries of an older OMNRF map, drawn prior to 1992, and a current OMNRF map from 2018 were visually compared to determine which district data should be combined to represent the current district structure (Table 1).

The lynx return data for each district was graphed to show variation in lynx numbers over the 44-year study period. Peak returns years in each district were determined visually, and synchrony across the districts was determined based on how well the identified peak years aligned. To analyze peak strength across all 16 districts, a mode table was developed to choose common peak years; common low years were then set halfway between peak years. Peak strength was defined as the ratio of peak-year lynx returns to corresponding low-year returns and was calculated for each peak year following the first one (four in total), and for each district. Mean peak strength and standard error of the mean were determined for each peak year across all districts. A Z-test was conducted for each peak-strength ratio to determine if there was any statistical significance to the peaks, i.e., was the peak-strength ratio significantly larger than 1,

when peak-year returns to low year-returns would be at a 1:1 ratio. Finally, to explore the refugium model, the OMNRF districts were filtered by forest type (Figure 1).

Statistical analyses were conducted separately on the collection of ten districts in the Boreal Forest region (Chapleau, Dryden, Hearst, Kirkland Lake, Nipigon, Red Lake, Sioux Lookout, Thunder Bay, Timmins, Wawa) and five districts in the Great Lakes-St. Lawrence Forest region (Fort Frances, Kenora, North Bay, Sault Ste. Marie, Sudbury). The district of Cochrane was excluded from the separate statistical analysis by forest region as it is located north of the Boreal Forest, in the Hudson Bay Lowlands forest region. However, Cochrane was included in the analysis of all 16 districts together.

Table 1. Combined OMNRF districts following a 1992 boundary change.

Current forest districts	Older districts included in the new forest districts
Cochrane	Cochrane, Moosonee
Chapleau	Chapleau
Dryden	Dryden, Ignace
Fort Frances	Fort Frances, Atikokan
Hearst	Hearst, Kapuskasing
Kenora	Kenora
Kirkland Lake	Kirkland Lake
North Bay	North Bay, Temagami
Nipigon	Nipigon, Geraldton, Terrace Bay
Red Lake	Red Lake
Sioux Lookout	Sioux Lookout
Sault Ste. Marie	Sault Ste Marie, Blind River
Sudbury	Sudbury, Espanola
Thunder Bay	Thunder Bay
Timmins	Timmins, Gogama
Wawa	Wawa
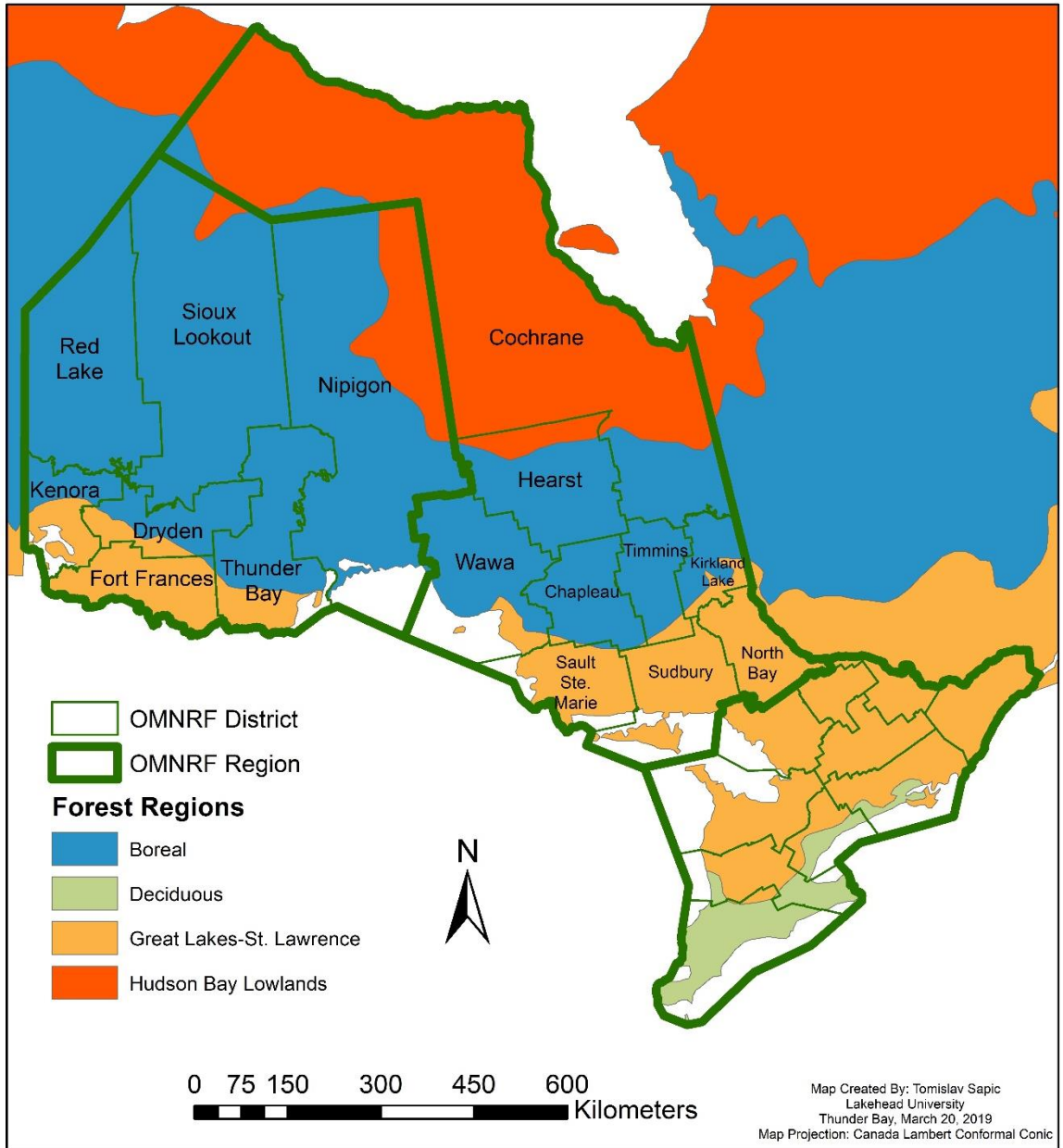
Figure 1. Forest regions of Ontario and Ontario Ministry of Natural Resources and Forestry (OMNRF) district and regional boundaries.

RESULTS

Graphed lynx return data from each of the 16 districts (Figure 2 to Figure 17) provided a visually simple way of assessing synchrony and identifying peak years in each district (Table 2). Synchrony in single peak years was not evident across Ontario's northern districts, with the exception of 1973. Using a summary of modes across districts (Table 3), common peak years were identified as 1973, 1982, 1994, 2002, and 2013. Set halfway between peaks, common low years were identified: 1977, 1988, 1998, 2007.

Table 2. Peak years in lynx pelt returns by OMNRF district (**bold** = modal year, --- = no visible peak, * = weak peak).

District	Peak 1	Peak 2	Peak 3	Peak 4	Peak 5
Cochrane	**1973**	**1982**	1991	**2002**	**2013**
Chapleau	---	1981	1991	**2002**	**2013**
Dryden	**1973**	**1982**	**1994**	2000	**2013**
Fort Frances	**1973**	1982*	1993	2000	2012
Hearst	**1973**	**1982**	1993	2003	**2013**
Kenora	**1973**	**1982**	1994*	**2002**	2012
Kirkland Lake	**1973**	1981	**1994**	2003	**2013**
North Bay	**1973**	1981	**1994**	2004	**2013**
Nipigon	**1973**	1981	1993	**2002**	2012
Red Lake	---	**1982**	1994*	2000	2012
Sioux Lookout	**1973**	1979	**1994**	2002*	2012*
Sault Ste. Marie	**1973**	**1982**	1988	2004	**2013**
Sudbury	**1973**	**1982**	1992	2004	2012
Thunder Bay	**1973**	1979	**1994**	**2002**	**2013**
Timmins	**1973**	**1982**	1993	2003	**2013**
Wawa	---	1981	**1994**	2003	2012
Modal year	1973	1982	1994	2002	2013
Number of occurrences	13	9	8	6	9

Figure 2. Lynx returns in the Red Lake District from 1973 to 2016.

Figure 4. Lynx returns in the Nipigon District from 1973 to 2016.

Figure 3. Lynx returns in the Sioux Lookout District from 1973 to 2016.
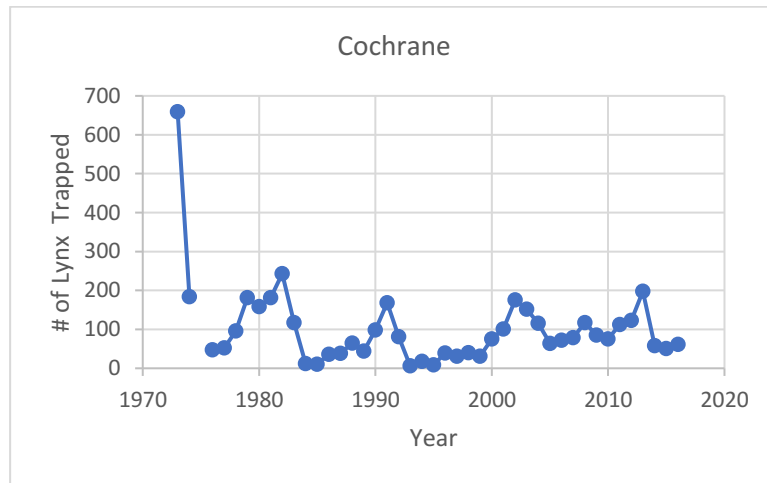
Figure 5. Lynx returns in the Cochrane District from 1973 to 2016.

WESTERN DISTRICTS
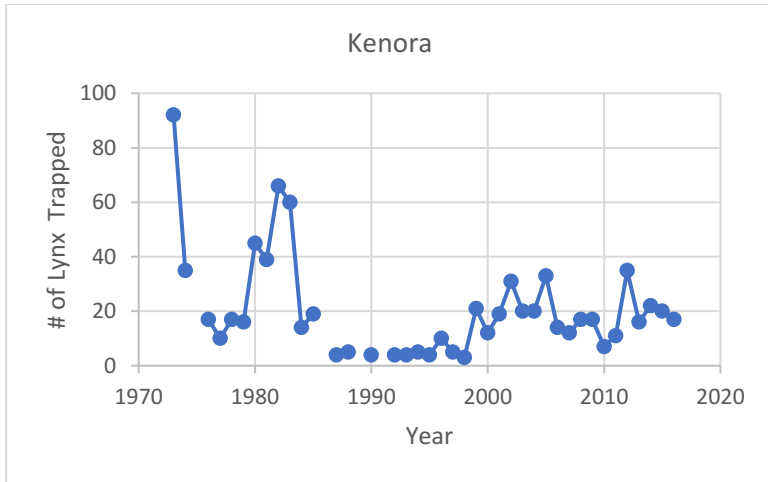
Figure 6. Lynx returns in the Kenora District from 1973 to 2016.
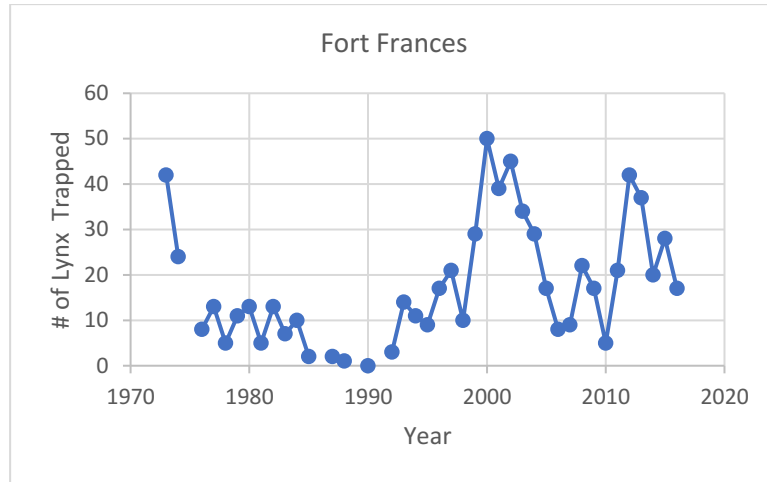
Figure 8. Lynx returns in the Fort Frances District from 1973 to 2016.
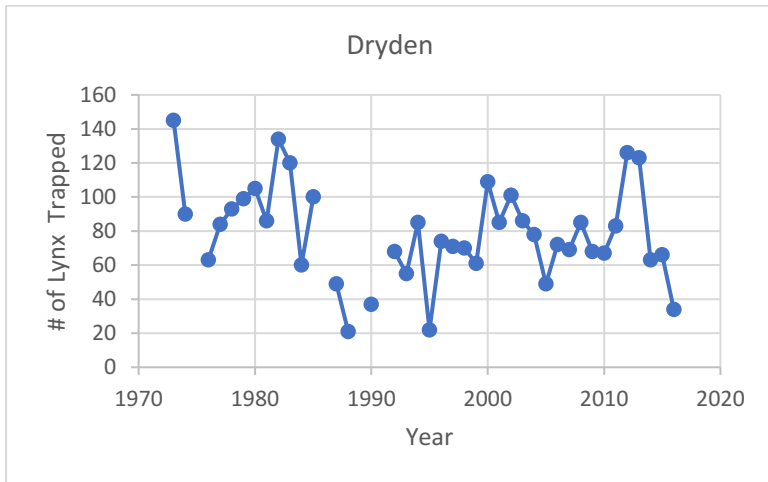
Figure 7. Lynx returns in the Dryden District from 1973 to 2016.
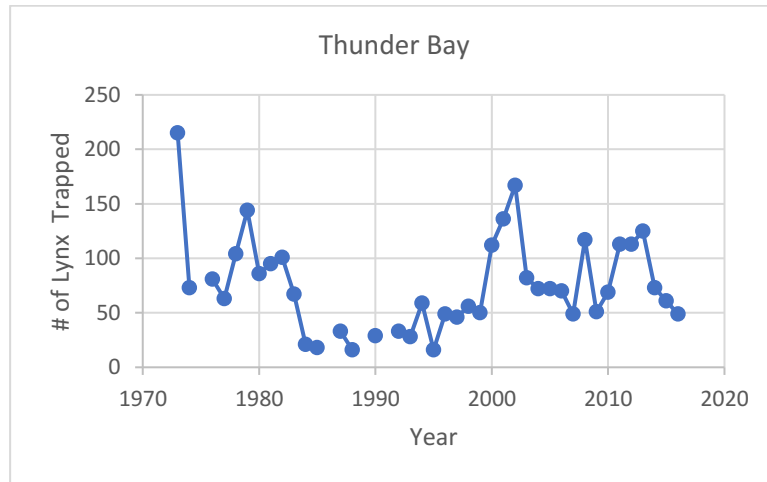
Figure 9. Lynx returns in the Thunder Bay District from 1973 to 2016.

EASTERN DISTRICTS
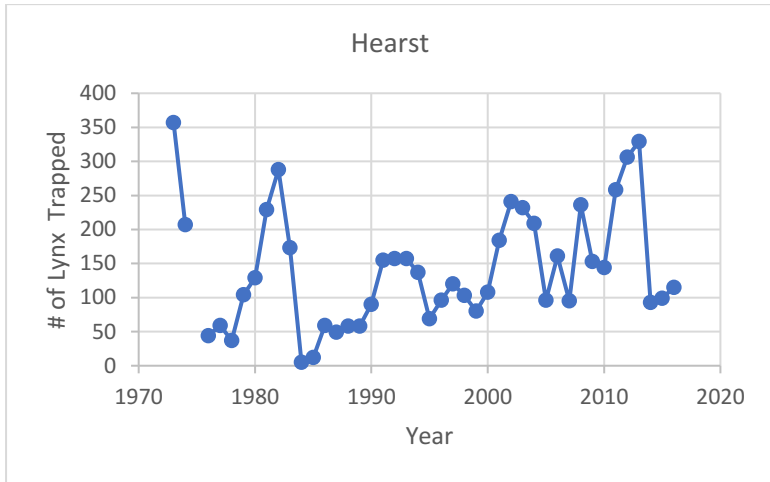
Figure 10. Lynx returns in the Hearst District from 1973 to 2016.
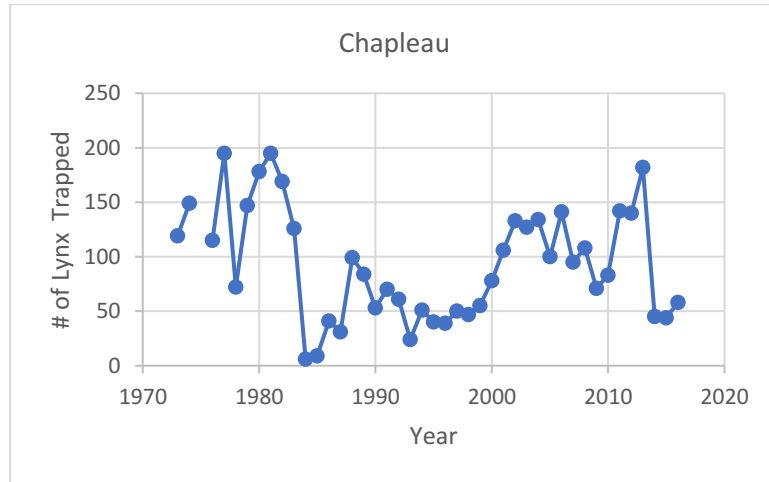
Figure 12. Lynx returns in the Chapleau District from 1973 to 2016.
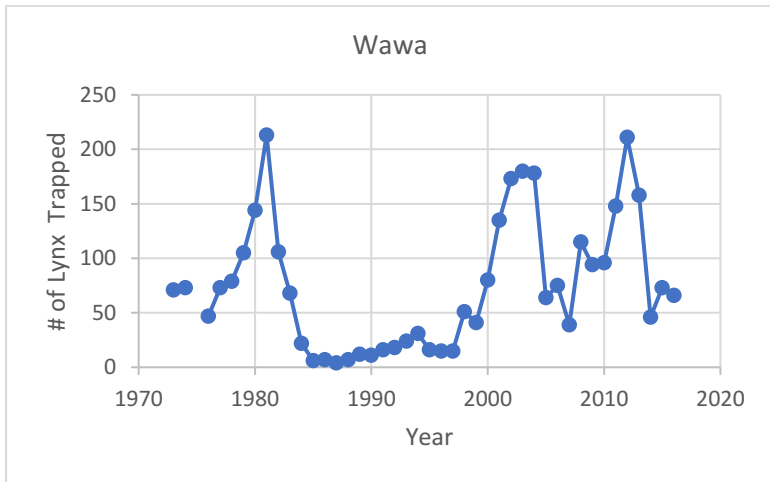
Figure 11. Lynx returns in the Wawa District from 1973 to 2016.
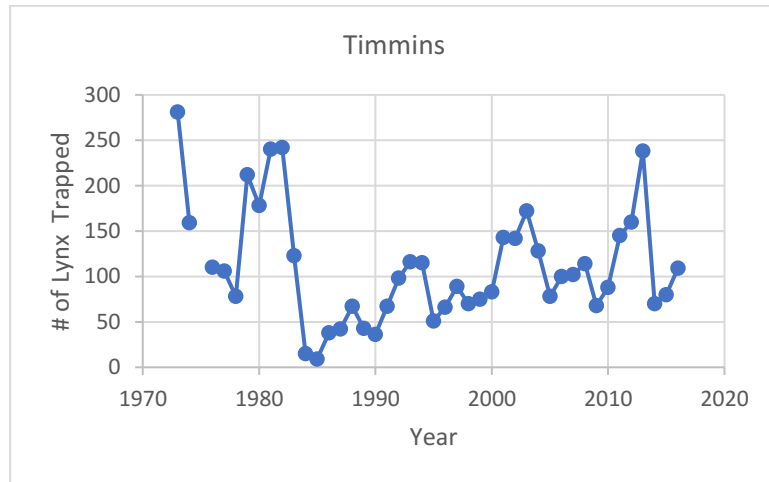
Figure 13. Lynx returns in the Timmins District from 1973 to 2016.

SOUTHERN DISTRICTS
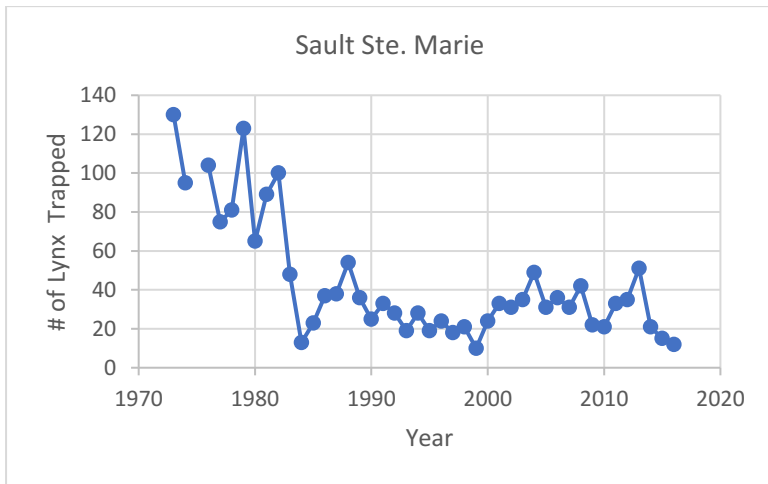
Figure 14. Lynx returns in the Sault Ste. Marie District from 1973 to 2016.
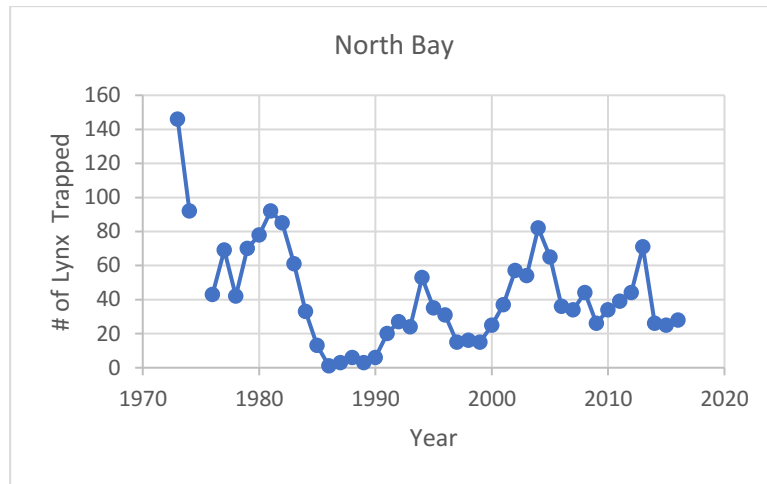
Figure 16. Lynx returns in the North Bay District from 1973 to 2016.

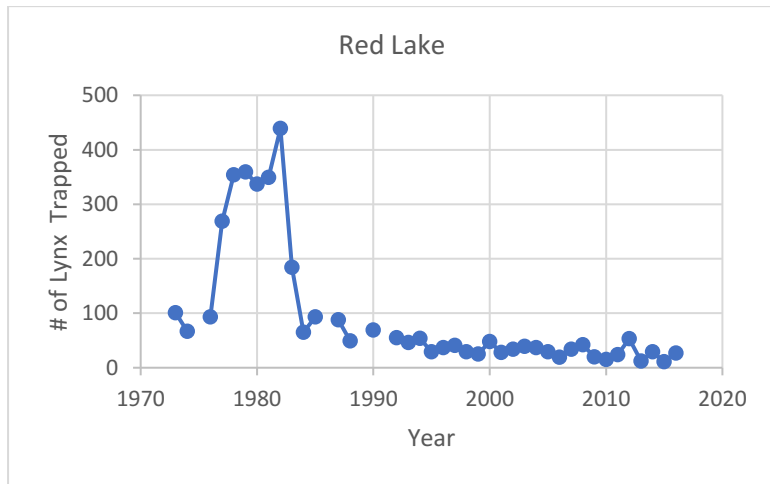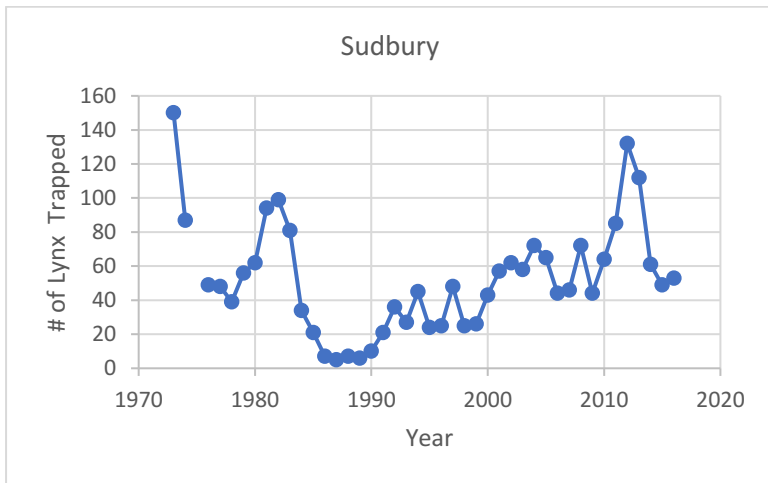Figure 15. Lynx returns in the Sudbury District from 73 to 2016.
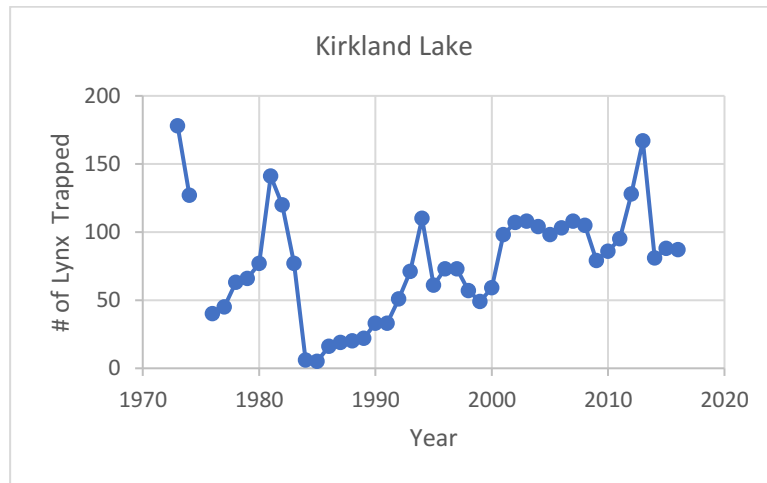
Figure 17. Lynx returns in the Kirkland Lake District from 1973 to 2016.

Table 3. Number of forest districts with peak lynx pelt returns in the modal peak year.

Peak year	Number of districts
1973	13
1982	9
1994	8
2002	6
2013	9

The range of peak strength was greatest in the 16 forest districts together (Table 4), and peaks were significant (i.e., the peak strength exceeded 1) for all four peak years ($p \leq 0.05$). Peak strength was weakest in the Boreal Forest districts (Table 5) and strongest in the Great Lakes-St. Lawrence Forest districts (Table 6). However, in the third analysis of the six more southerly forest districts, the 1994 peak was not significant (i.e., $p > 0.05$).

Table 4. Results summary of statistical analysis (SEM, standard error of mean peak strength) comparing estimated peak to low years of lynx pelt returns to a ratio of 1:1 for all 16 forest districts in Northern Ontario.

Years Compared (peak/low)	Average Peak Strength	Average SEM	Range of Peak Strength			Z-value	Probability of a Significant Peak (p-value)
			Lowest	Highest	Difference		
1982/1977	2.31	0.42	0.87	6.60	5.73	3.30	<0.01
1994/1988	3.46	0.81	0.28	11.00	10.72	4.61	<0.01
2002/1998	3.27	0.56	1.17	10.33	9.16	5.97	<0.01
2013/2007	2.56	0.34	0.35	5.93	5.58	6.17	<0.01
Mean:	2.90	0.535	0.67	8.47	7.80	5.01	<0.01

Table 5. Results summary of statistical analysis (SEM, standard error of mean peak strength) comparing estimated peak to low years of lynx pelt returns to a ratio of 1:1 for the ten Boreal Forest districts in Northern Ontario.

Years Compared (peak/low)	Average Peak Strength	Average SEM	Range of Peak Strength			Z-value	Probability of a Significant Peak (p-value)
			Lowest	Highest	Difference		
1982/1977	1.95	0.30	0.87	4.88	4.01	2.75	<0.01
1994/1988	2.73	0.41	0.52	5.50	4.98	3.59	<0.01
2002/1998	2.56	0.27	1.17	4.75	3.58	4.99	<0.01
2013/2007	2.68	0.40	0.35	5.93	5.58	3.64	<0.01
Mean:	2.48	0.345	0.73	5.27	4.54	3.74	<0.01

Table 6. Results summary of statistical analysis (SEM, standard error of mean peak strength) comparing estimated peak to low years of lynx pelt returns to a ratio of 1:1 for the five Great Lakes-St. Lawrence Forest districts in Northern Ontario.

Years Compared (peak/low)	Average Peak Strength	Average SEM	Range of Peak Strength			Z-value	Probability of a Significant Peak (p-value)
			Lowest	Highest	Difference		
1982/1977	2.55	0.59	1.00	6.60	5.60	1.68	0.05
1994/1988	5.56	1.21	0.52	11.00	10.48	1.54	0.06
2002/1998	4.47	0.90	1.48	10.33	8.86	4.00	<0.01
2013/2007	2.32	0.28	1.33	4.11	2.78	4.07	<0.01
Mean:	3.725	0.745	1.08	8.01	6.93	2.82	0.03

DISCUSSION

Published literature suggests that peaks in Canada lynx abundance occur first in the central areas of the continent and then progress outwards in a wave pattern over the next few years (Smith 1983, Ranta et al. 1997, Krebs et al. 2013). This pattern corresponds to progressively later peak abundance of lynx in Ontario's northwestern districts compared to the more southeastern districts in the range. However, this type of synchronous wave across the 16 forest districts was not found in the Ontario trapper lynx returns, as there was no consistent delay in the peak years from the northwestern to southeastern districts. Except for the first peak in lynx returns, peaks were also not synchronous, although in the most common later peak years, average lynx returns were at least double the previous low-year returns, and the peaks in the common years were significant across all districts, using average ratio of peak- to low-year returns (peak strength) of greater than 1 as the criterion.

The refugium model put forth by Wolff (1980) would predict that peaks in lynx abundance would be weaker, or smaller in amplitude, in the southern range of this snowshoe hare predator, if the Canada lynx tracks snowshoe hare abundance. For the ability of Ontario's harvest data to reflect evidence of the refugium model, the Z-values calculated for peak strength can be compared. The 16 forest districts together and the Boreal Forest districts had mean Z-values of 5.01 and 3.74, respectively, compared to the lower mean Z-value of 2.82 calculated for the Great Lakes-St. Lawrence Forest districts across the four peak years. The Great Lakes-St. Lawrence Forest districts, which are in the southern part of the habitat range for Canada lynx and snowshoe hare,

and also tend to be more fragmented, providing support for the refugium model. However, the highest peaks in the Great Lakes-St. Lawrence Forest districts were stronger than in the Boreal Forest districts, likely due to a bias encompassing the lowest and most variable (i.e., highest range) of trapped lynx returns in the database for the Great Lakes-St. Lawrence Forest, compared to higher, more stable returns reported in Boreal Forest districts. This difference itself lends support for the refugium model.

Many biases became apparent throughout this study and these can be grouped into field biases, trapper biases, and data biases. One field bias exists in the differential occurrence of habitat fragmentation areas across the province. Habitat fragmentation is most commonly a result of human activities whether through the development of a large urban area, or rather a few roads being built through a small strip of the habitat. Since human activity is much more prevalent and widespread across southern Ontario, there may have been a reflection of this in the data through an amplification in the low lynx returns in the southern forest districts. Another field bias deals with a similar effect, but in the northern range. Forestry activities can alter lynx and hare habitat, affecting the occurrence of lynx and hare or affecting trapping activities in the districts. Forestry activities are more common in Northern Ontario and the softwood species of the Boreal Forest, spruce (*Picea*), pine (*Pinus*) and fir (*Abies*), are the most commonly extracted and more easily managed species. Forest harvesting returns the forest to an early successional stage, which is beneficial for snowshoe hare, but it also removes lynx denning sites (Mowat and Slough 2003). With the influence of forestry practices, lynx numbers in the northern range may be higher than expected due to an increased quality

of hare habitat, or they may be lower than expected due to habitat fragmentation by logging roads and the reduced occurrence and quality of lynx denning sites.

Trapping effort has many contributing factors to bias. The price for a pelt has a major influence, varying each year and sometimes by a considerable amount (Brand and Keith 1979, McDonald and Harris 1999, Dorendorf 2015). The highest average price of a lynx pelt on record in Ontario was in 1984 at $567.62, whereas 1970 and 1996 both saw the lowest average prices on record at $26.85 (Statistics Canada 2019). This substantial difference in potential profit for a trapper means that their prediction of the upcoming season's average price is very likely to influence the amount and level of effort put into trapping lynx that year. Other factors include yearly quotas, which may cap the number of lynx a trapper is allowed to harvest, weather conditions, which may influence the trapper's willingness to conduct all of their trapping activities, previous success – or lack thereof, – which may also influence a trapper's willingness and level of effort (Brand and Keith 1979, McDonald and Harris 1999, Dorendorf 2015). Trapper lag is another possible bias that can influence trapper return data (Weinstein 1977). Trapping activities and effort are likely to increase following a successful year, thereby increasing the harvest that following year, resulting in what appears to be a lag in a peak year relative to actual peaks in lynx abundance.

Visual interpretation of cycle peaks from graphed data suggests discrepancy inherent in the approach to the data, especially in distinguishing weaker peaks or determining common peak years when many small peaks appear in less than a 10-year timeframe. For example, in Red Lake District, from 1990 and 2000, there are three possible peak years due to the extremely low amplitude of each, differing from low

years by only 10 or 20 lynx returns. Another data bias is that lynx harvest in a district

may be so low year-to-year that each harvested has a very large impact on the statistical

analysis. This is especially impactful in the southern districts, which rarely have over

100 lynx returns processed, even during peak years. Conversely, almost all of the Boreal

Forest districts have over 100 lynx returns at the cycle peaks. Even during the low cycle

years, the harvested numbers are for the most part still higher in the Boreal Forest

districts than the southern districts, which makes the numbers much more indicative of

true cycles.

CONCLUSION

Analysis of lynx pelt returns did not suggest exact synchrony of the lynx cycle across Northern Ontario, but modal peak years were identified, which consistently had larger returns of lynx pelts than corresponding low years at the midpoint from the previous peak year. This trend was significant across all forest districts. Field and trapper biases and other biases inherent in the data likely had an influence on the interpretations in this thesis. Future studies of the lynx cycle could approach trapper return data at the more focused scale of individual traplines and aim towards a more precise geographic component. Investigations at this recommended scale could reduce the amount and influence of biases in the work. For example, trends seen in the returns of individual traplines and specific information from trappers (i.e., number of traps set per season, locations of individual traps that successfully trapped a lynx, etc.) could help to more accurately assess the presence and strength of cycle peaks. At a larger scale, including data about habitat fragmentation and forestry practices on the landscapes may lead to an explanation of extremes (high or low) in the cycle. For example, evaluating patch size or total area impacted by recent forestry activities in Ontario's districts may show outliers useful in interpreting the lynx return dataset.

LITERATURE CITED

Banfield, A.W.F. 1974. The mammals of Canada. University of Toronto Press, Toronto. 438 pp.

Birks, H.J.B., and K.J. Willis. 2008. Alpines, trees, and refugia in Europe. Plant Ecology and Diversity 1(2): 147-160.

Birks, H.J.B. 2015. Some reflections on the refugium concept and its terminology in historical biogeography, contemporary ecology and global-change biology. Biodiversity 16(4): 196-212.

Bittner, S.L., and O.J. Rongstad. 1982. Snowshoe hares and allies (*Lepus americanus* and allies). Pages 146-163 *in* Chapman, J.A. and G.A. Feldhamer (eds). Wild mammals of North America: Biology, Management, and Conservation. Johns Hopkins University Press, Baltimore, Maryland, USA. 1147 pp.

Boonstra, R., D. Hik, G.R. Singleton, and A. Tinnikov. 1998. The impact of predator-induced stress on the snowshoe hare cycle. ESA, Ecological Monographs 68(3): 371-394.

Brand, C.J., and L.B. Keith. 1979. Lynx demography during a snowshoe hare decline in Alberta. Journal of Wildlife Management 43(4): 827-849.

Brand, C.J., L.B. Keith, and C.A. Fischer. 1976. Lynx Responses to Changing Snowshoe Hare Densities in Central Alberta. Journal of Wildlife Management 40(3): 416-428.

Dorendorf, R. 2015. Motivations and drivers of trapper catch per unit effort in Alaska. M.Sc. Thesis, University of Alaska Fairbanks, Fairbanks, Alaska. 123 pp.

Elton, C., and M. Nicholson. 1942. The ten-year cycle in numbers of the lynx in Canada. Journal of Animal Ecology 11(2): 215-244.

Gause, G.F. 1934. The struggle for existence. Williams & Wilkins, Baltimore, Maryland, USA. 177 pp.

Griffin P.C., and L.S. Mills. 2002. Sinks without borders: snowshoe hare dynamics in a complex landscape. Oikos 118(10): 1487-1498.

Hodges, K.E. 2000. Ecology of snowshoe hares in southern boreal and montane forests. Pages 163-206 *in* Ruggiero, L.F., K. B. Aubry, S. W. Buskirk, G. M. Koehler, C. J. Krebs, K. S. McKelvey, and J. R. Squires, (eds). Ecology and conservation of lynx in the United States. University Press of Colorado, Boulder, Colorado, USA. 474 pp.

Huffaker, C.B. 1958. Experimental studies on predation: dispersion factors and predator-prey oscillations. Hilgardia 27: 795-835.

Keith, L.B., J.R. Cary, O.J. Rongstad, and M.C. Brittingham. 1984. Demography and ecology of a declining snowshoe hare population. Wildlife Society Bulletin 90: 3-43.

Keith, L.B., J.R. Cary, T.M. Yuill, and I.M. Keith. 1985. Prevalence of helminths in a cyclic snowshoe hare population. Journal of Wildlife Diseases 21(3): 233-253.

Kesterson, M.B. 1988. Lynx home range and spatial organization in relation to population density and prey abundance. Unpublished M.Sc. Thesis, University of Alaska, Fairbanks, Alaska, USA.

Koehler, G.M., and K.B. Aubry. 1994. Chapter 4: Lynx. Pages 74-98 *in* Ruggiero, L.F., K.B. Aubry, S.W. Buskirk, L.J. Lyon, and W.J. Zielinski, (eds). The scientific basis for conserving forest carnivores: American marten, fisher, lynx, and wolverine in the western United States. Gen. Tech. Rep. RM-254. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 184 pp.

Krebs, C.J., K. Kielland, J. Bryant, M. O'Donoghue, F. Doyle, C. McIntyre, D. DiFolco, N. Berg, S. Carriere, R. Boonstra, S. Boutin, A.J. Kennedy, D.G. Reid, K. Bodony, J. Putera, H.K. Timm, and T. Burke. 2013. Synchrony in the snowshoe hare (*Lepus americanus*) cycle in northwestern North America. Canadian Journal of Zoology 91(8): 562-572.

Krebs, C.J., R. Boonstra, and S. Boutin. 2017. Using experimentation to understand the 10-year snowshoe hare cycle in the boreal forest of North America. Journal of Animal Ecology 87(1): 87-100.

Krebs, C.J., R. Boonstra, S. Boutin, and A.R.E. Sinclair. 2001. What drives the 10-year cycle of snowshoe hares? BioScience 51(1): 25-35.

Kurta, A. 1995. Mammals of the Great Lakes Region. University of Michigan Press, Ann Arbor. 376 pp.

McDonald, R.A., and S. Harris. 1999. The use of trapping records to monitor populations of stoats *Mustela erminea* and weasels *M. nivalis*: the importance of trapping effort. Journal of Applied Ecology 36(5): 667-688.

McKelvey, K.S., K.B. Aubry, and Y.K. Ortega. 2000. History and distribution of lynx in the contiguous United States. Pages 207-264 *in* Ruggiero, L.F., K. B. Aubry, S. W. Buskirk, G. M. Koehler, C. J. Krebs, K. S. McKelvey, and J. R. Squires, (eds). Ecology and conservation of lynx in the United States. University Press of Colorado, Boulder, Colorado, USA. 474 pp.

Mowat, G., and B.G. Slough. 2003. Habitat preference of Canada lynx through a cycle in snowshoe hare abundance. Canadian Journal of Zoology 81: 1736-1745.

Murray D.L., J.R. Cary, and L.B. Keith. 1997. Interactive effects of sublethal nematodes and nutritional status on snowshoe hare vulnerability to predation. Journal of Animal Ecology 66(2): 250-264.

Murray, D.L. 2003. Snowshoe Hare and other hares. Pages 145-175 *in* Feldhamer, G.A., B. Thompson, and J.A. Chapman, (eds). Wild mammals of North America: Biology, Management, and Conservation, second edition. Johns Hopkins University Press, Baltimore, Maryland, USA. 1232 pp.

North American Fur Auctions (NAFA). 2018. February/March 2018 wild fur report. North American Fur Auctions. http://www.nafa.ca/wp-content/uploads/2018/03/2018-03-22-WF-Full-report-E-CDN.pdf. Nov 20, 2018.

Ontario Fur Managers Federation (OFMF). 2016. Fur Harvest, Fur Management and Conservation Course Manual. Ontario Ministry of Natural Resources and Forestry, Sault Ste. Marie, Ontario. 341 pp.

Ontario Fur Managers Federation (OFMF). 2018a. Summary of Ontario Fur Management Regulations. Ontario Fur Managers Federation. https://furmanagers.com/wp-content/uploads/2018/08/mnrf-regulations-english.pdf. Mar 14, 2019.

Ontario Fur Managers Federation (OFMF). 2018b. Mandatory Season End-Harvest Report. Ontario Fur Managers Federation. https://furmanagers.com/wp-content/uploads/2020/07/harvest-report-and-renewal-2019.pdf. Mar 14, 2019.

Ontario Fur Managers Federation (OFMF). 2019. Lynx. Ontario Fur Managers Federation. https://furmanagers.com/lynx/. Mar 12, 2019.

Ontario Ministry of Natural Resources and Forestry (OMNRF). 2018. Trapping in Ontario. Ontario Ministry of Natural Resources. https://www.ontario.ca/page/trapping-ontario. Nov 20, 2018.

Parker, G.R., J.W. Maxwell, L.D. Morton, and G.E.J. Smith. 1983. The ecology of the lynx (*Lynx canadensis*) on Cape Breton Island. Canadian Journal of Zoology 61(4): 770–786.

Quinn, N.W.S., and G. Parker. 1987. Lynx. Pages 683-694 *in* Novak M., J.A. Baker, M.E. Obbard, and B. Malloch. Wild Furbearer Management and Conservation in North America. Ontario Ministry of Natural Resources, Toronto, ON. 1150 pp.

Quinn, N.W.S., and J.E. Thompson. 1987. Dynamics of an exploited Canada lynx population in Ontario. Journal of Wildlife Management 51(2): 297-305.

Ranta, E., V. Kaitala, and J. Lindström. 1997. Dynamics of Canadian lynx populations in space and time. Ecography 20(5): 454-460.

Severaid, J.H. 1942. The Snowshoe Hare: Its Life History and Artificial Propagation. Maine Department of Inland Fisheries and Game. 94 pp.

Slough, B.G., and G. Mowat. 1996. Population dynamics of lynx in a refuge and interactions between harvested and unharvested populations. Journal of Wildlife Management 60: 946-961.

Smith, C.H. 1983. Spatial trends in Canadian snowshoe hare, *Lepus americanus*, population cycles. Canadian Field-Naturalist 97(2): 151-160.

Sovell, J.R., and J.C. Holmes. 1996. Efficacy of ivermectin against nematodes infecting field populations of snowshoe hares (*Lepus americanus*) in Yukon, Canada. Journal of Wildlife Diseases 32(1): 23-30.

Statistics Canada. 2019. Number and value of pelts produced. Statistics Canada. https://www150.statcan.gc.ca/t1/tbl1/en/cv.action?pid=3210029301#timeframe. Apr 21, 2019.

Stenseth, N.C., W. Falck, O.N. Bjørnstad, and C.J. Krebs. 1997. Population regulation in snowshoe hare and Canadian lynx: Asymmetric food web configurations between hare and lynx. PNAS 94: 5147-5152.

Tumlinson, R. 1987. Mammalian species: *Felis lynx*. American Society of Mammalogists 269.

U.S. Fish & Wildlife Service (USFWS). 2018. Canada lynx (*Lynx canadensis*). U.S. Fish & Wildlife Service. https://www.fws.gov/midwest/endangered /mammals/lynx/index.html. Nov 20, 2018.

Ward, R.M.P., and C.J. Krebs. 1985. Behavioural responses of lynx to declining snowshoe hare abundance. Canadian Journal of Zoology 63(12): 2817-2824.

Weinstein, M.S. 1977. Hares, lynx, and trappers. The American Naturalist 111(980): 806-808.

Wirsing, A.J., T.D. Steury, and D.L. Murray. 2002. A demographic analysis of a southern snowshoe hare population in a fragmented habitat: evaluating the refugium model. Canadian Journal of Zoology 80(1): 169-177.

Wolff, J. 1980. The role of habitat patchiness in the population dynamics of snowshoe hares. Ecological Monographs 50(1): 111-130.

APPENDIX I

TRAPPER RETURN HARVEST DATA FOR LYNX OBTAINED FROM THE

ONTARIO MINISTRY OF NATURAL RESOURCES AND FORESTRY (OMNRF).

Year	Atikokan (AT)	Blind River (BL)	Cochrane (CC)	Chapleau (CP)	Dryden (DR)	Espanola (EP)	Fort Frances (FF)	Geraldton (GE)	Gogama (GO)
1973	28	123	200	119	93	43	14	179	120
1974	17	86	151	149	71	29	7	75	58
1975	no data	no data	no data	no data	no data	no data	no data	no data	no data
1976	5	102	32	115	52	23	3	46	74
1977	9	69	24	195	66	23	4	122	64
1978	5	74	38	72	76	11	0	174	53
1979	11	113	64	147	77	30	0	160	111
1980	13	53	75	178	83	24	0	229	81
1981	5	76	121	195	63	37	0	275	96
1982	12	70	197	169	102	34	1	273	80
1983	6	28	98	126	89	23	1	111	39
1984	9	10	11	6	45	13	1	54	1
1985	2	21	4	9	53	12	0	27	1
1986	no data	34	25	41	no data	5	no data	no data	13
1987	2	35	34	31	15	2	0	27	4
1988	1	51	63	99	14	3	0	27	18
1989	no data	32	40	84	no data	2	no data	no data	8
1990	0	19	96	53	12	2	0	47	8
1991	no data	32	164	70	no data	4	no data	no data	22
1992	3	20	81	61	45	7	0	75	27
1993	13	16	6	24	28	0	1	57	35
1994	9	22	18	51	42	8	2	70	47
1995	9	16	9	40	15	1	0	46	16
1996	16	20	36	39	37	4	1	51	12
1997	21	16	30	50	28	22	0	74	25
1998	10	19	40	47	25	8	0	29	18
1999	28	10	31	55	21	8	1	31	19
2000	44	22	73	78	49	11	6	31	28
2001	25	29	101	106	40	13	14	45	38
2002	31	23	176	133	51	16	14	44	33
2003	25	21	152	127	50	10	9	17	59
2004	25	29	115	134	48	18	4	57	29
2005	13	23	64	100	35	19	4	5	32
2006	8	21	72	141	30	8	0	14	35
2007	7	25	79	95	42	7	2	5	32
2008	21	24	117	108	39	21	1	41	25
2009	13	20	85	71	22	11	4	46	23
2010	2	12	75	83	24	12	3	26	20
2011	17	30	112	142	28	23	4	43	33
2012	24	27	123	140	54	35	18	38	37
2013	24	42	197	182	53	39	13	42	70
2014	16	17	58	45	35	16	4	9	17
2015	15	13	51	44	32	7	13	13	20
2016	13	11	61	58	18	9	4	21	32

Year	Hearst (HE)	Ignace (IG)	Kapuskasing (KA)	Kenora (KE)	Kirkland Lake (KL)	Moosonee (MO)	North Bay (NB)	Nipigon (NG)	Red Lake (RL)
1973	174	52	183	92	178	459	81	182	101
1974	108	19	99	35	127	33	43	54	67
1975	no data	no data	no data	no data	no data	no data	no data	no data	no data
1976	25	11	19	17	40	15	9	60	93
1977	43	18	16	10	45	28	41	205	269
1978	26	17	11	17	63	58	22	199	354
1979	64	22	40	16	66	117	43	211	359
1980	89	22	40	45	77	83	43	170	337
1981	160	23	69	39	141	60	66	244	349
1982	182	32	106	66	120	46	60	132	439
1983	97	31	76	60	77	19	48	86	184
1984	2	15	3	14	6	1	32	60	65
1985	3	47	9	19	5	6	12	51	93
1986	36	no data	23	no data	16	11	1	no data	no data
1987	17	34	32	4	19	4	3	43	88
1988	21	7	37	5	20	2	6	39	49
1989	31	no data	27	no data	22	4	3	no data	no data
1990	45	25	45	4	33	2	4	40	69
1991	62	no data	93	no data	33	4	18	no data	no data
1992	59	23	98	4	51	0	18	33	55
1993	66	27	91	4	71	0	16	52	46
1994	70	43	67	5	110	0	38	32	54
1995	24	7	45	4	61	0	21	31	29
1996	32	37	64	10	73	3	21	42	37
1997	45	43	75	5	73	1	11	49	41
1998	25	45	78	3	57	0	11	30	29
1999	31	40	49	21	49	0	11	31	25
2000	30	60	78	12	59	2	21	52	48
2001	84	45	100	19	98	0	31	80	28
2002	92	50	149	31	107	0	47	110	34
2003	68	36	164	20	108	0	39	52	39
2004	76	30	133	20	104	1	56	60	37
2005	32	14	64	33	98	0	49	31	29
2006	27	42	134	14	103	0	28	25	19
2007	21	27	74	12	108	0	25	18	34
2008	64	46	172	17	105	0	29	46	42
2009	42	46	111	17	79	0	19	27	20
2010	49	43	95	7	86	0	16	23	15
2011	74	55	184	11	95	0	19	89	24
2012	97	72	209	35	128		29	118	53
2013	102	70	227	16	167	1	49	114	12
2014	28	28	65	22	81		19	44	29
2015	18	34	81	20	88		17	60	11
2016	23	16	92	17	87	0	24	68	27

| Year	Sioux Lookout (SL)	Sault Ste Marie (SS)	Sudbury (SU)	Thunder Bay (TB)	Temagami (TE)	Timmins (TI)	Terrace Bay (TR)	Wawa (WA)	TOTAL
1973	210	7	107	215	65	161	169	71	**3426**
1974	26	9	58	73	49	101	97	73	**1714**
1975	no data	no data	no data	no data	no data	no data	no data	no data	**0**
1976	21	2	26	81	34	36	71	47	**1059**
1977	79	6	25	63	28	42	102	73	**1669**
1978	100	7	28	104	20	25	166	79	**1799**
1979	151	10	26	144	27	101	210	105	**2425**
1980	136	12	38	86	35	97	142	144	**2332**
1981	123	13	57	95	26	144	204	213	**2894**
1982	97	30	65	101	25	162	152	106	**2859**
1983	81	20	58	67	13	84	73	68	**1663**
1984	33	3	21	21	1	14	21	22	**484**
1985	34	2	9	18	1	8	13	6	**465**
1986	no data	3	2	no data	0	25	no data	7	**242**
1987	13	3	3	33	0	38	16	4	**504**
1988	14	3	4	16	0	49	14	7	**569**
1989	no data	4	4	no data	0	35	no data	12	**308**
1990	13	6	8	29	2	28	43	11	**644**
1991	no data	1	17	no data	2	45	no data	16	**583**
1992	26	8	29	33	9	71	51	18	**905**
1993	14	3	27	28	8	81	69	24	**807**
1994	29	6	37	59	15	68	45	31	**978**
1995	18	3	23	16	14	35	13	16	**512**
1996	17	4	21	49	10	54	19	15	**724**
1997	21	2	26	46	4	64	26	15	**813**
1998	4	2	17	56	5	52	0	51	**661**
1999	6	0	18	50	4	56	3	41	**639**
2000	14	2	32	112	4	55	1	80	**1004**
2001	10	4	44	136	6	105	8	135	**1344**
2002	19	8	46	167	10	109	10	173	**1683**
2003	10	14	48	82	15	113	15	180	**1473**
2004	18	20	54	72	26	99	28	178	**1471**
2005	13	8	46	72	16	46	10	64	**920**
2006	3	15	36	70	8	65	6	75	**999**
2007	7	6	39	49	9	70	5	39	**837**
2008	18	18	51	117	15	89	8	115	**1349**
2009	10	2	33	51	7	45	14	94	**912**
2010	17	9	52	69	18	68	2	96	**922**
2011	14	3	62	113	20	112	33	148	**1488**
2012	24	8	97	113	15	123	48	211	**1876**
2013	20	9	73	125	22	168	10	158	**2005**
2014	13	4	45	73	7	53	19	46	**793**
2015	6	2	42	61	8	60	11	73	**800**
2016	7	1	44	49	4	77	9	66	**838**

APPENDIX II

COMBINED TRAPPER RETURN HARVEST DATA FOR LYNX FOLLOWING

THE 1992 BOUNDARY CHANGES.

Year	Cochrane	Chapleau	Dryden	Fort Frances	Hearst	Kenora	Kirkland Lake	North Bay	Nipigon
1973	659	119	145	42	357	92	178	146	530
1974	184	149	90	24	207	35	127	92	226
1975	no data	no data	no data	no data	no data	no data	no data	no data	no data
1976	47	115	63	8	44	17	40	43	177
1977	52	195	84	13	59	10	45	69	429
1978	96	72	93	5	37	17	63	42	539
1979	181	147	99	11	104	16	66	70	581
1980	158	178	105	13	129	45	77	78	541
1981	181	195	86	5	229	39	141	92	723
1982	243	169	134	13	288	66	120	85	557
1983	117	126	120	7	173	60	77	61	270
1984	12	6	60	10	5	14	6	33	135
1985	10	9	100	2	12	19	5	13	91
1986	36	41	no data	no data	59	no data	16	1	no data
1987	38	31	49	2	49	4	19	3	86
1988	65	99	21	1	58	5	20	6	80
1989	44	84	no data	no data	58	no data	22	3	no data
1990	98	53	37	0	90	4	33	6	130
1991	168	70	no data	no data	155	no data	33	20	no data
1992	81	61	68	3	157	4	51	27	159
1993	6	24	55	14	157	4	71	24	178
1994	18	51	85	11	137	5	110	53	147
1995	9	40	22	9	69	4	61	35	90
1996	39	39	74	17	96	10	73	31	112
1997	31	50	71	21	120	5	73	15	149
1998	40	47	70	10	103	3	57	16	59
1999	31	55	61	29	80	21	49	15	65
2000	75	78	109	50	108	12	59	25	84
2001	101	106	85	39	184	19	98	37	133
2002	176	133	101	45	241	31	107	57	164
2003	152	127	86	34	232	20	108	54	84
2004	116	134	78	29	209	20	104	82	145
2005	64	100	49	17	96	33	98	65	46
2006	72	141	72	8	161	14	103	36	45
2007	79	95	69	9	95	12	108	34	28
2008	117	108	85	22	236	17	105	44	95
2009	85	71	68	17	153	17	79	26	87
2010	75	83	67	5	144	7	86	34	51
2011	112	142	83	21	258	11	95	39	165
2012	123	140	126	42	306	35	128	44	204
2013	198	182	123	37	329	16	167	71	166
2014	58	45	63	20	93	22	81	26	72
2015	51	44	66	28	99	20	88	25	84
2016	61	58	34	17	115	17	87	28	98

Year	Red Lake	Sioux Lookout	Sault Ste. Marie	Sudbury	Thunder Bay	Timmins	Wawa	TOTAL
1973	101	210	130	150	215	281	71	**3426**
1974	67	26	95	87	73	159	73	**1714**
1975	no data	no data	no data	no data	no data	no data	no data	**no data**
1976	93	21	104	49	81	110	47	**1059**
1977	269	79	75	48	63	106	73	**1669**
1978	354	100	81	39	104	78	79	**1799**
1979	359	151	123	56	144	212	105	**2425**
1980	337	136	65	62	86	178	144	**2332**
1981	349	123	89	94	95	240	213	**2894**
1982	439	97	100	99	101	242	106	**2859**
1983	184	81	48	81	67	123	68	**1663**
1984	65	33	13	34	21	15	22	**484**
1985	93	34	23	21	18	9	6	**465**
1986	no data	no data	37	7	no data	38	7	**no data**
1987	88	13	38	5	33	42	4	**504**
1988	49	14	54	7	16	67	7	**569**
1989	no data	no data	36	6	no data	43	12	**no data**
1990	69	13	25	10	29	36	11	**644**
1991	no data	no data	33	21	no data	67	16	**no data**
1992	55	26	28	36	33	98	18	**905**
1993	46	14	19	27	28	116	24	**807**
1994	54	29	28	45	59	115	31	**978**
1995	29	18	19	24	16	51	16	**512**
1996	37	17	24	25	49	66	15	**724**
1997	41	21	18	48	46	89	15	**813**
1998	29	4	21	25	56	70	51	**661**
1999	25	6	10	26	50	75	41	**639**
2000	48	14	24	43	112	83	80	**1004**
2001	28	10	33	57	136	143	135	**1344**
2002	34	19	31	62	167	142	173	**1683**
2003	39	10	35	58	82	172	180	**1473**
2004	37	18	49	72	72	128	178	**1471**
2005	29	13	31	65	72	78	64	**920**
2006	19	3	36	44	70	100	75	**999**
2007	34	7	31	46	49	102	39	**837**
2008	42	18	42	72	117	114	115	**1349**
2009	20	10	22	44	51	68	94	**912**
2010	15	17	21	64	69	88	96	**922**
2011	24	14	33	85	113	145	148	**1488**
2012	53	24	35	132	113	160	211	**1876**
2013	12	20	51	112	125	238	158	**2005**
2014	29	13	21	61	73	70	46	**793**
2015	11	6	15	49	61	80	73	**800**
2016	27	7	12	53	49	109	66	**838**

APPENDIX III

OMNRF MAPS OF DISTRICT AND REGIONAL BOUNDARIES IN ONTARIO.
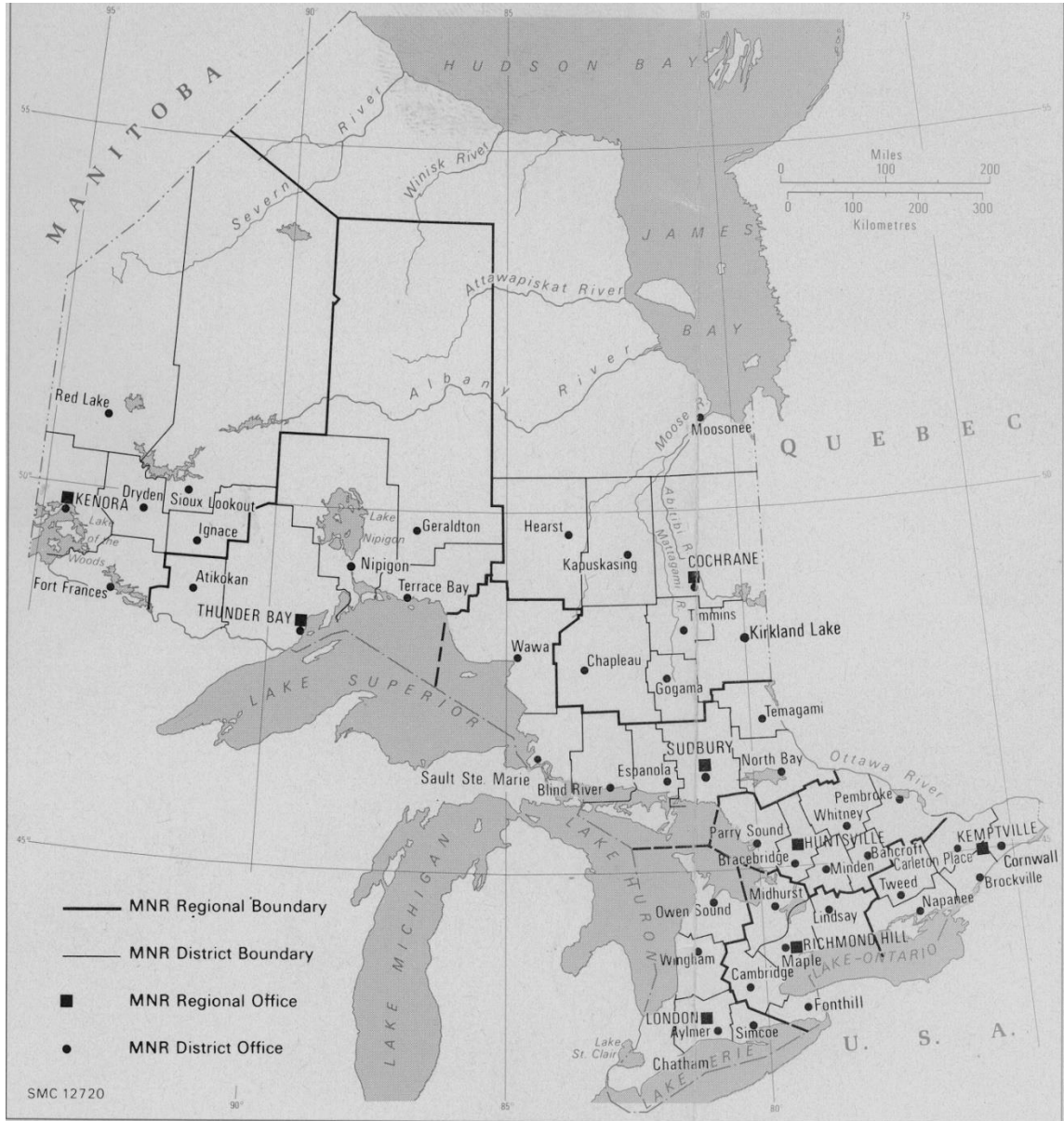
APPENDIX IV

MODE TABLE PROVIDING THE FULL LIST OF ONTARIO DISTRICTS FOR

EACH POSSIBLE PEAK YEAR.

Year	Districts with peaks	Total number of districts (mode)
1973	Cochrane, Dryden, Fort Frances, Hearst, Kenora, Kirkland Lake, North Bay, Nipigon, Sioux Lookout, Sault Ste. Marie, Sudbury, Thunder Bay, Timmins	13
1979	Sioux Lookout, Sault Ste. Marie, Thunder Bay	3
1981	Chapleau, Kirkland Lake, North Bay, Nipigon, Wawa,	5
1982	Cochrane, Dryden, Fort Frances, Hearst, Kenora, Red Lake, Sault Ste. Marie, Sudbury, Timmins	9
1988	Chapleau, Sault Ste. Marie	2
1991	Cochrane, Chapleau, Sault Ste. Marie	3
1992	Dryden, Sioux Lookout, Sudbury	3
1993	Fort Frances, Hearst, Nipigon, Timmins	4
1994	Dryden, Kenora, Kirkland Lake, North Bay, Red Lake, Sioux Lookout, Thunder Bay, Wawa	8
2000	Dryden, Fort France, Red Lake	3
2002	Cochrane, Chapleau, Kenora, Nipigon, Sioux Lookout, Thunder Bay	6
2003	Hearst, Kirkland Lake, Timmins, Wawa	4
2004	North Bay, Sault Ste. Marie, Sudbury	3
2008	Nipigon, Sault Ste. Marie, Thunder Bay, Timmins, Wawa	5
2012	Fort Frances, Kenora, Nipigon, Red Lake, Sioux Lookout, Sudbury, Wawa	7
2013	Cochrane, Chapleau, Dryden, Hearst, North Bay, Sault Ste. Marie, Thunder Bay, Timmins	9