University of Alberta

Furbearer harvests and landscape change in the Rocky Mountain foothills of Alberta

by

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ABSTRACT

Trapping for furbearers remains a popular outdoor activity in Alberta despite low fur prices and extensive industrial development. Using thirty years of marten harvest records, interviews with trappers, and GIS maps of industrial activity, I investigated the influence of landscape change on furbearer harvests. I used an information-theoretic approach to explore reasons for differences between active and inactive traplines and for variation in trapper success. Active traplines had less access, fewer oil/gas wells, and more mature forests, indicating that industrial development was influencing trapper effort. Industrial activity and vegetation type also explained a large amount of the spatial variation in marten harvests as well as temporal changes in harvests. In more heavily developed areas, trappers targeted coyotes instead of marten. The nature and extent of industrial development in Alberta is contributing to the decision by trappers to trap as well as influencing fur harvest patterns.

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A large portion of my research consisted of not only compiling large amounts of data, but also organizing and analyzing these data in a GIS. Charlene Nielsen and Gerardo Marquez provided excellent technical support and patience, and aided in backcasting land-use features to determine landscape change.

Finally I thank all my friends and family who supported me through this challenging but fruitful experience. All the letters, cards, and care packages did not go unnoticed. The graduate students at the U of A truly enriched my experience. In particular, the Boyce lab (Carrie, Jen, Kyle, Chris, Tammy, Cathy, Scott, and Cam) provided me distractions from work, stimulating lunch and white board discussions, ping pong games, American/Maine jokes, road trips, dog walks, weekend fun, and editorial comments to my thesis (especially Carrie). The Merrill lab members (Jacqui, Mark, Darcy, Maria, and Hannah) also were very helpful with a good working knowledge of the study area, and provided statistical advice and good friendships. I also acknowledge Edmonton's green spaces, in particular Mill Creek, for providing me with my daily dose of nature during my off-leash dog walks. Finally, I owe a huge thanks to Nathan Webb and Brody, who got me out in the field to experience the best of the foothills and who add companionship and never-ending adventure to my life.

DEDICATION

I would like to dedicate this piece of work to all the mentors and scholarship donors who helped me get this far by inspiring and supporting my educational endeavors, and teaching me a lot about attitude, perseverance, and attaining personal and professional success.

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CHAPTER 1

GENERAL INTRODUCTION

The fur trade is an integral component of Canada's history with trapping records dating back to the 1700's from the Hudson's Bay Company archives. In 1985, approximately 100,000 Canadians earned all or part of their incomes from the fur industry, including 80,000 licensed trappers and 2000 individuals employed in fur manufacturing (AEFLW 1985). Trapping is still a way of life for many people today and furbearers are valued for their economic and ecological importance. In recent years, wildlife pelts contributed $20-30 million to the Canadian economy annually (Stats Canada 2002). In Alberta, the 2004-2005 trapping season yielded over $2.1 million from sales of wild fur (ABSRD 2005).

Furbearers, in general, have been well-studied because of cooperation with trappers to conduct research. Trapping records are a useful source of information on furbearers that, in some circumstances, would not otherwise be collected. Biologists have used harvest records to create an index of furbearer abundance (Smith & Brisbin 1984), adjust harvest quotas (Fryxell et al. 2001), estimate population densities (Fryxell et al. 1999, Cattadori et al. 2003), examine cyclic fluctuations (Viljugrein et al. 2001, Erb et al. 2001), evaluate status and distribution (Erickson 1982, Buskirk & Harlow 1989), collect biological information (Strickland & Douglas 1987, Simon et al. 1999), and assess the effects of trapping and forestry practices on furbearers (Quick 1956, Payer 1999). Trapper observations and harvests have been instrumental in the wise management of furbearers. Habitat loss is a concern for many trappers and the impact of multiple development activities on sustainable trapping are unclear (AEFLW 1985). Although individual trappers on a registered trapline system manage harvests in Canada, few studies have examined the cumulative effects of human disturbance on trappers and fur harvests. The rate of human-caused disturbance and population growth (1901-2001) in Alberta exceeds any other province (GFWC 2000, Stats Canada 2004), highlighting the importance of studying the effects of industrial development on sensitive wildlife. Harvest records may be one avenue to study the relationship between trappers, furbearers, and industry on a landscape that is rapidly changing.

Alberta is a unique province with many opportunities and challenges. With a diversity of ecotones and a majority of the land under provincial jurisdiction, there is an opportunity for wise management of natural resources; however, multiple overlapping user groups create management challenges and their impact on the environment is uncertain. In Alberta, annual sales of the forestry and petroleum sectors combined were greater than $40 billion (AEP 2004). The petroleum sector has drilled between 12,000-18,000 new wells annually for the past 4 years and currently there are more than 290,000 km of pipelines in Alberta (AB.EUB 2000, 2004). Energy companies can remove as much timber as forestry operations and contribute to increased fragmentation by building gravel well pads, roads, pipelines, seismic lines, and other infrastructure (Schneider 2002), so their footprint should not be overlooked. In addition to forestry and energy development, grazing, mining, trapping, and many forms of recreation take place on public lands, often creating conflicts for the same land base. In Alberta, a cumulative effects assessment (CEA) takes place prior to project development, providing a regulatory mechanism to place limits on human activity (AEP 1998, Bayne et al. 2004); however, a major challenge for regulators has been a lack of baseline information and understanding of environmental interactions (AEP 1998). Researchers can provide resource managers with relevant information to assist with making appropriate land-use decisions to maintain economic prosperity and biodiversity.

THESIS OBJECTIVES & FORMAT

The main purpose of my thesis was to investigate the relationship between the harvest of selected furbearers and landscape change using fur harvest records, interviews with trappers, and patterns of industrial activity (mainly energy and forestry) through time and space. In chapter 2 I will examine the attitudes, experiences, and knowledge of trappers in relation to furbearers and land-use activities based on interviews and telephone surveys. In chapter 3 I integrate information from trapping surveys and landscape variables to describe spatial and temporal variation in marten fur harvests. Finally, in chapter 4 I discuss general conclusions and management recommendations to improve trapping and industrial activity relations, reporting of furbearer harvests in the province, and variables to consider in land-use planning to maintain multiple activities and biodiversity on the landscape.

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CHAPTER 2

CHARACTERIZATION OF TRAPPER ATTITUDES AND BEHAVIOUR ON REGISTERED TRAPLINES IN WEST-CENTRAL ALBERTA

INTRODUCTION

Limited, outdated information exists on the sociology of trappers making it difficult to properly manage and understand a controversial activity. Although trapping is an important part of North American history and provides many benefits, public attitudes for trapping are increasingly less tolerant, making it essential to better understand today's trappers and the value of their services (Todd 1981). Biologists use fur harvests to monitor furbearer population trends and use trapper knowledge for other local wildlife status information (Skinner & Todd 1988). Loss of trapping would result in increased costs for Fish and Wildlife agencies to monitor wildlife, loss in economic value of furbearers, revenue from the sale of trapline registration fees, cultural identity, and income that is important for northern communities or low income families, and increased nuisance animal complaints and agency costs to dispatch animals (Brown & Lasiewski 1972, Armstrong & Rossi 2000, McKinstry & Anderson 2003). The International Association of Fish and Wildlife Association (IAFWA 2005) estimates that without trapping in the United States, it would cost the public $132-265 million to manage furbearers, including $16-32 million to control beavers alone. A better understanding of the demographics and values of trappers and trapping would improve the overall management of furbearers and relationships between trappers and managers, industry, and the general public. In addition, knowledge of the motivations for trapping can help biologists understand the reasons for the change in harvest patterns.

Trapper behaviour and attitudes are affected by many social, economic, and biological factors including weather, fur prices, furbearer sign, income, socioeconomic conditions, and landscape variables (Erickson 1982, Daigle et al. 1998). Trapping participation has declined over time across North America (McKinstry & Anderson 2003) and some of the causes include increased urban populations with less direct contact with nature, animal rights campaigns and public opposition to trapping, low pelt prices and market forces, and habitat loss as a result of development (Daigle et al. 1998). In Canada, Alberta had the 3rd highest 2002/03 total furbearer value, next to Ontario and Quebec (IAFWA 2005), indicating that trapping remains a popular activity producing revenue today. In Alberta, approximately 2,500 trapping licenses are purchased each year with total fur values annually between $1.5- $10 million in the past 10 years (Barrus et al. 1997); however, following the national trend, the number of registered trappers has been reduced by more than half over the past 20 years in Alberta (Poole & Mowat 2001). Trapping participation is difficult to accurately quantify because of variability in the number of junior partners, spouses and children who participate without a license, private resident trappers who do not necessarily have to register as a trapper, and aboriginal people who are not required to hold a license to trap on reserve lands.

In the United States, trapping had the least participation of 45 animal-related activities (Kellert 1980). In 1984, approximately 0.4% of the Canadian population trapped in any given year, with Alberta having higher participation rates (2.3%) than the nationwide survey (Todd & Boggess 1987). Trappers scored high on their knowledge and naturalistic attitudes towards animals and their environment, and scored low on utilitarian and negativistic views towards animals (Kellert 1980), indicating deep motivations for trapping. In addition, trappers represented the most rural people of any animal-related activity group (Kellert 1980). Similar to hunting, participation in trapping can be difficult because of steep initial costs of equipment (e.g., trapline, traps, all-terrain vehicle, etc.), a limited number of registered traplines are available to purchase, and a high degree of knowledge and skill is required to be successful.

Despite a decline, trapping still is an important activity that yields supplemental or a significant portion of income and an accompanied (close to nature) lifestyle. The primary end product of trapping is the fur, but many other parts of the animals are valuable. Meat from furbearers can be used for human or dog consumption. Carcasses can be used or sold as bait, and additional parts of furbearers can be used to make lures, crafts, or clothing (Meredith & Todd 1979, Todd & Boggess 1987). For example, beavers (*Castor canadensis*) are extremely valuable and can be used for multiple purposes including: castor glands are used to make lures and perfumes; meat is consumed by humans and pets, or used as bait; fur is made into clothing and hats; beaver tail is used as a leather for wallets and boots, and other parts (e.g., claws, teeth) can be used for crafts (Novak 1987). Most people who trap also participate in other consumptive outdoor activities (sometimes in conjunction with trapping) like big game and upland bird hunting, picking wild plants, collecting firewood, and gardening (Daigle et al. 1998), as well as non-consumptive activities. With low fur prices, costs of trapping, such as fuel and equipment, can be greater than the revenues obtained from the sale of pelts. The lifestyle associated with trapping carries a deeper meaning than just the economic incentives. Therefore, the total value of furbearer trapping may be largely underestimated if worth, other than pelt value, is not considered.

Trappers represent a unique segment of the population. In 1979, the majority of trappers in Alberta were male (98%) but more women tended to participate in Fish and Wildlife Districts with a large aboriginal community (Meredith & Todd 1979). Although age varied by region, the average trapper was five years older (50 yrs. old) than the average Albertan, ranging in age from 19-92 years, with the majority of trappers in the older age classes (Meredith & Todd 1979). Today, 13% of the annual trappers enrolled in trapping education classes offered by The Alberta Trappers Association are women and 75% of participants are less than 50 years old, indicating that there is more interest by females and younger people (J. Mitchell, ATA, personal communication).

Although approximately 5% of the Alberta population was of native origin (treaty Indian, non-status Indian, or Metis), native trappers made up 50% of the sampled trappers in 1979 (Meredith & Todd 1979). However, the number of licensed native trappers in Alberta has declined dramatically with fewer than 100 (<5% of all trappers) today (Poole & Mowat 2001). Native trappers had more trapping-related experience but earned significantly less income from trapping than non-native trappers (Meredith & Todd 1979). This disparity could be due to differences in the value of harvested species (e.g. beaver vs. lynx), effort, or social reasons. Mean trapping experience ranged from 16-26 years, with 33% of the trapper sample having more than 30 years of experience (Meredith & Todd 1979).

Trappers were second, next to birders, in their knowledge of wildlife in a survey conducted on 60 demographic groups and 20 animal-related groups in the United States (Kellert 1980). Trappers were well-informed about wildlife and their habitats yet had less formal education and annual income than the Alberta population (Meredith & Todd

1979). In 1979, approximately half of the sampled trappers obtained all their winter income from trapping with other sources of income that include pension, social assistance, farming, and logging (Meredith & Todd 1979). Although income from trapping is variable, it is estimated that trappers earn between $1,000 to greater than $10,000 in a given year from the sale of pelts (Slough et al. 1987).

Thus, it is clear that trappers have unique characteristics that differ from the human population, both by their age and gender, income, formal education, and knowledge of the environment. Although socioeconomic factors of trapping have been studied, relatively little is known about trapper attitudes towards land-uses and how these relate to reality. Insight into trapper attitudes and behaviour in relation to actual landscape differences will shed light on a hotly debated topic that lacks resolution without data. The objective of this study was to quantify trapper motivations, knowledge of furbearers and habitats, effort and trapping techniques, and attitudes about land-use practices. This survey was similar to Meredith and Todd's (1979) questionnaire but differs because it examined the attitudes component in relation to landscape structure, which is an important contributor to understanding the sociology of trapping in Alberta.

METHODS

Study Area

This study was conducted in the west-central foothills of Alberta on registered fur management areas (registered traplines) north of the Red Deer River, south of Highway 16, and between Banff/ Jasper National Parks and the eastern boundary of the green zone (Fig. 2.1). This area is approximately 28,000 km^2 and includes 136 registered traplines and 350 townships. Registered traplines overlap forested areas of Alberta and allow individual trappers exclusive rights to harvest fur on provincial (Crown) lands. The average registered trapline is 2 townships (200 km^2) in size and are bounded by natural (e.g., river, creek, etc.) or anthropogenic features (e.g., roads). Traplines commonly have a senior holder and junior partner(s). At the time of the annual license renewal, all trappers are required to submit an affidavit of all the furbearers harvested from the previous season. There are 2 types of trappers: *resident* trappers trap on private and other non-Crown land in the white (nonforested) zone of the province and *registered* trappers have rights to harvest fur from a government-designated trapline in the forested parts of Crown land and were the focus of this study.

The topography is undulating hills in the east and becomes increasingly rugged in the west with white spruce (*Picea glauca*), lodgepole pine (*Pinus contorta*), larch (*Larix occidentalis*), and quaking aspen (*Populus tremuloides*) comprising the dominant tree species. The province manages this area primarily for resource extraction (petroleum, forestry, and mining) and recreational activity. Oil and gas development and timber extraction have increased over the past 3 decades, creating improved truck and trail access for hunters, trappers, and other user groups. West Fraser (formally Sunpine Forest Products Ltd. and Weldwood of Canada Ltd.), Sundance Forest Industries Ltd., and Weyerhaeuser Company harvest lumber on Forest Management Agreements in this area. The proportion of a trapline disturbed by industrial activity ranges from 0.4- 46%.

Several species of wildlife are trapped in this area, including beaver, coyote (*Canis latrans*), fisher (*Martes pennanti*), red fox (*Vulpes vulpes*), lynx (*Lynx canadensis*), marten (*M. americana*), mink (*Mustela vison*), muskrat (*Ondatra zibethicus*), river otter (*Lontra canadensis*), red squirrel (*Tamiasciurus hudsonicus*), short-tailed weasel *(M.*

erminea), long-tailed weasel (*M. frenata*), least weasel (*M. rixosa*), wolf (*C. lupis*), and wolverine (*Gulo gulo*). Marten was chosen as a focal species because it is the most-targeted furbearer trapped in the study area, is perceived to be sensitive to industrial disturbance (Thompson 1994), and is the species for which the most reliable, long-term harvest data were available. On average, the study area accounts for approximately 1/10th of the total annual reported Alberta marten harvest.

Trapper Interviews

Alberta Sustainable Resource Development (ABSRD) provided contact information for senior holders of registered traplines in the study area. Trappers were contacted by phone or in person and asked to participate in a survey that consisted of structured and open-ended questions (App.1). Because time was limited, trappers who reported consistent marten harvests over the study time period were targeted for this survey to increase reliability. Traplines with marten harvest data throughout the time period reduced the bias associated with other reasons for not trapping, such as a death in the family or health problems. The survey took approximately 5-15 minutes to complete and trappers were encouraged to provide supplemental comments. I made up to 4 attempts to contact trappers by phone. The objective of the survey was to determine: 1) trapping experience, 2) knowledge of furbearers and habitat, 3) trapping effort, and 4) attitudes and perceptions to land-uses. Only trappers with phone numbers or who were in attendance at the 2004 Alberta Trapper's Association convention and/or picnic were included in the survey for logistical reasons.

Landscape Variables

Most of the spatial data were acquired from the ABSRD Data Distribution Branch and included roads, seismic lines, powerlines, pipelines, oil/gas wells, and other facilities (e.g., gravel pits, coal mines, and gas plants). For this analysis, all linear features (e.g., roads, seismic lines) were summed and referred to as "access". Cutblock data was acquired from forestry companies and supplemented using the Central East Slopes Wolf and Elk Study (CESWES) cutblock layers (Beyer et al. 2004). The disturbance layer (Disturb) was the summed area of all linear features, facilities, and forestry activities. Fragmentation (effective mesh size) was calculated using the disturbance layer to integrate habitat loss and dissection of the landscape. Closed-conifer forest cover (>50% closed canopy) was quantified using recent satellite imagery from the Foothills Model Forest (FMF) (Franklin et al. 2001), which covered most of the study area, and also from CESWES habitat layers (Beyer et al. 2004). Climate data (e.g., snowfall and temperature) were acquired from Environment Canada. Adjacent traplines with marten harvests were considered marten trapline neighbours. All data were integrated in a geographical information system (GIS) and standardized by registered trapline area.

Statistical Analysis

The survey consisted of quantitative and qualitative response data, which required different approaches for statistical analysis. Landscape features and marten harvests (Table 2.1) were quantified for each trapline and related to qualitative survey data. To better understand potential biases in the interviewed trapper sample, I compared the mean differences in landscape variables and marten harvest activity between traplines in which a trapper was and was not interviewed. Trapper's attitudes towards industrial activities were grouped (e.g., positive, negative) and a *t*-test was used to explore differences in the amount of disturbance on traplines. Interview data also were compared to the Meredith and Todd (1979) survey for the same region to determine whether differences occurred since the last survey was taken 20 years ago. In addition, quantitative survey data were summarized by Fish and Wildlife Districts to characterize broad-scale geographic patterns. I used a Kruskal-Wallis single-factor analysis of variance (ANOVA) by ranks to determine whether there was a difference between landscape variables by district; consequently, a post-hoc Tukey test (with unequal sample sizes) of all pairwise comparisons was calculated to determine which districts significantly differed (Zar 1999).

RESULTS

There were major differences in the composition of registered traplines between trappers who were and were not interviewed in the study area (Table 2.2). In general, interviewed trappers had traplines with significantly less access density, greater proportion of closed-conifer forest cover, warmer yearly average temperatures, more snowfall, were larger in size, had lower density of well sites, and as expected, larger marten harvests. The trappers who were not interviewed were either not active, did not catch marten, did not have a telephone number, or I was unsuccessful at reaching them by phone. The survey was biased against people without telephones, and I found that many native trappers did not have telephones. However, the Fish and Wildlife Districts with a high proportion of native trappers have declined in recent decades, indicating that native trappers are not as active as they once were in the foothills (ABSRD district secretaries, personal communication).

I interviewed trappers who varied in the number of junior partners and years experience and ownership, as well as a broad variety of motivations, effort, opinions, attitudes and concerns, and whose traplines encompassed a range of industrial activities (Table 2.3). Although marten were the most-targeted furbearer species, the majority of trappers set traps for other furbearers present in the area to maximize their time, money, and effort. Trappers were perceptive to changes that had occurred on their traplines with 80%, 90%, and 30% of trappers mentioning an increase in forestry, oil and gas, and other types of activity on their traplines, respectively. Although the oil and gas industry impacted more traplines (i.e., all traplines had seismic lines), the majority of trappers expressed concern about the effects of forestry practices on marten habitat and population persistence. Other concerns expressed by trappers included general industrial or oil and gas activity, overtrapping by neighbouring trappers, and recreational activity, while 17% of trappers had no major concerns. The majority of those with no major concerns had traplines with minimal industrial activity and generally were located in the western part of the study area. Trappers who indicated no major concerns yet had traplines in areas of moderate to high industrial development had good working relationships with the forestry companies.

Human Demographics

A total of 79 trappers (both Sr. and Jr. partners) across 85 registered traplines were interviewed, comprising 58% of the registered trappers in the study area (Fig. 2.2). Incidentally, additional trappers were interviewed on traplines adjacent to the study area and these trappers were included in the summarization of general results (e.g., experience, ownership) to increase sample size (n = 90 registered traplines). Traplines of interviewees were organized geographically by Fish and Wildlife Districts within the study area including Evansburg, Edson, Hinton, Nordegg, Rocky Mountain House (RMH), and Sundre (Fig. 2.3, Fig. 2.4).

Three percent (n = 3) of Sr. holders of a registered trapline were female and 97% were male. But based on information from trappers and female spouses who answered survey questions, an estimated 8-10% of the trappers in the study area were female. This is comparable to Meredith & Todd's survey where female trappers made up 5% of all trappers in this area of the province (range: 0-15% for each district) (Table 2.4). The majority (98%) of trappers had one or more junior partners. The average number of junior partners per trapline was 1.3 people (range: 0-3). Junior partners usually consisted of children, spouse, and/or friends. Nineteen percent (n = 15) of trappers were active on more than 1 registered trapline.

Trapping Practices

The average interviewed trapper had 32 years of experience (range: 4-79 years) and 2% of trappers had less than 10 years of trapping experience (Fig. 2.5). Trappers from the Evansburg District were the most experienced with an average of 38 years of trapping experience, while trappers in the Sundre District had the least experience of 26 years. Small sample size prevented statistical comparisons with the Hinton area. Traplines had been owned for 17 years (range: 1-55 years) on average and 22% of trappers had owned their registered trapline for 5 years or less (Fig. 2.6). Duration of trapline ownership was greater than in the Meredith & Todd (1979) survey where trappers had owned their traplines an average of 10 years. This is to be expected because more time has elapsed, enabling trappers to have owned their traplines for longer. Trappers had owned their traplines the longest in Evansburg than any other district ($\bar{x}$ = 30 years, *SD* = 15.5), whereas Nordegg District trappers have owned their traplines for the least amount of time ($\bar{x}$ = 11 years, *SD* = 7.6). Nordegg traplines had the highest amount of conifer forest cover and least disturbance of any other district whereas Evansburg District traplines on average had the most disturbance of any district and the smallest proportion of active marten traplines.

Only 3% of trappers targeted and caught exclusively marten on their trapline; the majority of trappers set traps opportunistically for a wide variety of furbearers including weasel, red squirrel, fisher, wolf, lynx, coyote, red fox, beaver, muskrat, mink, and wolverine. However, marten were the most-targeted furbearer in the study area because "they are abundant" and "they are easy to process relative to their value." After marten, wolves and lynx were the next most-frequently targeted species.

The number of traps per unit area is one way to assess effort. The average density of marten traps annually set was 0.25 traps/km^2 (range: 0.03-1.55). Trappers indicated that their trapping effort varied through time, within seasons and among years. Most trappers had a certain number of traps that they set each year and maintained typical trap-tending schedules but this was highly dependent on work, income, health and other factors that affected overall effort. The majority of trappers used a conibear trap set in a box cubby to catch marten but additional trap types were used including ground cubbies, carved cubbies from trees, conibears nailed to a tree or leaner pole, self contained trap, and a Kania trap. Trappers looked for similar habitat types or other features when considering marten trap placement (off a road or trail) such as ground structure, mature trees, thick timber, waterways, squirrel, rabbit, and mice sign, marten tracks, ridges, swamps, drainages, and edges. The most frequently mentioned preferred habitat feature was mature or old growth forests.

Trappers indicated that a number of variables influenced their trapping effort from year to year including (in order of increasing frequency): furbearer sign/population status, recreational activity (e.g., hunting, snowmobiles, etc.), income, free time, personal and family health, fur prices, weather conditions, amount of industrial activity (particularly during trapping season), and work schedule (Fig. 2.7). Schedules varied from checking traps only on the weekends, taking one month off from work to trap, or setting traps until a personal quota was met. In addition, the relationship between the proportion of years with reported marten harvests per decade (a proxy for effort) and industrial variables varied temporally. During the 1970 and 1980-decades, the proportion of years with reported marten harvests was inversely associated with access ($r = -0.24$ (70s), -0.22 (80s), 135 d.f., $p<0.05$) and well density ($r = -0.42$ (70s), -0.33 (80s), 135 d.f., $p<0.05$), and positively associated with closed-conifer cover ($r = 0.28$ (70s), 0.17 (80s), 135 d.f., $p<0.05$); traplines were more frequently trapped with less access, fewer wells, and more mature conifer cover. For the 1990-decade, only trapline area was significantly associated with the proportion of years with harvests ($r = 0.3$, 135 d.f., $p<0.05$); trappers were more active on larger traplines.

Trapper Motivation

Reasons for trapping are complex and difficult to quantify. Pelt price has been shown to influence trapper effort in the past when pelt prices were high (Poole & Mowat 2001).

In this survey I tried to identify a threshold price that affected trapper effort. When asked at what pelt value would cause trappers to stop trapping or decrease effort, 45% of trappers answered that pelt prices were not affecting their decision to trap and that they were out trapping for other furbearers anyway. However, 55% of trappers did mention a threshold marten pelt price that would cause them to decrease effort or stop trapping marten (mean: $26, range: $5-$70). Most trappers found this question difficult because pelt prices were so low that trappers hoped to break even once costs for fuel and equipment were taken into consideration. Because trapping requires significant costs, certainly one of the motivations is to sell the furs to compensate expenses. However, I found no significant relationship between marten pelt value and the change in the number of marten harvested ($r = -0.15$, 32 d.f., $p > 0.05$) in the study area from 1967-2003 (Fig. 2.8). Overwhelmingly trappers said that they enjoyed trapping because of the lifestyle and were not in it for the money.

Trappers identified many factors that affected their motivations or ability to trap and these included: family values/passing down the knowledge, health, pelt prices, free time/work schedule, weather conditions, industrial activity, past and present trapping success, animal sign, and income. Approximately 30% of surveyed trappers mentioned that they trapped with a family member(s) and 1/3 of all traplines had been in the family for decades. Trapping participation with the family was an important attribute for many trappers.

Attitudes Towards Land-Use Activities

Forestry

Trappers were most concerned (60%) about forestry practices and reasons included: harvest of mature timber, amount of clearing, herbicide spraying, size of cutblocks, lack of road reclamation, wide riparian buffers, and structure left in cutblocks, fire prevention, the threat of proposed logging, and lack of personal contact, cooperation, and respect. Trappers who had negative attitudes towards forestry on average had a significantly larger proportion of their traplines disturbed ($\bar{x}$ = 0.15, *SD*= 0.09) and cut ($\bar{x}$ = 0.11, *SD*= 0.09), greater access density, and more fragmentation than those who had positive or neutral attitudes towards forestry (Table 2.5). Meanwhile, those traplines with neutral/positive attitudes had less activity on their traplines (Disturbed proportion $\bar{x}$ = 0.09, *SD* = 0.07 and proportion cut $\bar{x}$ = 0.06, *SD* = 0.05). Trappers with positive attitudes toward forestry had a range of disturbance (Cut proportion range: 0.01-0.12), but also mentioned that they had good relations with forestry because they:

> *"felt respected," "were happy with forest management by specific companies," (Weyerhaeuser had the most positive feedback of any company (32%)) "were working with forestry to maintain some areas of old growth," and "sit on a forestry public board."*

Many trappers who had negative attitudes about forestry operations on their traplines mentioned wanting to get involved on forestry public advisory boards. One trapper indicated that mutual agreements could work to maintain forestry and trapping:

> *"Forestry needs to work with trappers more to create harvest plans that suit both. Personal contact like a knock on the door would be nice."*

Trappers with negative attitudes towards forestry, however, also had a wide range in the proportion of trapline cumulatively disturbed (0.02-0.36) and cut (0.0001-0.34). Overall, trappers appeared to be sensitive to any amount of cutting on their trapline or on adjacent traplines, recognizing that the effects of cutting are not isolated. One trapper observed the following scenario after recent forest cutting:

"The adjacent trapline was cut and the marten moved over to my line and I caught double the number of marten I usually catch in one season."

Despite varied attitudes, the number of marten harvested per unit area in the 1990-decade did not vary between traplines with negative or positive/neutral attitudes towards forestry or general industrial development.

Energy Development

Concerns over energy activities were fewer in number and included: amount of activity, access width and amount, safety, and loss of traps during seismic clearing. The majority of trappers did not have negative attitudes towards energy development despite widespread impacts and larger footprints. Instead, most trappers (63%) were indifferent while 1/3 of trappers had negative attitudes towards energy activities. Trappers with positive attitudes towards energy development (5%) included comments such as:

"lots of access thanks to oil and gas," "cooperation to help me out," and "compensation for time to move traps."

While trappers with negative attitudes (32%) had the following observations:

"difficult to trap when oil and gas are active during trapping season because activity seems to chase animals out," "75-fold increase in the number of wells in the past 8 years," "feel discouraged to trap because of activity," "don't get to mailbox often enough to get notices," "plans change frequently," "amount of

activity partly motivated reasons for selling trapline," "energy clears more trees then forestry," "overabundance of access," "companies need to address impacts," "received 15 letters last week notifying me to move my traps for seismic exploration," "marten won't cross wide pipelines without structure," "lack of compensation," and "lost traps to seismic exploration."

General Industrial Activity

Sixty percent of trappers had negative attitudes towards industrial activity collectively. Trappers who mentioned industrial disturbance as a concern gave these specific reasons: general disruption, pollution, habitat loss, access, and cumulative environmental impacts. Trappers with negative attitudes towards general industrial activity had traplines with significantly greater access and wells per unit area, greater proportion clearcut and disturbed, and more fragmentation than those who had positive/neutral attitudes (Table 2.6). One trapper commented on his experiences:

"It's getting to the point where you can't trap because there's too much industrial activity. It's harder to get fur off the land. I used to catch 20 marten and now only a few if I'm lucky."

Other Activity

The majority of trappers did not have clear negative or positive attitudes towards other types of activities or feel that other activities were detrimental to trapping. However, some trappers said that recreational vehicle traffic, mining, native hunting in winter, and theft and vandalism on their traplines were reasons for concern. Trappers recognized that industrial development facilitated other types of activities on their trapline but few conflicts with other recreationalists were mentioned.

Fish and Wildlife District Comparisons

Access and well density, proportion of conifer, fragmentation, and the total number of years active varied among Fish and Wildlife Districts (Table 2.7). The Nordegg District had the least access and well density, frequency of years trapped, and fragmentation, and the most mature conifer forest cover, whereas the Evansburg District had the most access, well density, and fragmentation, and the least conifer forest cover. However, only certain district comparisons had variables that were statistically different (Table 2.8). The Nordegg District had the most differences from other districts in the amount of habitat and industrial footprint. The Evansburg District had significantly greater access and well density and less conifer forest cover than Nordegg District traplines. Edson had significantly greater proportion of years with reported marten harvests and more fragmentation than Nordegg traplines. There was much variability between districts in the amount of access, mature conifer, and wells. Unequal sample sizes made it difficult to statistically distinguish between some variables measured by district.

DISCUSSION

I took an interview approach to determine how trappers interpreted changes in the landscape and what factors were important determinants to participate in trapping. The interview method targeted trappers which were active (for marten) and had telephone numbers. This design biased against inactive and native trappers without phones. The gaps in the map of interviewed trappers (Fig. 2.2) correspond to (1) native trapline ownership west and surrounding Nordegg, and (2) inactive traplines in the northeast part of the study area where trappers targeted other furbearers like coyote and beaver. The highest density of access and wells and least amount of closed-conifer cover is in the northeast, just west of Drayton Valley. It makes sense that trappers would focus on habitat generalists like coyotes in heavily disturbed landscapes. I only surveyed one known native trapper and attempted to contact several others unsuccessfully. The fact that many native traplines were inactive and located in remote areas with minimal disturbance and limited access indicates the importance of access for trapping. However, many other traplines with similar conditions were able to catch marten suggesting other reasons for not trapping. I was primarily interested in what motivated active trappers, those people who operated under a range of disturbances. Interviewed traplines had less industrial activity (access and wells) on their traplines, were larger in size, had more mature conifer cover, and harvested more marten, which is what I would expect, given sensitivities expressed in the interviews to disturbance. Further evidence suggests that the interviewed trappers make up a representative sample of active marten traplines because the probability of an active trapline increased with more closed-conifer forest, larger trapline size, and fewer wells (see Chap. 3).

The survey also revealed changing motivations for trapping. Economic incentives may have been important drivers in the early fur trade, but today, trappers continue to trap for cultural benefits. The majority of trappers interviewed said that pelt values did not influence their decision to trap because they enjoyed spending time with family and friends on the trapline and managing the fur resource. Many traplines have been in the family for decades. Lack of economic incentives expressed by interviewed trappers was also apparent when no relationship was found between the change in marten harvests and marten pelt value. Although trapping as an industry is defined by the total revenue from the sale of furs, the actual motivations for trapping are complex and descriptions of these reasons are comparable to most hobbies or recreations (i.e., spend time with family, connect with nature).

There are many recreational and industrial players on Alberta's public lands, which result in conflicts for overlapping natural resources. The major theme that emerged from the interviews was that trappers were concerned about declining furbearer habitats and wanted to be involved with management plans, especially related to forestry. Research supports trapper concerns about habitat loss as a result of forestry operations (Allen 1987, Bissonette et al. 1989, Buskirk 1992), but less is known about the effects of energy development on forested wildlife. Trappers with traplines undergoing industrial activity perceived the detrimental outcome of development; trappers caught more marten in undisturbed habitats (see Chap.3). Concerns about the effects of the forest industry on furbearers are not a new concern. A joint committee was formed in 1985 to increase the understanding of Alberta's forestry and trapping conflicts (AEFLW 1985). The committee conducted a meta-analysis and concluded that reduced furbearer production and loss in revenue was expected when a large proportion of the trapline was logged and when trappers were experiencing high fur returns prior to development; however, recommendations for future studies were warranted.

Despite a lapse in 20 years, relatively little research has been done to create a better understanding on the effects of forestry on trapping. Forestry companies manage forests at a larger scale than a trapline to maximize fiber returns and plan for long-term sustainability. Since the timber industry is managing across many traplines, incorporating timber harvest plans on individual traplines might be a key consideration to benefit forestry and trapping initiatives. Improvements need to be made to involve trappers at a local scale to improve communication and habitat enhancement of disturbed areas. Many trappers who were involved on forestry advisory committees mentioned the positive results of cooperation. Some companies already review trapline management plans and make sure to consider special trapping areas in their operating plans. Forestry can be compatible with maintaining forest-dependent wildlife on the landscape by adjusting the amount of timber that is harvested on any one trapline, as well as the shape and structure of cutblocks (Bissonette et al. 1989). This will require forestry to adopt more progressive techniques (e.g., structure retention) that are less detrimental to forest-interior wildlife and maintain better communication with trappers.

There are at least 40x the number of energy companies operating in the study area as compared to the number of forestry companies. Energy development is a major driver of landscape change in Alberta yet is not perceived by trappers as big of a threat as forestry, but rather as a nuisance. Industrial activity, collectively, was a concern for the majority of trappers and those with negative attitudes also had traplines with a greater proportion of clearcuts, greater density of access and wells, and more fragmentation than traplines with positive or neutral attitudes. Instead, some trappers perceived benefits afforded by increased access and were indifferent about the effects of energy activity such as the creation of wide openings, despite evidence that marten avoid crossing pipelines (Marklevitz 2003). I was surprised that few trappers expressed concerns about the effects on marten from oil or gas wells even though well sites are composed of all gravel and have a long-term footprint. But trappers who had negative attitudes had double the density of wells as compared to those who had positive or neutral attitudes towards industrial activity. Trappers who mentioned industrial activity as a threat to trapping probably were capturing the scope of energy development without specifically targeting individual practices like pipelines or well sites. The number of wells is growing exponentially and although smaller in size than clearcuts, wells and associated roads are certainly changing landscape structure. Many trappers work for the energy sector or were compensated for disturbance, which could alter their viewpoints. The greater economic prosperity brought by the energy industry might also account for the differences in attitude for various disturbances. Nonetheless, although energy activity is more widespread, forestry operations have cleared more land and trappers are paying attention to the effects of habitat loss on marten.

Trappers in west-central Alberta are experienced, knowledgeable, and want to be involved with land management decisions. Both the forestry and energy sectors are altering the landscape, but only forestry is held accountable for managing for biodiversity (Schneider 2002). Many trappers recognize the cumulative impact of industrial development and want companies to be accountable for minimizing adverse effects on forest-dependent species like marten; but this is a difficult task when multiple companies operate independently, seemingly with few regulations and mitigation rules enforced by the government. Forestry companies could combine their requirements for monitoring fish and wildlife resources and timber harvest plans in cooperation with trappers. Energy companies also should include trappers in their management plans by meeting with trappers to discuss 5-year schedules of seismic exploration, wells, and other facilities to avoid conflict with cabins and trap locations. If industry is willing to meet half-way, trappers need to step up and be involved by sitting on public advisory boards, being active in the Alberta Trappers Association, meeting with industrial representatives to discuss ways to improve habitat, or participating in research so the positive benefits of trapping are recognized. Having a trapline management plan that includes which furbearers are targeted and where will benefit trappers at the table with industry. Attitude surveys are important to link the perceptions of trappers to reality and to document the changing motivations of trapping. Fish and Wildlife agencies should continue to monitor the response of trappers to landscape change, especially since trapper concerns are justified (see Chap.3). Trappers can be indicators for the relative status of furbearers, particularly since effort is less driven by market forces today. These indicators are necessary to document of the status of wildlife in an intensively managed multi-use landscape.

Table 2.1. Descriptions of abbreviated variables used to characterize differences among registered traplines in west-central Alberta. Numbers used with a variable indicate data for a specific decade (e.g., 90=1990, etc.).

Variable code	Description	Units	Data Source
Access	Density of roads, seismic, power and pipeline	km/km^2	ABSRD
ConPro	Proportion of trapline composed of closed-conifer	--	FMF, CESWES
Cut	Proportion of total area cut	--	CESWES, Forestry
Disturb	Proportion of disturbance (road, seismic, facility, ROW, and forestry)	--	ABSRD, FMF, etc.
Frag.area	Effective mesh size standardize by trapline area	--	GIS disturb. layers
MarNeigh	Number of adjacent traplines with reported marten harvests	#	ABSRD
MartenDens	Density of marten harvest	$\#/ km^2$	ABSRD
Mtemp	Mean temperature	˚C	Environment Canada
Snow	Mean snowfall	cm	Environment Canada
Sumyrsactive	Proportion of total years with marten harvests	--	ABSRD
TrapArea	Trapline area	km^2	ABSRD
Well	Well density	$\#/km^2$	ABSRD
Yrsexperience	Number of years of trapping experience	#	Trapper interview
Yrsown	Number of years trapline held	#	Trapper interview

Table 2.2. A comparison of mean, standard error (SE), *t* statistic, and *p*-values between registered traplines where a trapper was or was not interviewed. Significant variables ($\alpha \leq 0.05$) are shown in bold. Numbers used with a variable indicate data for a specific decade (e.g., Access90= Access density measured in 1990-decade). Refer to Table 2.1 for variable descriptions.

VARIABLE	Not Interviewed (n=61) Mean (SE)	Interviewed (n=75) Mean (SE)	*t*-statistic	*p*-value
Access90	4.17 (0.31)	3.1 (0.19)	3.002	0.003
ConPro90	0.37 (0.02)	0.44 (0.02)	-2.216	0.029
Cut90	0.0789 (0.01)	0.088 (0.01)	-0.632	0.528
Disturb90	0.131 (0.01)	0.126 (0.01)	0.3355	0.738
Frag.area90	0.131 (0.03)	0.105 (0.02)	-0.4037	0.687
MartenDens90	0.03 (0.01)	0.05 (0.01)	-2.68	0.009
MarNeigh	3.6 (0.19)	4.0 (0.17)	-1.433	0.154
Mtemp90	2.2 (0.13)	2.95 (0.11)	-4.333	0.000
Snow90	15.45 (0.35)	16.49 (0.52)	-2.002	0.047
TrapArea	165.3 (15.69)	229.8 (13.3)	-3.195	0.002
Well90	0.913 (0.17)	0.42 (0.07)	2.792	0.007

Table 2.3. Minimum, maximum, average, and standard deviation of variables that were obtained from interviews with trappers and from GIS maps of industrial activity in the 1990-decade. Further descriptions of variables can be found in Table 2.1.

VARIABLE	MIN	MAX	MEAN	S.D.
Experience (yrs)	4	79	32	15.3
Ownership (yrs)	1	55	17	11.6
Jr. Partners (#)	0	3	1	0.7
Trap Area (km^2)	61	682	227	118.6
Trap Density (#traps/km^2)	0.029	1.545	0.245	0.246
Threshold Price ($)	5	70	26	12
Access90 (km/km^2)	0.1	7.5	3.1	1.7
ConPro90	0.13	0.78	0.43	0.16
Well90 (#/km^2)	0	4.3	0.4	0.7
Disturb90	0.004	0.458	0.126	0.098
Frag.area90	0.001	0.989	0.105	0.211
Marten Trapline Neighbors (#)	0	8	4	1.6
Total Trapline Neighbors (#)	3	9	5	1.4
Cut90	0	0.43	0.09	0.09

Table 2.4. Comparisons between responses to the trapper questionnaire by Meredith & Todd (1979) and responses from my survey of west-central Alberta trappers. Where available, mean, standard deviation (S.D.), range, and sample size (*n*) are reported by total study area sample for the number of years of experience by the senior trapper, the number of years that the trapper has held the trapline, the percent females holding fur harvest management permits, and the total number of trappers and junior partners working each line.

	Meredith & Todd (1979)			Mullen (2004)		
Variable	Mean (S.D.)	Range	*n*	Mean (S.D.)	Range	*n*
# years experience	24.3 (15.8)		125	32 (15)	4-79	78
# years trapline held	9.8 (8.7)		150	16.8 (11.6)	1-55	78
% female	5	0-15	158	3		90
# trappers	1.9 (0.6)	1-12	115	2.3 (0.7)	1-4	72

Table 2.5. Summary of mean and standard errors (in parentheses) for landscape variables yielding significant ($\alpha \leq 0.05$) *t*-test results grouped by trapper attitudes towards forestry characterized as either neutral/positive (0/+) or negative (-) as identified from trapper surveys. Refer to Table 2.1 for definitions of variables.

	Attitudes Towards Forestry			
Variable	0/+ (*n*=37)	- (*n*=42)	*t*-statistic	*p*-value
Access90	2.57 (0.31)	3.53 (0.22)	-2.5888	0.0118
Cut90	0.06 (0.01)	0.11 (0.01)	-2.4342	0.0172
Disturb90	0.09 (0.01)	0.15 (0.01)	-2.803	0.0064
Frag.area90	0.18 (0.05)	0.03 (0.01)	3.3294	0.0019

Table 2.6. Summary of mean and standard errors (in parentheses) of variables yielding significant *t*-test results ($\alpha \leq 0.05$) grouped by attitudes towards industrial disturbance characterized as either neutral/positive or negative as identified during interviews with trappers. Refer to Table 2.1 for definitions of variables.

	Attitudes Towards Industrial Activity			
Variable	0/+ (*n*=31)	- (*n*=48)	*t*-statistic	*p*-value
Access90	2.26 (0.3)	3.61 (0.22)	-3.6748	0.0005
Cut90	0.06 (0.01)	0.1 (0.01)	-2.0186	0.0477
Disturb90	0.09 (0.01)	0.15 (0.01)	-2.5778	0.0124
TrapDensity	0.18 (0.03)	0.28 (0.04)	-2.1359	0.0363
Well90	0.26 (0.09)	0.55 (0.11)	-2.1849	0.0319
Frag.area90	0.21 (0.05)	0.03 (0.01)	3.4774	0.0015

Table 2.7. Mean and standard errors (in parentheses) of variables that significantly differed ($\alpha \leq 0.05$) by Alberta Fish and Wildlife District. Hinton District traplines were removed from the analysis because of small sample size ($n = 3$). Refer to Table 2.1 for variable descriptions.

Significant Variables	Edson	Evansburg	Nordegg	RMH*	Sundre
Access90	3.49 (0.24)	6.2 (0.42)	1.44 (0.2)	3.21 (0.31)	2.38 (0.5)
ConPro90	0.42 (0.03)	0.24 (0.03)	0.61 (0.03)	0.39 (0.03)	0.48 (0.06)
Well90	0.26 (0.04)	1.62 (0.58)	0.07 (0.02)	0.66 (0.14)	0.27 (0.09)
Sumyrsactive	0.75 (0.03)	0.69 (0.08)	0.52 (0.07)	0.65 (0.04)	0.68 (0.04)
Frag.area90	0.04 (0.02)	0.002 (0.0004)	0.28 (0.08)	0.08 (0.04)	0.12 (0.05)

* Rocky Mountain House, Alberta

Table 2.8. Variables that significantly differed ($\alpha \leq 0.05$) by district using an ANOVA and post-hoc Tukey test (with unequal sample sizes) showing pairwise comparisons, difference in means, standard error (SE), calculated q value, and the studentized range (critical q value). Calculated q values greater than critical value ($q_{0.05, 76, 5} = 3.95$) were significantly different. Refer to Table 2.1. for variable descriptions.

Response Variable	Significant Comparison	Difference (SE)	*q*
Access90	Evansburg-Nordegg	4.63 (0.708)	6.52
	Evansburg-Rocky	2.92 (0.675)	4.29
	Evansburg-Sundre	3.8 (0.757)	5.00
ConPro90	Edson-Nordegg	0.19 (0.038)	4.95
	Evansburg-Nordegg	0.37 (0.052)	7.12
	Evansburg-Sundre	0.24 (0.06)	4.03
	Nordegg-Rocky	0.22 (0.039)	5.7
Well90	Edson-Evansburg	1.36 (0.212)	6.43
	Edson-Nordegg	0.19 (0.023)	8.23
	Edson-Rocky	0.4 (0.019)	21.62
	Evansburg-Nordegg	1.55 (0.225)	6.9
	Evansburg-Rocky	0.96 (0.046)	20.87
	Evansburg-Sundre	1.35 (0.24)	5.63
	Nordegg-Rocky	0.59 (0.024)	24.31
	Nordegg-Sundre	0.2 (0.036)	5.54
	Rocky-Sundre	0.39 (0.031)	12.38
Sumyrsactive	Edson-Nordegg	0.23 (0.047)	4.92
Frag.area90	Edson-Nordegg	0.24 (0.048)	5.01
	Nordegg-Rocky	0.2 (0.049)	4.07

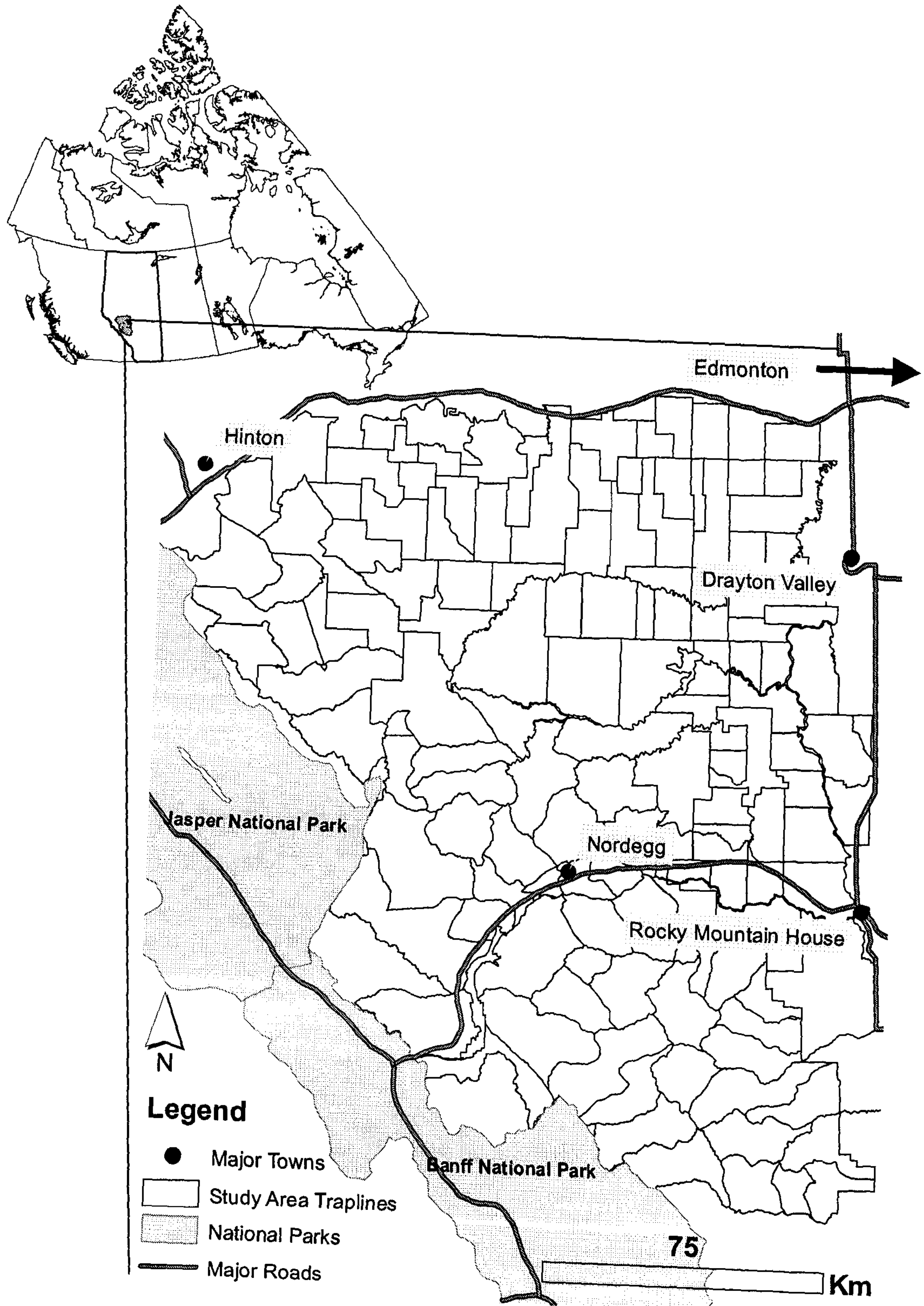

Figure 2.1. Study area map showing registered traplines, major roads, towns, and park boundaries in west-central Alberta.

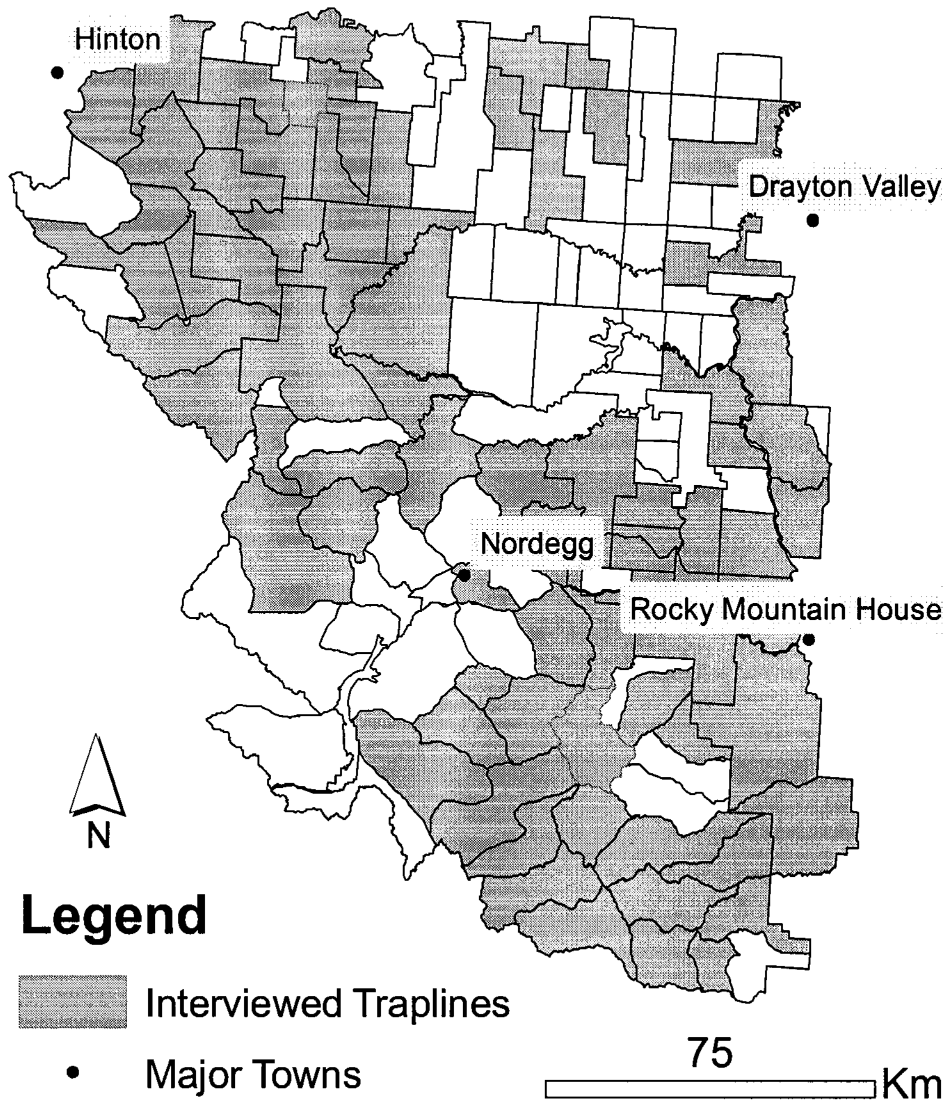

Figure 2.2. Spatial description of registered traplines where the trapper participated in interviews.

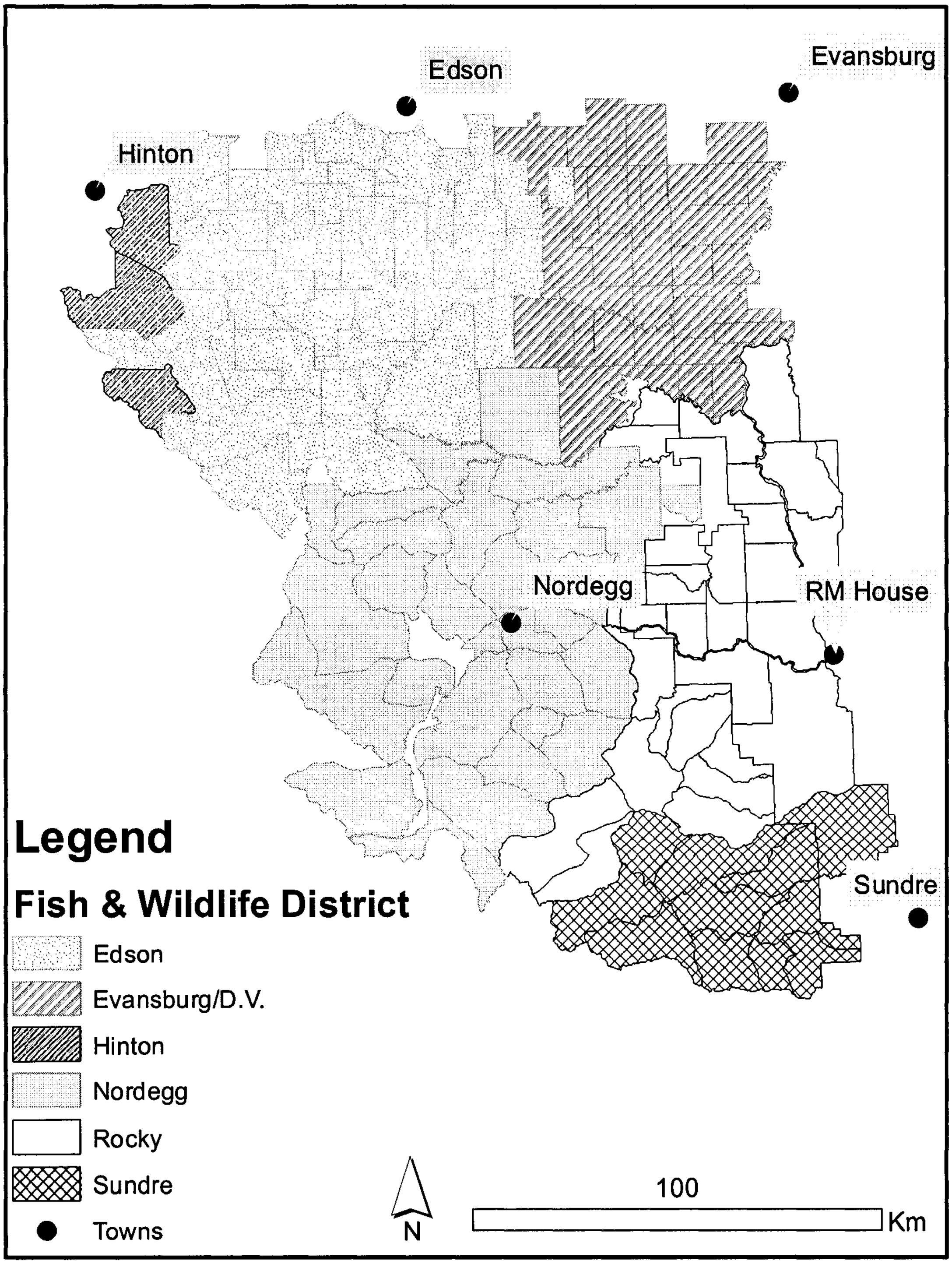

Figure 2.3. Designation of registered traplines by ABSRD Fish and Wildlife Districts in the study area.

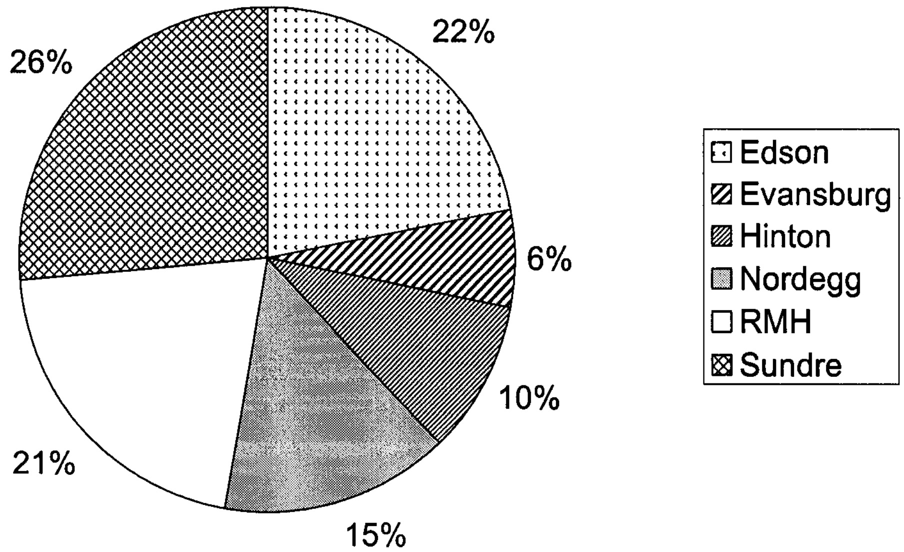

Figure 2.4. The percentage of total trappers interviewed by Fish and Wildlife District in the study area.

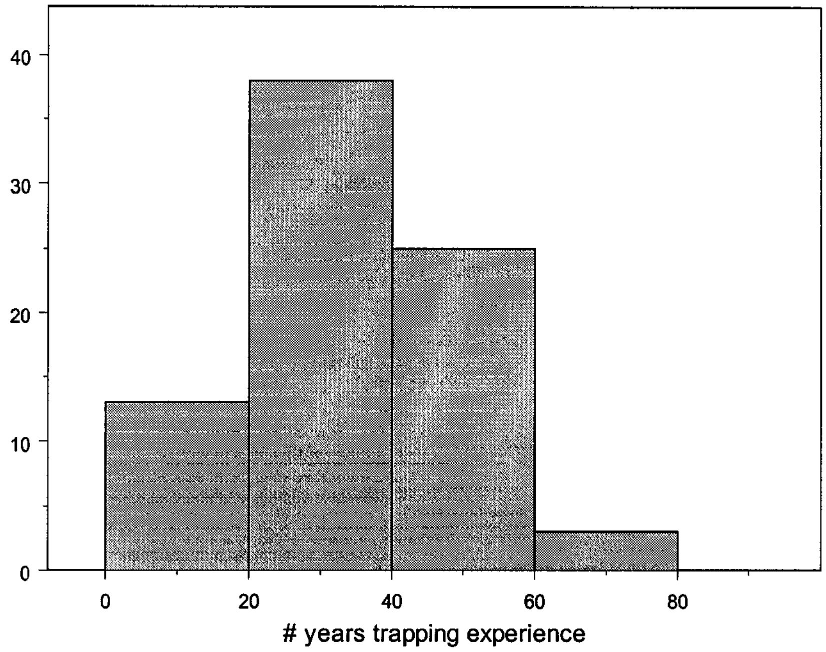

Figure 2.5. Frequency of the number of years of trapper experience as identified from surveys.

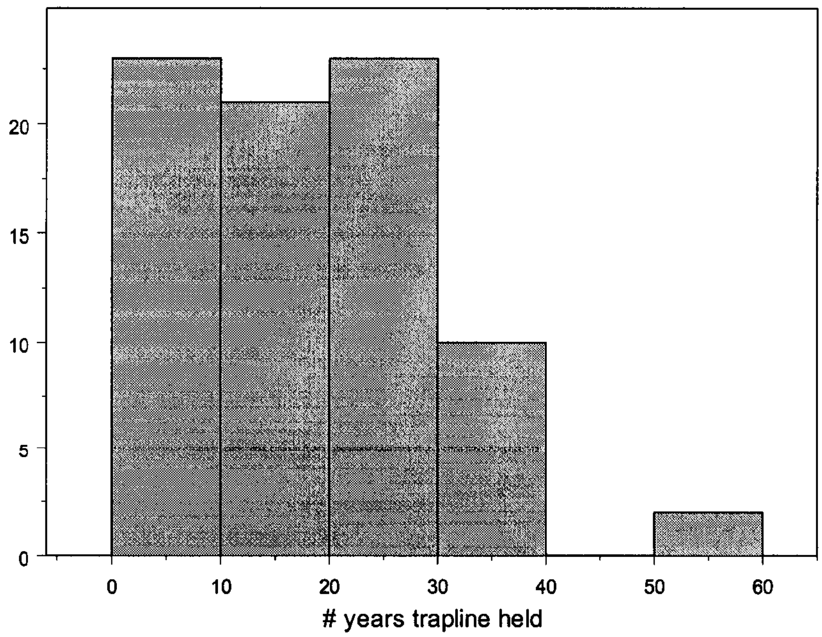

Figure 2.6. Frequency of trapline ownership as identified from surveys.

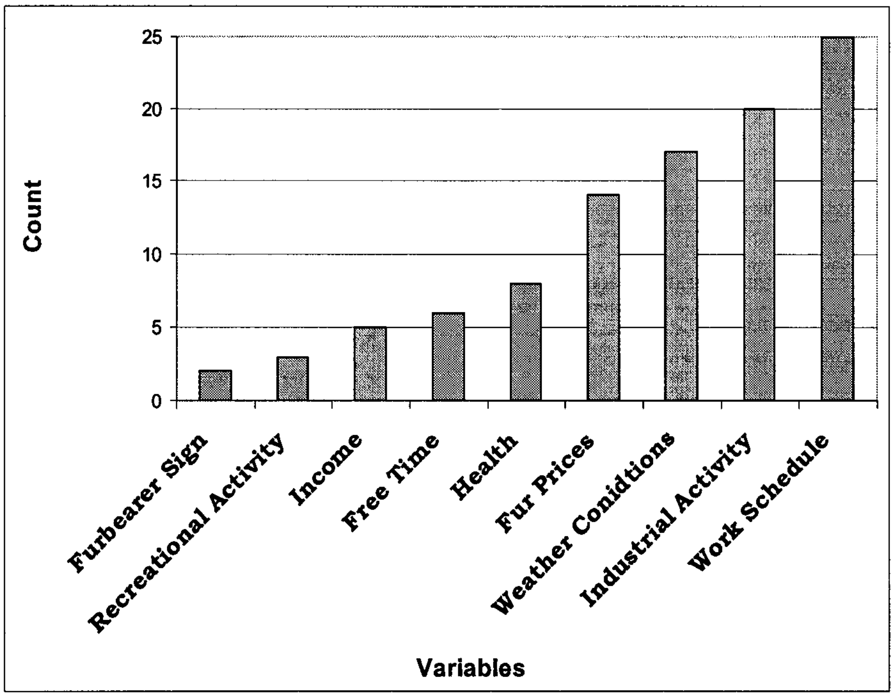

Figure 2.7. Frequency of variables identified from interviews that affected trapper effort in west-central Alberta.

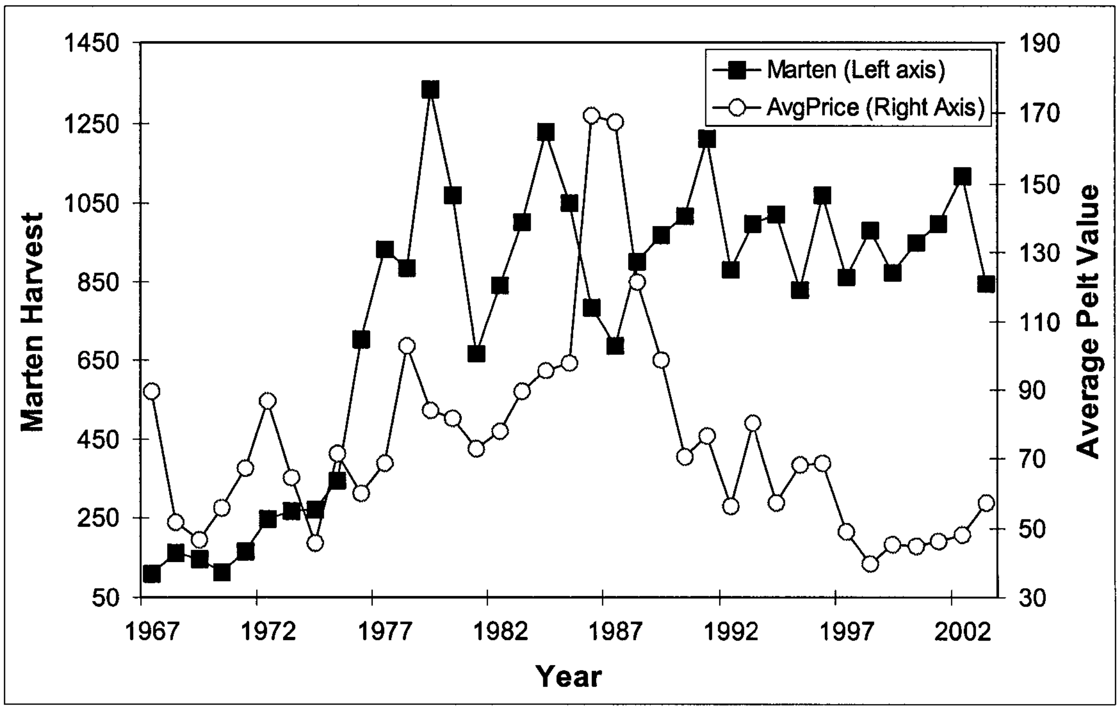

Figure 2.8. Reported marten harvests and adjusted (based on 2003 CAD$) average pelt prices from 1967-2003 in west-central Alberta.

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CHAPTER 3

FUR HARVESTS AND LANDSCAPE CHANGE IN WEST-CENTRAL ALBERTA

INTRODUCTION

Fur trapping is still a popular recreational activity in Alberta despite low fur prices and extensive industrial development. Alberta's economic prosperity has led to serious changes in the integrity of the environment (Timoney & Lee 2001), highlighting the importance of documenting the effects of industrial development on sensitive wildlife. In addition to the effects on wildlife habitat, the traditional uses of the land have been altered in response to industrial activities in the foothills of Alberta (Mullen, Chap.2). The implications of cumulative habitat loss suggest that forest-interior wildlife and traditional wildlife uses will decline. Understanding how wildlife respond across a gradient of disturbances is important in planning industrial development in accordance with maintaining sensitive species on the landscape.

American marten have economic and ecological value throughout the northern mature, mesic forests in which they occur in North America. Marten are important furbearers that are easily trapped (Obbard et al. 1987, Strickland 1994) and also are considered ecological indicators of healthy forests (McLaren et al. 1998). Declines of this mustelid have been attributed to human activities with overtrapping and habitat loss being the most significant causes (de Vos 1952, Strickland & Douglas 1987). Although harvests are managed today on a registered trapline system in Canada, few studies have examined how landscape change has influenced marten.

Marten trapping records date back to the 1700's from the Hudson's Bay Company, and historically, were the second most valuable fur next to beaver in North America (Yeager 1950, Obbard et al. 1987). Today, marten are considered a "bread and butter" furbearer, with its fur accounting for 1/3 of the total pelt value in Alberta (Barrus et al. 1997). However, because of its curious nature and popularity among trappers, marten are vulnerable to overharvest and local extinctions (Yeager 1950), making them an important focal species to monitor. Biologists in Alberta have used harvested species and/or trapping records in a variety of ways including: collecting demographic and biological information (e.g., diet, genetics, etc.), monitoring population trends and distribution, and determining status of selected mammals (F. Kunnas, ABSRD, personal communication; Boyd 1977, Skinner & Todd 1988, Poole & Mowat 2001). Poole & Mowat (2001) analyzed Alberta furbearer trends from 1977-1997 and concluded that provincial marten harvests fluctuated over time with no consistent trend (Fig.3.1) and suggested a need to investigate these indices at a finer-scale. Marten harvests in the foothills peaked in the 1980's (Fig. 3.2), at the same time that marten pelt value and the amount of mature forests increased (Andison 1998). Although there have been several initiatives to analyze furbearer trends, no research has examined the change in marten harvests as a function of land-use and landscape change at the trapline level. Short-term fur harvests alone may not be a good indicator of furbearer populations, but area-specific harvest information collected over many years (20-50 years) may be useful in determining trends in relative abundance (Erickson 1982).

Research in northeastern U.S. and Canada has documented marten use of mature, well-stocked deciduous and mixed forests that provided adequate vertical and horizontal structure (Chapin et al. 1997, Potvin et al. 2000), while studies in western North America have suggested that marten require coniferous old-growth forests (Bissonette et al. 1989). Regardless of region, structure in the form of snags, slash piles, and down woody debris, are important habitat components, providing marten with protection from predators, access to food, thermoregulation, and reproductive benefits (Taylor & Abrey 1982, Bissonette et al. 1989, Corn & Raphael 1992, Paragi et al. 1996). These structural components are generally found in mature forests (Schneider 2001), but also can be obtained in younger forests as a result of natural disturbance (i.e., fire, insect defoliation, etc.) (Chapin et al. 1997).

Marten have been considered an ecological indicator, barometer, or high-interest species (Koehler et al. 1975, Buskirk & Ruggiero 1994, Lee & Hanus 1998) because of their large spatial requirements, narrow habitat use, longevity, low reproductive output, and sensitivity to habitat loss and human-induced mortality (Archibald & Jessup 1984, Buskirk 1992, Smith & Schaefer 2002). Marten were selected as a focal species for carnivore conservation planning in the Rocky Mountains, and a coarse-scale habitat model, based on snowfall and canopy, was created for this region (Carroll et al. 2000). Many other researchers have recognized the ecological role of marten and have modelled habitat suitability (Takats et al. 1999, Fecske et al. 2002), vulnerability to extinction (Lacy & Clark 1993), and have suggested that marten might be used as an ecological indicator for monitoring sustainable forestry (McLaren et al. 1998). This implies that marten and forestry can coexist.

Previous research has focused on the response of marten to timber harvest, the primary cause of habitat loss (Thompson 1994, Chapin et al. 1997, Huggard 1999, Potvin

& Breton 2000). Researchers compared marten habitat selection and demographics in an untrapped reserve, and a trapped and untrapped industrial forest in northern Maine and found that timber harvest reduced suitable habitat and decreased population productivity (Payer 1999). In untrapped reserves without development, marten had higher survival and an older population age structure (Fortin & Cantin 1994, Thompson 1994), occupied all available habitats (habitat saturation), had smaller home ranges, and the density of lactating females was three times greater than in industrial untrapped forests (Payer 1999). In Quebec, Potvin & Breton (1997) studied the short-term effects of clearcutting on marten (without recreational trapping present) and found lower survival, larger home ranges, and longer movements in cutover forests. Marten hunting success also appeared to be greater in uncut forests where they captured up to 120% more prey biomass than in logged forests in one Ontario study (Thompson & Colgan 1994). The association of marten harvests to forestry activity, however, are not well understood.

Fur harvests reflect information about status, behaviour, and relative population abundance (Todd & Geisbrecht 1979). The direction of the relationship between marten harvests and industrial development, in the form of access, wells, and forestry, is speculated. Access, such as roads, pipelines, and quad trails, could result in an increase or decrease in marten harvests. Roads and pipelines increase habitat fragmentation (Reed et al. 1996) creating dispersal or movement barriers (Marklevitz 2003) and increasing human-induced mortality by affording access for trapping (Thompson 1988). Conversely, increased density of seismic lines create openings in the forest canopy and unburned slash from trees cut can create structure for small mammals (e.g., meadow (*Microtus pennsylvanicus*), heather (*Phenacomys intermedius*), and long-tailed voles (*M.*

longicaudus) (Huggard 1999, Pattie & Fisher 1999). Increased access density is positively correlated with marten harvests in the short-term because access allows trappers to spatially distribute their traps over a larger area, increasing the probability of marten being caught (Marshall 1951). Thus, access improves trapper success up to a certain point where access may be so abundant that overharvest could occur if effort is not adjusted.

There are many contributions to the composition and configuration of landscapes both by dissection (e.g., roads) and habitat loss (e.g., clearcuts, wells). McGarigal et al. (2001) found that roads had a greater impact on landscape structure than forest harvesting in their Colorado study area. There is some evidence to suggest that marten are sensitive to fragmentation. Marten responded negatively to low levels of habitat fragmentation when comparing relative population densities of marten across suitable habitats that differed in the degree of forest fragmentation, from natural openings to clearcuts (Hargis et al. 1999). Researchers found that marten densities were positively associated with habitat quality, with high densities occurring where breeding females had high body weights, good body condition, and high overwintering success (Hargis & Bissonette 1997). Marten also are more abundant in undisturbed forest with large core areas (Snyder & Bissonette 1987, Bissonette et al.1989). Hargis and Bissonette (1997) found that marten avoided landscapes composed of greater than 25% openings, suggesting that marten are sensitive to low levels of fragmentation within their home range. Fahrig (1997) concluded that habitat loss had a more pronounced effect on population extinction processes than habitat fragmentation, especially on forest-dependent interior species. Reductions in the amount of closed-conifer forests via clearcutting and total area disturbed by all development will result in declining marten harvests because of increased natural and man-made mortality, decreased density, and lower reproductive output in cutover habitats (Thompson 1994, Payer 1999). Although the relationship between marten populations and habitats are well known, this association has not been found using fur harvest records. Our study will examine this hypothesis to determine whether fewer marten were harvested where there were reductions in the amount of mature coniferous forests. If there is a response by marten harvests to loss of habitat, monitoring the amount of suitable habitat may be one plausible avenue to maintaining marten on the landscape (Raphael 1994).

A suite of social and biological variables influence fur harvests, making it difficult to understand the effects of landscape change on the population dynamics of different furbearers. The objective of this chapter was to model marten fur harvests relative to trapper effort, habitats, and land-use variables. Key management concerns over the influence of the rate and amount of industrial activity on harvests will be considered in a multiple competing models framework. A better understanding of the variables that influence harvest dynamics can improve furbearer management and guide future land-use decisions to maintain marten and trapping on the landscape.

METHODS

Study Area

This study was conducted in the west-central foothills of Alberta on registered traplines north of the Red Deer River, south of Highway 16, and between Banff/ Jasper National Parks and the eastern boundary of the green zone (Fig. 3.3). This area is approximately 28,000 km^2 and includes 136 registered traplines and 350 townships. The average trapline is ~2 townships (200 km^2) and range between 1/3 to 6 1/2 townships (33-650 km^2) in size. The topography is rolling in the east and mountainous in the west with white spruce (*Picea glauca*), lodgepole pine (*Pinus contorta*), larch (*Larix occidentalis*), and quaking aspen (*Populus tremuloides*) comprising the dominant tree species. The province manages this area primarily for resource extraction (petroleum, forestry, and mining) and recreational activity. West Fraser (formally Sunpine Forest Products Ltd. and Weldwood of Canada Ltd.), Sundance Forest Industries Ltd, and Weyerhaeuser Company harvest timber on Forest Management Agreement areas (FMA). Over 200 energy companies extract oil and gas resources, with Burlington Resources Canada, Imperial Oil Resources, and PennWest Petroleum among the top players. Oil and gas development and timber extraction have increased over the past 3 decades (Timoney & Lee 2001), creating much access for hunters, trappers, and other user groups. Traplines in this study area encompass a range of disturbances (Table 3.1, 3.2) along a gradient increasing in amount from west to east. Access and well densities on registered traplines range from 0.12-9.31 km/km^2 ($\bar{x}$ = 3.58, *SD* = 2.07) and 0-6 oil/gas wells/km^2 ($\bar{x}$ = 0.64, *SD* = 0.99); the density of oil and gas wells in this area is greater than the average in Alberta ($\bar{x}$ = 0.46) (Timoney & Lee 2001). The proportion of a trapline logged and area disturbed range between 0-0.43 ($\bar{x}$ = 0.08, *SD* = 0.09) and 0.004-0.46 ($\bar{x}$ = 0.13, *SD* = 0.09) while the proportion composed of closed-conifer forest varies between 0.07-0.78 ($\bar{x}$ = 0.41, *SD* = 0.17).

Data Collection

Fur Harvests

Marten harvest data were collected from hard-copy affidavits available from the Alberta Sustainable Resource Development (ABSRD) District Fish & Wildlife Offices in Drayton Valley, Sundre, Rocky Mountain House, Nordegg, Hinton, Edson, and Evansburg. Marten harvests were recorded from 1963 to the present and organized by registered trapline. Trappers are required to report fur harvests (affidavits) to ABSRD each summer/fall when reapplying for a trapping license. This means that a trapper has to record how many of each furbearer species were caught during the previous season. ABSRD has recorded this information into an electronic database, but upon further investigation, I found many inconsistencies between online records and trappers' recollections. Using the hard-copy affidavits improved the reliability of marten harvest records and were consistent with trapper memory recall. Additional furbearer data were obtained from 1985-2003 from the ABSRD furbearer database to investigate harvest trends for other species, while recognizing that the accuracy of electronic records was not verified with the hard-copy affidavits. However, records of other species were known to be more accurate than for marten harvest records (B. Treichel, ABSRD, personal communication). Legal land descriptions and a geo-referenced spatial layer of registered traplines for the study area also were obtained from ABSRD.

Landscape Variables

The study area included multiple industrial leaseholders and in which research had taken place by other organizations, so I used several methods to quantify landscape variables and landscape change (App.2) on registered traplines. Most of the spatial data were acquired from the ABSRD Data Distribution Branch (Contact: K. Tripp, ABSRD, Edmonton AB.) and were a part of the Base Layers Features database. Spatial layers included roads, seismic exploration lines, powerlines, pipelines, railways, wells, and other facilities (e.g., gravel pits, coal mines, and gas plants). These data were created from recent satellite imagery to represent a complete collection of base features in the province, with the exception of well sites, which were provided to the government by the Alberta Energy Utilities Board. Cutblock data were acquired from forestry companies and supplemented using the Central East Slopes Wolf and Elk Study (CESWES) cutblock layers (Beyer et al. 2004). Closed-conifer cover within each trapline was quantified using recent satellite imagery from Foothills Model Forest (FMF) (Franklin et al. 2001), which covered most of the study area, and also from CESWES habitat layers.

No area measurements were available for linear features or well sites so I estimated areas based on literature (Timoney & Lee 2001) and field measurements to create a disturbance layer. Individual features were organized by decade and trapline. Roads, powerlines, pipelines, seismic, and wells were buffered by respective attributes (App. 3), and these features were joined with facilities and forestry to form a disturbance layer for each decade and trapline.

Historic fire data were examined, but fire was found be a minor source of landscape change in recent decades so area burned was not included in the analysis. In addition, climate variables (e.g., temperature, snowfall, and precipitation) from weather stations in the study area were obtained from Environment Canada's Online National Climate Data and Information Archive to examine weather as a source for variation in fur harvests. However, weather was not unique for each trapline and instead was based on proximity or other attributes (i.e., mountainous terrain) relative to weather stations, which created multiple traplines with the same weather information. Also, it was difficult to find weather stations with consistent data for the study period 1970-2003 during all months of the year, so analysis that incorporated weather variables was limited.

Fragmentation

Another way to quantify the effects of disturbance on landscape structure is through a fragmentation metric. Fragmentation is characterized by divisions of the landscape into smaller parcels (Forman 1995) and typically accompanies habitat loss; however, it is difficult to tease apart the independent effects of fragmentation and habitat loss when occurring simultaneously (Fahrig 1997). Jaeger (2000) developed fragmentation metrics that behave consistently across all phases of fragmentation. The metrics are based on the ability of 2 animals placed in different areas of a region to find each other. There are several terms associated with these metrics including: degree of landscape division (D), splitting index (S), and effective mesh size (Msiz). The degree of landscape division is the probability that 2 randomly chosen points in the landscape under investigation are not situated in the same undissected area. Splitting index is the number of patches when dividing the total region into equally sized areas in such a way that the new configuration leads to the same degree of landscape division. The effective mesh size is the area when the region under investigation is divided up into S areas (each of the same size) with the same degree of landscape division and was corrected for trapline area (km^2/km^2):

$$Msiz = \frac{A_t}{S} = \frac{1}{A_t}\sum_{i=1}^{n} A_i^2$$

where n = number of patches, A_i = sizes of the ith patch, A_t= total area of region, $S = n$ = number of patches remaining at a given degree of division.

Essentially, these metrics are very similar, and the effective mesh size was used in data analysis because it was the most interpretable. More fragmented landscapes will have a smaller mesh size area. I used the Subdivision Analysis extension for ArcView 3.x (Lang 2004) to calculate fragmentation metrics. The trapline was the region used to calculate mesh size and the entire landscape (all traplines) was used as the reference area. Effective mesh size is simply referred to as *Frag.area* in the thesis.

Landscape Change

Attributes of individual features (e.g., roads, seismic lines, etc.) were calculated and summarized for each decade to determine landscape change. In addition, contributions to landscape change varied through time, making it important to understand the relationships between different disturbances and habitats. Simple regression and correlation statistics were used to describe the amount and change in different habitat and disturbance variables.

Modelling Methods

I quantified important habitats, fragmentation, effort, and disturbance variables that have been shown to influence marten trapping. All covariates were incorporated into a GIS and summarized by trapline and decade. Habitat type, other than closed-conifer, were available for the 1990-decade only. Annual study area data were available for multiple terrestrial furbearer harvests and pelt prices and were examined for long-term trends from 1970-2003 (Appendices 4-8). All analyses were conducted in S-PLUS 6.2 (Crawley 2002, Insightful Corporation 2004), STATA 8.0 (Stata Corporation 2003), ARCGIS 9.0 (ESRI 2004), and ARCVIEW 3.3 (ESRI 2002). Variables used in analyses are described in Table 3.1.

Active-Inactive Trapline Status

Understanding the variation in trapline status can help explain what variables are important in predicting the behaviour of trappers. The number of years that traplines reported marten harvests per decade differed (Table 3.3), suggesting a need to determine why some traplines were active and others not through time. Initial exploratory analyses (t-tests) compared the composition of active and inactive traplines by decade. Traplines with ≥5 years of reported marten harvests/decade for all 3 decades were defined active, whereas those traplines with consistently less than 5 years of marten harvests/decade were deemed inactive. I used logistic regression to fit a priori candidate models to predict the probability of active (≥5 years in which there were any recorded marten harvests/decade) or inactive (<5 years of recorded harvests/decade) trapline status (Hosmer & Lemeshow 1989). Candidate models (Table 3.4) were selected based on a literature review of factors that influence fur harvests. The trapline was the unit of replication and decade was used as a dummy variable with the 1970-decade as the reference baseline to examine whether the number of active traplines differed across time. Exploratory analyses were conducted to determine the structure of the relationship between trapline status and each covariate. I examined Pearson's correlation coefficients between predictor covariates and to avoid multicollinearity I did not include variables in the same model that were strongly correlated ($r>|0.7|$). Fragmentation was highly correlated with access, wells, and disturb ($r>0.75$) because these individual variables were used to calculate fragmentation, and high correlations were found between cut and disturb ($r = 0.8$, 407 d.f., $p<0.05$), and access and disturb ($r = 0.78$, 407 d.f., $p<0.05$). Using the Akaike Information Criterion (AIC) I ranked candidate models based on lack of fit and the principle of parsimony (Burnham & Anderson 2002). I used the information-theoretic approach over standard null-model hypothesis testing so that I could compare multiple biologically plausible alternative models in a meaningful way. Models were ranked based on the smallest Akaike value and the AIC differences (Δ_i) that indicated how well each model compared to the top ranked ("best") model. Models with AIC differences of <10 have some support, while values <4 have substantial support (Burnham & Anderson 2002). A weight of evidence (w_i) also was calculated to determine how likely each model was the best model given the data. To assess fit of the predicted logistic regression models using all the information of the observed and predicted probabilities, I used the threshold-independent receiver operating characteristic (ROC) method to calculate the area under the curve (AUC) (Fielding & Bell 1997). The AUC values range between 0 and 1 with values near 0.5 considered to be poor model accuracy because correct classifications are essentially random, and values of >0.7 specified good model accuracy (Swets 1988).

Change in Harvest

I used linear regression to model the relationship between the change in average marten harvest per unit area from the 1980 to 1990-decade (*logMar89*) relative to the change in marten habitats, trapper effort, and industrial activity (Table 3.5). Univariate scatterplots of the change in harvest and each predictor variable were examined for nonlinear relationships. Variables were log transformed to meet the assumption of normality and bivariate linearity as indicated in Table 3.5. In addition, the predictor variables that were highly correlated (r>|0.7|) were not included in the same models to avoid multicollinearity. High correlations were found between cut and disturb (r = 0.87, 135 df, p<0.05), access and disturb (r = 0.78, 135 df, p<0.05), fragmentation and disturb (r = -0.78, 135 df, p<0.05) and between access and fragmentation (r = -0.86, 135 df, p<0.05). AICc, corrected for small sample size (n/K<40), was used to rank candidate models and the coefficient of determination (R^2) and weight of evidence (w_i) of the top models (Δ_i<4) were examined (Burnham & Anderson 2002). Residual plots and outliers (Cook's Distance) were assessed for the top AIC models.

Harvest per Unit Area

I modelled marten harvest per unit area as a function of selected landscape change and habitat variables (Table 3.6). The response variable was the average number of marten harvested per unit area within a trapline during the 1990-decade. The distribution of the response and many predictor variables were log transformed to meet the assumption of normality and bivariate linearity. In addition, the predictor variables that were highly correlated (r>|0.7|) were not included in the same models. High correlations were found between fragmentation and access (r = -0.89, 135 d.f., p<0.05) and between change in disturbance and change in cut (r = 0.95, 135 d.f., p<0.05) and amount cut (r = 0.71, 135 d.f., p<0.05). I calculated AICc, corrected for small sample size, ranked models based on AIC differences, and assessed model uncertainty using Akaike weights. I examined the residuals and screened for outliers for the top AIC models (Δ_i<4).

Corrected Harvest

Finally, I modelled marten harvest by decade corrected for variation in the proportion of years trapped as a function of land-use and habitat variables (Table 3.7). Accounting for variation in the number of years when trapping occurred allowed me to examine how harvests were affected by disturbance. The response variable was the average marten harvest divided by the proportion of years with reported marten harvests for each trapline and decade. Decade was used as a dummy variable to examine the effects of time on marten harvests with the 1970-decade used as a baseline. Predictor variables included the proportion of the trapline in closed-conifer forest, area of clear-cut timber harvested, disturbed area, fragmentation metric, density of access, and density of oil and gas wells. The response variable, proportion cut, total disturbed, access, wells, and fragmentation variables were $\log_e$ transformed to improve skewed distributions. As expected, high correlations were found between disturbance area and the fragmentation metric ($r = -0.78$, 407 d.f., $p<0.05$) and access ($r = 0.78$, 407 d.f., $p<0.05$), and between fragmentation and access ($r = -0.91$, 407 d.f., $p<0.05$). AICc was used to rank candidate models and models with AIC differences <4 were examined for model uncertainty and for the total variation explained in the response variable. Residual plots and outliers were examined for the top AIC models.

RESULTS

Landscape Change

Landscape change (1970-1980, 1980-1990, and 1970-1990) was calculated for the study area by individual disturbance feature (Table 3.8, Fig. 3.4). The study area has experienced a sharp increase in all industrial development. The amount of powerlines, seismic lines, and roads has nearly doubled, while the area disturbed by forestry, number of wells, and area of facilities has tripled since the 1970-decade. Pipelines have increased by 900%, the most of any other activity. For most disturbance features, the greatest increase occurred between the1980s and 1990s. In the 1990-decade, the average density of seismic lines (2.28 km/km^2) was 5x that of road density (0.48 km/km^2) and 7x that of pipeline density (0.32 km/km^2), comprising 65% of the total access density (3.6 km/km^2) in the study area, respectively.

Contributions to the amount and change in closed-conifer forest and landscape structure varied temporally (by decade). Closed-conifer cover was positively associated with proportion of area cut in the 1970 ($r = 0.44$, 135 d.f., $p<0.05$) and 1980-decades ($r = 0.19$, 135 d.f., $p<0.05$) and negatively associated ($r = -0.2$, 135 d.f., $p<0.05$) in the 1990-decade. Density of wells was negatively associated to closed-conifer habitats in the 1970 ($r = -0.46$, 135 d.f., $p<0.05$), 1980 ($r = -0.52$, 135 d.f., $p<0.05$), and 1990-decades ($r = -0.61$, 135 d.f., $p<0.05$). Access density and proportion of area disturbed also were negatively associated with closed-conifer cover in the 1980 ($r = -0.31$ (access), -0.22 (disturb), 135 d.f., $p<0.05$) and 1990-decades ($r = -0.38$ (access), -0.35 (disturb), 135 d.f., $p<0.05$). The 1970 to 1980 and 1980 to 1990-decadal change in closed-conifer forest was negatively associated to cut ($r = -0.92$ (70-80), -0.8 (80-90), 135 d.f., $p<0.05$), change in cut ($r = -0.29$ (70-80), -0.29 (80-90), 135 d.f., $p<0.05$) and access density ($r = -0.19$ (70-80), -0.2 (80-90), 135 d.f., $p<0.05$). In the 1970, 1980, and 1990-decades the proportion of area cut and well density explained 36%, 42%, and 52% of the total variation in the proportion of closed-conifer. Well density alone explained 40% in the proportion of closed-conifer cover in the 1990-decade. The change in closed-conifer from the 1970 to

1980 and 1980 to 1990-decades was best predicted by the proportion cut with 85% and 66% being explained in the decadal change in closed-conifer. Therefore, industrial disturbance, especially forestry, explained a large proportion in the amount and loss in closed-conifer forest cover over time.

Variables related to decreased fragmentation also varied temporally. In the 1970-decade, access density ($r = -0.33$, 135 d.f., $p<0.05$) was inversely associated with less fragmentation, whereas in the 1980 and 1990-decades cut ($r = -0.32$ (80s), -0.42 (90s), 135 d.f., $p<0.05$), access density ($r = -0.87$ (80s), -0.89 (90s), 135 d.f., $p<0.05$), and well density ($r = -0.57$ (80s), -0.55 (90s), 135 d.f., $p<0.05$), were negatively related to reduced fragmentation. In addition, decreased fragmentation was positively associated with areas that had more closed-conifer habitat ($r = 0.17$, 407 d.f., $p<0.05$). This shows that, more recently, the energy sector has contributed to greater amounts of fragmentation. Although forestry was important in describing habitat loss, landscape fragmentation was mostly driven by energy activity.

Active-Inactive Trapline Status

Initial exploratory analysis revealed considerable variability in the frequency of traplines that were consistently active through time. Approximately 50% of all traplines reported 2 or more years with marten harvests/decade from 1973-2003 ($n = 79$ traplines), whereas only 1/3 of all traplines had 5 or more years with marten harvests/decade ($n = 45$ traplines). For consistently active traplines (≥5 years reported marten harvests/decade for all decades), I observed differences in land-use, habitat type, and landscape change between traplines that were and were not active through time (Table 3.9). In all decades, active traplines were larger in size and had a significantly greater proportion of closed-conifer forest cover (>50% closed canopy) than inactive traplines. The amount and type of vegetation types differed; active traplines had significantly less proportion of deciduous forests, open wetlands, and treed wetlands than inactive traplines. In the 1990-decade active traplines had less access and change in access density, and fewer oil/gas wells and less change in well density than inactive traplines. In the 1980-decade active traplines had less access and change in access, less well and change in well density, and reduced change in fragmentation metric than inactive traplines. Finally, in the 1970-decade, there were fewer oil and gas wells/unit area than on inactive traplines.

I used logistic regression to model active–inactive trapline status. The top models suggested that a number of disturbance features, vegetation type, and trapline characteristics were important in predicting whether a trapline was active or not over time (Table 3.10). The probability of a trapline being active was positively associated with trapline size and proportion of conifer habitat and cut, but inversely related to access and oil and gas well density. The probability of a trapline being active did not differ between decades. There was a quadratic form within a logistic regression framework relationship between the proportion of active traplines and proportion of trapline in closed-conifer forest (Fig. 3.5). Traplines had a higher probability of being active with more mature coniferous forests. The highest mean proportion of active traplines was when traplines had between 60-70% closed-conifer cover. Using the top ranked AIC model, the best prediction of whether a trapline was active or inactive occurred at the intersection of the sensitivity and specificity curves (Fig. 3.6). Holding all other variables in the model constant except for closed-conifer cover, I found that the threshold value for closed conifer at the probability cutoff (0.57) was when 1/3 of a trapline was covered in mature conifer forest. This is the point where prediction of active and inactive trapline status is maximized, in respect to closed-conifer cover. Small Akaike weights do indicate a lack of strong evidence in support of which model is the best and ROC scores were similar (0.67-0.72) among the most parsimonious models. Despite the difficulty in predicting trapping motivations, this analysis demonstrated the importance of many vegetation and industrial-activity variables in predicting trapline status, and several of the top AIC models are reasonably good predictors of active-inactive trapline status (AUC≥0.7).

Change in Harvest

The 3 top-ranked AIC models predicting the change in marten harvests between the 1980 and 1990-decade included the change in the proportion of area disturbed and cut, change in the density of access and oil/gas wells, and habitat variables present in the 1990-decade (Table 3.11). Change in marten harvest was positively associated with proportion of habitat (mixed and closed-conifer), change in access and well density, and negatively associated with the change in the proportion disturbed and cut. The confidence intervals for change in the proportion disturbed and cut excluded zero. The top 2 models that included change in disturbance and habitat had more support than change in disturbance alone. Akaike weights for the top models were indistinguishable making it difficult to choose a best model, and only 4-5% of the total variation in the change in harvest was explained by change in disturbance and habitat covariates.

Harvest per Unit Area

Change in industrial activity, decade, and vegetation variables explained close to a third of the variation in average marten harvest per unit area in the 1990-decade (Table

3.12). Top AIC models revealed that there was a positive relationship between average marten harvest and habitat (mixed, closed-conifer, upland herbaceous) and fragmentation patch size metric (traplines with less fragmentation reported larger harvests). Harvests were negatively associated with change in proportion cut, density of oil and gas wells, access density, and a few open-habitat vegetation types (shrub, treed wetland, barren, regen, and open conifer). Vegetation types (shrub, treed wetland, mixed, barren, closed and open conifer), change in closed-conifer, and fragmentation were the only covariates for which 95% confidence intervals excluded zero. The top AIC model was clearly the best model (w_i= 0.95) and included vegetation types, change in habitat, and change in industrial-activity covariates, whereas the habitat only model had a low weight of evidence (w_i= 0.03), demonstrating the importance of both habitat and disturbance in explaining the variation in marten harvests.

Corrected Harvest

The top models explained about 20% of the variation in the average number of marten harvested corrected for number of years trapped per decade on traplines (Table 3.13). Marten harvests were positively associated with proportion of closed-conifer forest and negatively associated with proportion of area cut, density of oil and gas wells, and access density. In addition, harvest on active traplines increased through time with the largest difference between the 1970 and 1990 decades. Decade, closed-conifer forest, and well-density covariates had 95% confidence intervals that excluded zero, indicating strong influence of these variables on harvests. The top models had similar support (low Akaike weights) and explained similar amounts of the variation in harvest, and again showed the combined importance of habitat and industrial disturbance on marten harvests. These models consistently indicate that when traplines are actively trapped, the harvests of marten are higher on traplines with more closed-conifer forests and fewer oil and gas wells.

DISCUSSION

Despite the complexity of trapper behaviour and fur-harvest dynamics, I was able to consistently show strong relationships between trapper harvests of marten and industrial activity, trapline characteristics, and active-inactive trapline status. Even when controlling for frequency of years trapped (a proxy for effort) and trapline area, harvests remained positively correlated with the proportion of mature conifer forests. There were no traplines with consistent marten harvests through time that had less than 20% closed-conifer forest cover or more than 36% of the trapline developed, indicating reduced trapping success on heavily disturbed traplines. The study area had a broad variety of industrial activities with the proportion of a trapline disturbed up to 0.46 and access and well densities reached amounts of up to 9.3 km access/km^2 and 5.7 wells/km^2 on inactive registered traplines. These figures were within the range found elsewhere in highly developed areas of the province (Cummings & Cartledge 2004). On the other end of the spectrum, four traplines (3%) had no oil or gas wells and 18 traplines (13%) had no logging activity, but all traplines had some form of access.

The top models did a good job at predicting trapline status, change in marten harvests, average harvests, and harvests corrected for number of years trapped using trapline-specific harvest data. There were consistent signatures in the data showing relationships between harvests and vegetation types, with the patterns comparable with literature reports of components of high-quality marten habitat (Bissonette et al. 1998). Marten use of mature coniferous forests is well documented (Koehler et al. 1975, Payer 1999, Potvin et al. 2000), but these relationships have not been shown using harvest data. Our research assumed that successful marten trapping was contingent on trappers selecting high-quality habitats in which to set traps. However, a large proportion of marten captures tend to be juveniles, especially early in the trapping season (Naylor & Novak 1994), suggesting some caution is needed when using trapping data. Although closed-conifer forests was consistently an important predictor variable in our models, the fact that many of the marten harvested were juveniles might explain the range in amount of area disturbed or clearcut on active traplines.

Other researchers have suggested that fur trends could be related to market prices (Erickson 1982), which could describe the overall decline in trapped furbearers in our study area (App.4,5,8); however, this was not the pattern for marten (Fig. 3.2). The number of trappers in the province has been declining (Poole & Mowat 2001), but the number of active registered traplines (≥5 years with marten harvests/decade) in the study area was consistent through time (n = 32-41) and the probability of a trapline being active did not differ between decades. The peak in the total number of registered trappers, however, paralleled the peak in marten pelt prices in the 1980's, making this relationship difficult to distinguish. We found no relationship between the change in marten harvest and pelt price in the foothills dataset. Instead, the increase in marten harvests in the study area could be related to increased access which invariably has increased trapper effort either by setting more traps or dispersing the same number of traps over a larger area (Buskirk & Lindstedt 1989) or as a result of maturation of the forests (Andison 1998).

Industrial development, although increasing at a fast rate, is relatively new on the landscape with remote areas still existing. Energy development has occurred since the 1950's, but large-scale logging didn't begin until the late 1980's. An increase in marten harvests despite declines in overall pelt prices indicates that trappers are motivated by factors other than fur value (see Chap.2).

Access is a crucial component of trapping, enabling trappers an efficient method to check traps from a vehicle, snowmobile, or quad. Forestry and energy companies are the major catalysts for landscape change in the foothills of Alberta and both sectors create access, in the form of roads, pipelines, or seismic lines. Access has been abundant since the 1970's (1.6 km/km^2 (1970s) vs. 3.1 km/km^2 (1990s)) in the majority of the study area, with the exception of traplines bordering the national parks. Despite the importance of access, active traplines had less access than inactive traplines. Many of the mountain traplines with limited access are active, which may explain the differences in the amount of access between active and inactive traplines. Because access is associated with other development (e.g., clearcuts, wells, and other infrastructure), less access on active traplines could be related to less development as well. If overharvest resulting from increased access were occurring through the decades, we would have expected to see an increase in harvests followed by a decline. But the total harvest has increased and 30% of traplines have had an increase in average harvest per unit area over time. Harvests might have increased because of improved access, but it is not feasible to determine with this dataset whether access (e.g., seismic lines) has enhanced small mammal abundance. Research and trapper observations found that marten avoid wide openings like pipelines

(Marklevitz 2003), suggesting that an accumulation of open spaces may have long-term detrimental consequences to marten abundance.

Active traplines were composed of significantly more closed-conifer forests than inactive traplines. In addition, there was a significant positive correlation between marten harvests and proportion of a trapline composed of mature conifer forests. Not only was habitat driving decisions to trap, but also trapper success of marten harvests improved with greater amounts of habitat. Although closed-conifer cover was a rough proxy for preferred marten habitat, it did an excellent job in describing the distribution of marten harvests. Trappers were more likely to be active and catch more marten with more habitat and habitat loss was driven by industrial activity. This provides evidence that development has influenced mature coniferous forests and has implications for the accumulation of disturbance features on the landscape for marten. Large-scale forestry really began in the late 1980's, so that areas concentrated by timber extraction prior to the 1990-decade did not have a negative effect on the amount of mature conifer. By the 1990-decade, however, an inverse relationship was found between proportion cut and closed-conifer cover, indicating that logging activities were related to a loss in mature conifer forests; this relationship has unavoidable consequences for forest-dependent species like marten.

Trappers also caught more marten in areas that were less fragmented in the 1990-decade. I found that access contributed the most to increased fragmentation in recent times. Linear features were important across time and have been shown to play an important role in altering landscape structure in other studies (McGarigal et al. 2001). In addition, there were no consistently active traplines that had less than 20% area composed of closed-conifer or greater than 36% area developed. Fahrig (1997) found that population survival was higher when the landscape was composed of at least 20% of important breeding habitat for simulated organisms regardless of habitat fragmentation. This 20% habitat threshold rule was important for habitat specialists such as the population persistence of the northern spotted owl (*Strix occidentalis caurina*) (Lamberson et al. 1992) and marten density (Hargis et al. 1999). Our results support previous marten habitat studies and the importance of greater than 20% good quality habitats for population persistence. Forestry companies could incorporate their management plans to maintain at least 20% of closed-conifer forest cover on registered traplines so that marten and logging can coexist on the landscape.

Trapper effort is obviously an important attribute to measure success and furbearer dynamics, but is difficult to quantify. A proxy for effort, proportion of years with reported marten harvests in each decade, was used for my analysis and was strongly associated with increased marten harvests; 80% of the variation in marten harvests was explained by proportion of years active. Trappers who were active for a greater number of years were more likely to be knowledgeable and have increased annual yields. This effort metric is easily available from harvest records to monitor trapline activity and catch. Proportion of years active also was associated with decreased disturbance; Proportion of years active increased in areas with fewer wells and more closed-conifer forest cover. Certainly researchers cannot predict trapper effort based on pelt prices alone and we have shown that disturbance plays a larger role in affecting trapper behaviour than previously thought.

Our data demonstrate that predicting active-inactive trapline status and marten harvests was possible using a long-term data set. We have shown consistent signals linking the importance of habitat and the negative effects of industrial disturbance on the success of marten captures. The literature supports the notion that marten are sensitive to habitat loss but this has not been documented using fur harvest data. We present information that was previously lacking for why traplines were inactive and experienced lower captures. Declines of many forest species are linked to anthropogenic activities in Alberta (Timoney & Lee 2001) and the continued removal of mature forests will result in a loss of forest-interior species like marten. Land-use planning can mitigate some of the negative effects of development if companies work with trappers to maintain at least 20% closed-conifer forest on registered traplines and/or to set aside special habitat areas. In return, trappers can be involved in forestry monitoring programs of wildlife and can contribute to discussions during forestry and energy advisory committee meetings. Wise management of the economic and environmental conditions is necessary to maintain natural resources for the future. Current "business as usual" strategies do not ensure sustainable resource use (Schneider 2002) and adaptive management using readily available trapping data could be used to balance competing demands for the environment.

Table 3.1. Descriptions, measurement units, and sources of landscape variables that were quantified using GIS to determine differences between traplines in west-central Alberta.

Variable code	Description	Units	Data Source
Access	Density of roads, seismic, power and pipeline	km/km^2	ABSRD
Access89	Change in access density from 1980 to 1990-decade	km/km^2	ABSRD
Barren	Proportion of barrenland (e.g. rock, no vegetation areas)	--	FMF
ConPro	Proportion of trapline composed of closed-conifer (>50% closed canopy)	--	FMF, CESWES
Cut	Proportion of total area cut	--	CESWES, Forestry
Cut89	Change in proportion cut from 1980 to 1990-decade	--	CESWES, Forestry
Decid	Proportion of deciduous forest	--	FMF
Disturb	Proportion of disturbance features (road, seismic, facility, ROW, and forestry)	--	ABSRD,FMF,CESWES,Forestry
Dist89	Change in proportion disturbed from 1980 to 1990-decade	--	ABSRD,FMF,CESWES,Forestry
Frag.area	Effective mesh size standardize by trapline area	km^2/km^2	GIS disturbance layers
Mixed	Proportion of mixed (conifer/deciduous) forest	--	FMF
OpenCon	Proportion of open coniferous forest (<50% closed canopy)	--	FMF
OpenWet	Proportion of open wetland	--	FMF
Regen	Proportion of regenerating forest	--	FMF
Shrub	Proportion of shrub	--	FMF
TrapArea	Trapline area	km^2	ABSRD
TreeWet	Proportion of treed wetlands	--	FMF
UpldHerb	Proportion of upland herbaceous	--	FMF
Well	Well density	#/km^2	ABSRD
Well89	Change in well density from 1980 to 1990-decade	#/km^2	ABSRD
X80, X90	Decade 1980 or 1990	--	--
Yrsactive	Proportion of years with reported marten harvests within a decade	--	ABSRD

Table 3.2. A comparison of min, max, mean, and standard deviation of variables measured in the 1990-decade in reference to registered traplines (n = 136) in the study area. Refer to Table 3.1. for variable descriptions.

VARIABLE	MIN	MAX	MEAN	S.D.
Access (km/km^2)	0.12	9.31	3.58	2.07
ConPro (km^2/km^2)	0.07	0.78	0.41	0.17
Cut (km^2/km^2)	0.00	0.43	0.08	0.09
Disturb (km^2/km^2)	0.004	0.46	0.13	0.09
Frag.area (km^2/km^2)	0.0008	0.99	0.1	0.21
Well ($\#/km^2$)	0.00	5.74	0.64	0.99
TrapArea (km^2)	37.6	682.0	200.9	121.2

Table 3.3. Sample size and percent of active (≥5 yrs. of reported marten harvests/decade) and inactive traplines overall and by decade.

TRAPLINE STATUS			
DECADE	**Active (%)**	**Inactive (%)**	TOTAL
1970	41 (30)	95 (70)	136
1980	32 (24)	104 (76)	136
1990	36 (26)	100 (74)	136
TOTAL	109 (27)	299 (73)	408

Table 3.4. A priori alternative candidate models for logistic regression modelling to predict the status of traplines as active or inactive. Variables are defined in Table 3.1.

Candidate Models	
Habitat	*X80+X90+ConPro+ConPro*^{2}*+lnTrapArea*
	X80+X90+ConPro+ConPro^2
All Disturbance	*X80+X90+lnDisturb*
	X80+X90+lnCut+Access+lnWell
Forestry	*X80+X90+lnCut+Access*
	X80+X90+lnCut
Oil	*X80+X90+lnWell+Access*
Habitat & Disturbance	*X80+X90+ConPro+ConPro*^{2}*+lnCut+lnWell+lnTrapArea*
	X80+X90+ConPro+ConPro^2*+lnWell*
	X80+X90+ConPro+ConPro^2*+lnCut*
Fragmentation	*X80+X90+ConPro+ConPro*^{2}*+lnfrag.area*
	X80+X90+lnfrag.area

Table 3.5. A priori alternative candidate models for modelling change in average marten harvest from the 1980 to 1990-decade using linear regression. Note that the numbers for each variable correspond to the decade variable was measured in (e.g. lnCut89 is the natural log of the change in cut from the 1980 to 1990-decade). Variables are defined in Table 3.1.

Candidate Models	
Change in Disturbance	
	lnCut89+lnWell89+Access89
Change in Disturbance and Amount of Habitat	
	Dist89+Mix9
	lnCut89+Mix9+ConPro9
	lnCut89+lnWell89+Access89+Mix9+ConPro9
	lnWell89+Access89+Mix9+ConPro9
Change in Disturbance and Habitat	
	lnCut89+lnWell89+Access89+Mix9+ConPro89+Mix9+lntreewet9+lnuplanherb9
	lnCut89+Mix9+ConPro89
Full	
	lnCut89+lnWell89+Access89+Mix9+ConPro89+lntreewet9+ lnuplanherb9+lnregen9+lnbarren9+lnopencon9+lndecid9+logcloscon

Table 3.6. A priori alternative candidate models for modelling the average marten harvest per unit area in the 1990-decade using linear regression. Variables are defined in Table 3.1.

Candidate Models
Habitat
Mix+lnshrub+lntreewet+lnbarren+ConPro89+lnopencon+lnmodcon+lnregen+lnuplanherb+lncloscon
Habitat & Fragmentation
ConPro+Mix+lnfrag.area
Habitat & Disturbance
ConPro+Mix+lnCut9+lnWell89+Access9
ConPro+lnWell89+lnshrub+lntreewet
lnCut89+lnWell89+lnshrub+lntreewet+Mix+ConPro89+Access89
Disturbance
lnAccess89+lnWell89+Dist89
Access89+lnWell89+Dist89+Access9+Cut9+Dist9+lnWell9

Table 3.7. A priori alternative candidate models for modelling the average marten harvest per unit effort (frequency of years trapped) over time using linear regression. Variables are defined in Table 3.1.

Candidate Models	
Habitat	
	X80+X90+ConPro
Habitat & Disturbance	
	X80+X90+ConPro+lnCut+lnWell+lnAccess
	X80+X90+ConPro+lnDisturb
	X80+X90+ConPro+lnWell
Fragmentation	
	X80+X90+ConPro+lnfrag.area
	X80+X90+lnfrag.area
Disturbance	
	X80+X90+lnCut+lnWell+lnAccess
	X80+X90+lnCut+lnAccess
	X80+X90+lnWell+lnAccess
	X80+X90+lnWell
	X80+X90+lnCut

Table 3.8. Landscape change by decade, specific feature, and amount increase estimated from forest inventory maps for the study area.

Feature	Decade	Amount	Amount Increase
Roads	1970	6,884 km	
	1980	8,297 km	1.2X since 1970
	1990	13,322 km	1.9X since 1970
			1.6X since 1980
Seismic lines/Trails	1970	36,792 km	
	1980	52,988 km	1.4X since 1970
	1990	63,566 km	1.7X since 1970
			1.2X since 1980
Wells[1]	1970	4,852	
	1980	7,507	1.5X since 1970
	1990	13,331	2.7X since 1970
			1.8X since 1980
Pipelines	1970	993 km	
	1980	2,154 km	2.2X since 1970
	1990	9,009 km	9.1X since 1970
			4.2X since 1980
Powerlines	1970	506 km	
	1980	621 km	1.2X since 1970
	1990	922 km	1.8X since 1970
			1.5X since 1980
Facilities[2]	1970	15 km^2	
	1980	50 km^2	3.3X since 1970
	1990	53 km^2	3.5X since 1970
			1.1X since 1980
Forestry[3]	1970	448 km^2	
	1980	685 km^2	1.5X since 1970
	1990	1,109 km^2	2.5X since 1970
			1.6X since 1980

[1] Number of wells, active and abandoned, oil, gas, and water, were included.
[2] Facilities include oil and gas plants, coal mines, gravel pits, etc.
[3] Forestry includes area with stand modifications from AVI (clearcut, clearing, and burn).

Table 3.9. Mean and standard error of landscape variables for inactive (<5 years reported marten harvests/decade) (n = 91) and active (≥5 yrs. reported marten harvests/decade for all 3 decades) (n = 45) marten traplines with means compared using 2-sample t-tests. The number after a variable implies the decade that each variable was measured in or the decadal change (e.g., Access9= Access in 1990-decade; Access89= Change in Access from 1980 to 1990-decade). Significant variables ($\alpha \leq 0.05$) are shown in bold. Variables are defined in Table 3.1.

	TRAPLINE STATUS					
	Inactive		**Active**			
Variable	Mean	S.E.	Mean	S.E.	t-statistic	p-value
INDUSTRY						
Access9	3.9	0.24	2.94	0.22	2.98	0.004
Access8	3.13	0.2	2.44	0.2	2.41	0.02
Access7	1.72	0.09	1.66	0.12	0.38	0.7
Access89	0.77	0.07	0.5	0.06	2.94	0.004
Access78	1.41	0.15	0.78	0.13	3.21	0.002
Cut9	0.09	0.01	0.08	0.01	0.2	0.85
Cut8	0.03	0.01	0.02	0.01	1.08	0.28
Cut7	0.02	0.01	0.013	0.01	1.04	0.3
Cut89	0.05	0.01	0.06	0.01	-0.63	0.53
Cut78	0.01	0.003	0.01	0.003	0.61	0.54
Disturb9	0.13	0.01	0.12	0.01	0.8	0.42
Disturb8	0.07	0.01	0.05	0.01	1.75	0.08
Disturb7	0.046	0.01	0.035	0.01	1.57	0.12
Disturb89	0.06	0.01	0.07	0.01	-0.27	0.78
Disturb78	0.02	0.003	0.02	0.003	1.18	0.24
Frag.area9	0.11	0.02	0.08	0.02	0.65	0.51
Frag.area8	0.151	0.03	0.148	0.04	0.07	0.95
Frag.area7	0.23	0.03	0.18	0.04	1.05	0.3
Frag.area89	-2.61	0.02	-2.84	0.02	1.28	0.2

Frag.area78	-0.08	0.01	-0.03	0.01	-3.11	0.002
Well9	0.82	0.12	0.27	0.04	4.25	≤0.001
Well8	0.49	0.09	0.12	0.03	3.83	≤0.001
Well7	0.35	0.08	0.06	0.01	3.51	≤0.001
Well89	0.33	0.04	0.15	0.02	4.19	≤0.001
Well78	0.14	0.02	0.06	0.02	2.79	0.006
HABITAT						
Barren9	0.06	0.01	0.05	0.01	1.07	0.29
ConPro9	0.37	0.02	0.49	0.02	-4.12	≤0.001
ConPro8	0.4	0.02	0.51	0.02	-3.84	≤0.001
ConPro7	0.42	0.02	0.52	0.02	-3.39	≤0.001
ConPro89	-0.03	0.01	-0.02	0.01	-1.09	0.28
ConPro78	-0.02	0.01	-0.01	0.004	-1.03	0.3
Decid9	0.05	0.01	0.02	0.01	3.61	0.02
Mixed9	0.19	0.01	0.17	0.02	1.15	0.25
OpenCon9	0.05	0.01	0.05	0.01	-0.67	0.51
OpenWet9	0.02	0.002	0.008	0.002	2.91	0.004
Regen9	0.1	0.01	0.09	0.01	0.26	0.79
Shrub9	0.04	0.003	0.04	0.004	0.07	0.94
TrapArea	182.7	11.7	237.7	19.9	-2.39	0.02
TreedWet9	0.09	0.01	0.05	0.01	2.94	0.004
UpldHerb9	0.02	0.003	0.02	0.003	1.13	0.26

Table 3.10. Summary of the most parsimonious (Δ_i<4) logistic regression models that predict probability of active marten traplines (≥5 years of marten harvests/decade). Variables included in each model, beta coefficients, standard errors (SE), lower and upper 95% confidence intervals (C.I.), area under the curve ROC values (AUC), Akaike differences (Δ_i), and Akaike weights (w_i) are reported. Variables for which confidence intervals exclude 0 are marked *. Variables are defined in Table 3.1.

Model	Variable	Coefficient	SE	C.I.	AUC	Δ_i	w_i
1	Constant*	-7.72	1.19	-10.05, -5.39	0.7	0.00	0.53
	X80	0.47	0.26	-0.04, 0.98			
	X90	0.36	0.26	-0.15, 0.87			
	*ConPro**	11.84	3.39	5.2, 18.48			
	ConPro^2*	-11.57	3.6	-18.63, -4.81			
	*lnTrapArea**	0.98	0.19	0.61, 1.35			
2	Constant	0.16	0.58	-0.98, 1.3	0.67	1.96	0.22
	*X80**	0.54	0.27	0.01, 1.07			
	X90	0.39	0.3	-0.2, 0.98			
	*lnCut**	0.16	0.06	0.04, 0.28			
	Access	-0.05	0.09	-0.23, 0.13			
	*lnWell**	-0.3	0.08	-0.46, -0.14			
3	Constant*	-6.19	1.32	-8.78, -3.59	0.72	3.04	0.12
	X80	0.45	0.22	-0.08, 0.98			
	X90	0.23	0.31	-0.37, 0.84			
	*ConPro**	8.91	3.64	1.78, 16.03			
	ConPro^2*	-9.18	3.75	-16.53, -1.84			
	lnCut	0.12	0.06	-0.002, 0.24			
	lnWell	-0.15	0.08	-0.31, 0.01			
	*lnTrapArea**	0.89	0.2	0.49, 1.29			

Table 3.11. Summary of the top (Δ_i<4) linear regression models that predict change in average marten harvest per unit area from 1980 to 1990-decade (N= 136). Variables included in each model, beta coefficients, standard errors (SE), lower and upper 95% confidence intervals (C.I.), total variation explained (R^2), Akaike differences (Δ_i), and Akaike weights (w_i) are reported. Variables whose confidence intervals exclude 0 are marked *. Variables are defined in Table 3.1.

Model	Variable	Coefficient	SE	C.I.	R^2	Δ_i	w_i
1	Constant*	0.4	0.001	0.398, 0.402	0.04	0.00	0.42
	*Dist89**	-0.02	0.01	-0.04, -4e-4			
	Mix9	0.01	0.01	-0.01, 0.03			
2	Constant*	0.5	0.02	0.46, 0.54	0.05	0.42	0.34
	ConPro9	0.004	0.004	-0.004, 0.01			
	*lnCut89**	-0.04	0.02	-0.08, -8e-4			
	Mix9	0.01	0.01	-0.01, 0.03			
3	Constant*	0.5	0.02	0.46, 0.54	0.04	2.56	0.12
	*lnCut89**	-0.04	0.02	-0.08, -8e-4			
	lnWell89	0.003	0.01	-0.02, 0.02			
	Access89	0.001	0.001	-9.6e-4, 0.003			

Table 3.12. Summary of the top (Δ_i<10) linear regression models that predict average marten harvest per unit area in the 1990-decade (N= 136). Variables included in each model, beta coefficients, standard errors (SE), lower and upper 95% confidence intervals (C.I.), total variation explained (R^2), Akaike differences (Δ_i), and Akaike weights (w_i) are reported. Variables whose confidence intervals exclude 0 are marked *. Variables are defined in Table 3.1.

Model	Variable	Coefficient	SE	C.I.	R^2	Δ_i	w_i
1	Constant*	0.54	0.02	0.5, 0.58	0.25	0.00	0.95
	lnCut89	-0.01	0.03	-0.07, 0.05			
	lnWell89	-0.01	0.01	-0.03, 0.01			
	Access89	-0.0003	0.001	-0.002, 0.002			
	*lnshrub**	-0.003	0.001	-0.005, -0.001			
	*lntreewet**	-0.08	0.02	-0.12, -0.04			
	*Mix**	0.03	0.01	0.01, 0.05			
	*Con89**	0.02	0.01	4e-4, 0.04			
2	Constant*	0.53	0.02	0.49, 0.57	0.26	6.9	0.03
	*Mix**	0.02	0.01	4e-4, 0.04			
	*lnshrub**	-0.003	0.002	-0.01, 9.2e-4			
	*lntreewet**	-0.1	0.03	-0.16, -0.04			
	*lnbarren**	-0.002	0.001	-0.004, -4e-5			
	*lnopencon**	-0.002	0.002	-0.01, 0.002			
	logmodcon	0.004	0.004	-0.004, 0.01			
	logcloscon	-0.003	0.004	-0.01, 0.001			
	lnuplanherb	0.0003	0.001	-0.002, 0.002			
	lnregen	-0.01	0.02	-0.05, 0.03			
	*Con89**	0.02	0.01	4e-4, 0.04			
3	Constant*	0.47	0.003	0.46, 0.48	0.15	8.63	0.01
	*lnfrag.area**	0.001	4e-4	2.2e-4, 0.002			
	*ConPro9**	0.02	0.01	4e-4, 0.04			
	*Mix**	0.03	0.01	0.01, 0.05			

Table 3.13. Summary of the most parsimonious (Δ_i<4) linear regression models that predict average marten harvest corrected for proportion of years trapped (N= 408). Variables included in each model, beta coefficients, standard errors (SE), lower and upper 95% confidence intervals (C.I.), total variation explained (R^2), Akaike differences (Δ_i), and Akaike weights (w_i) are reported. Variables whose confidence intervals exclude 0 are marked *. Variables are defined in Table 3.1.

Model	Variable	Coefficient	SE	C.I.	R^2	Δ_i	w_i
1	Constant*	1.76	0.09	1.58, 1.94	0.17	0.00	0.68
	*X80**	0.19	0.07	0.05, 0.33			
	*X90**	0.4	0.07	0.26, 0.54			
	*lnWell**	-0.07	0.02	-0.11, -0.03			
	*ConPro**	0.87	0.19	0.5, 1.24			
2	Constant*	5.47	2.45	0.67, 10.27	0.18	1.52	0.32
	X80	0.2	0.07	-0.12, 0.34			
	*X90**	0.43	0.08	0.27, 0.59			
	*ConPro**	0.88	0.19	0.51, 1.25			
	lnCut	-5.34	3.57	-12.34, 1.66			
	lnAccess	-0.01	0.196	-0.39, 0.37			
	*lnWell**	-0.08	0.02	-0.12, -0.04			

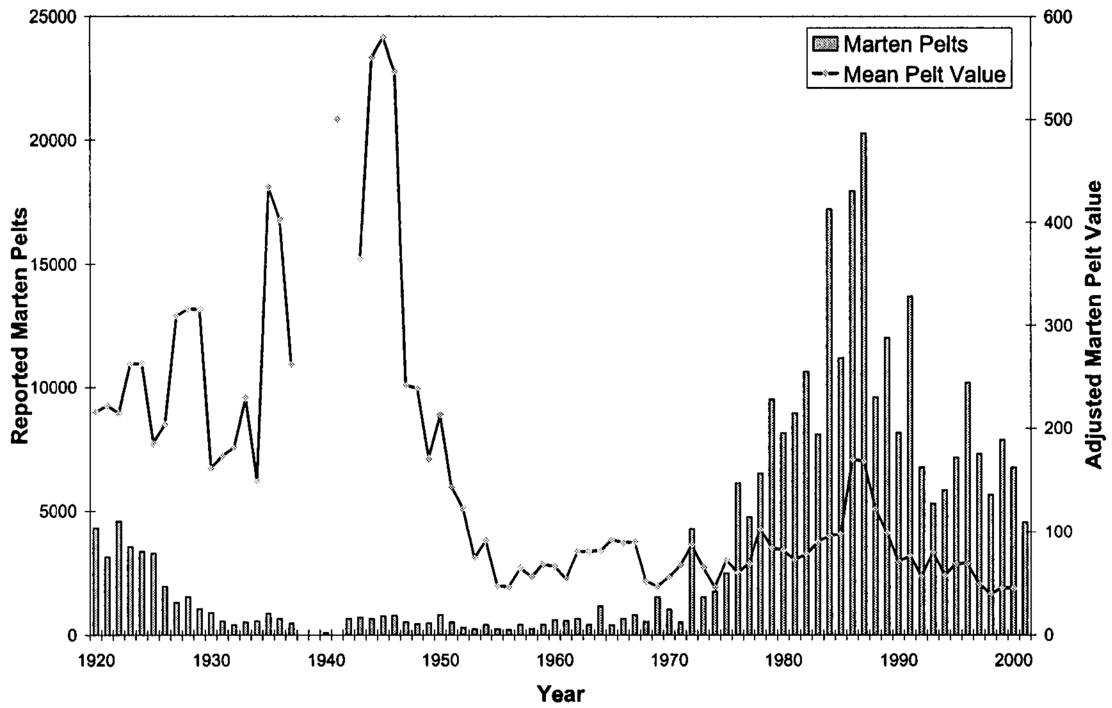

Figure 3.1. The total number of marten harvested (bars) and adjusted (based on 2001 CAD$) average marten pelt value (line) in Alberta from 1920-2001 as modified from Todd & Geisbrecht (1979) and Stats Canada.

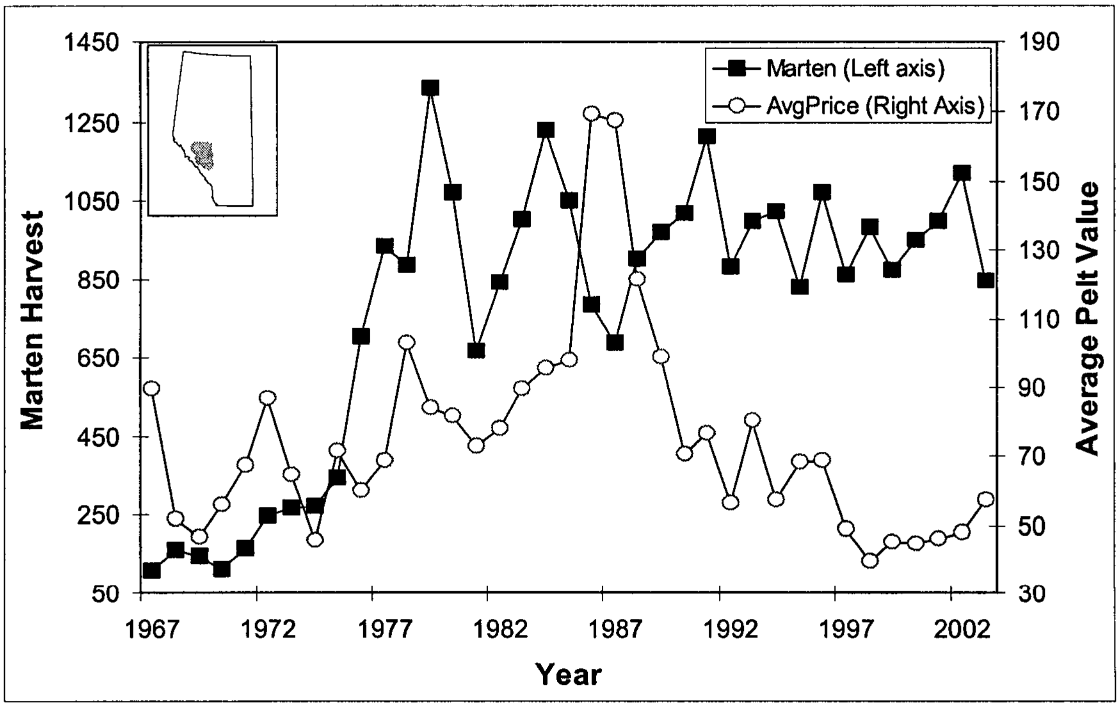

Figure 3.2. Reported marten harvests and adjusted (based on 2003 CAD$) average pelt prices from 1967-2003 in west-central Alberta.

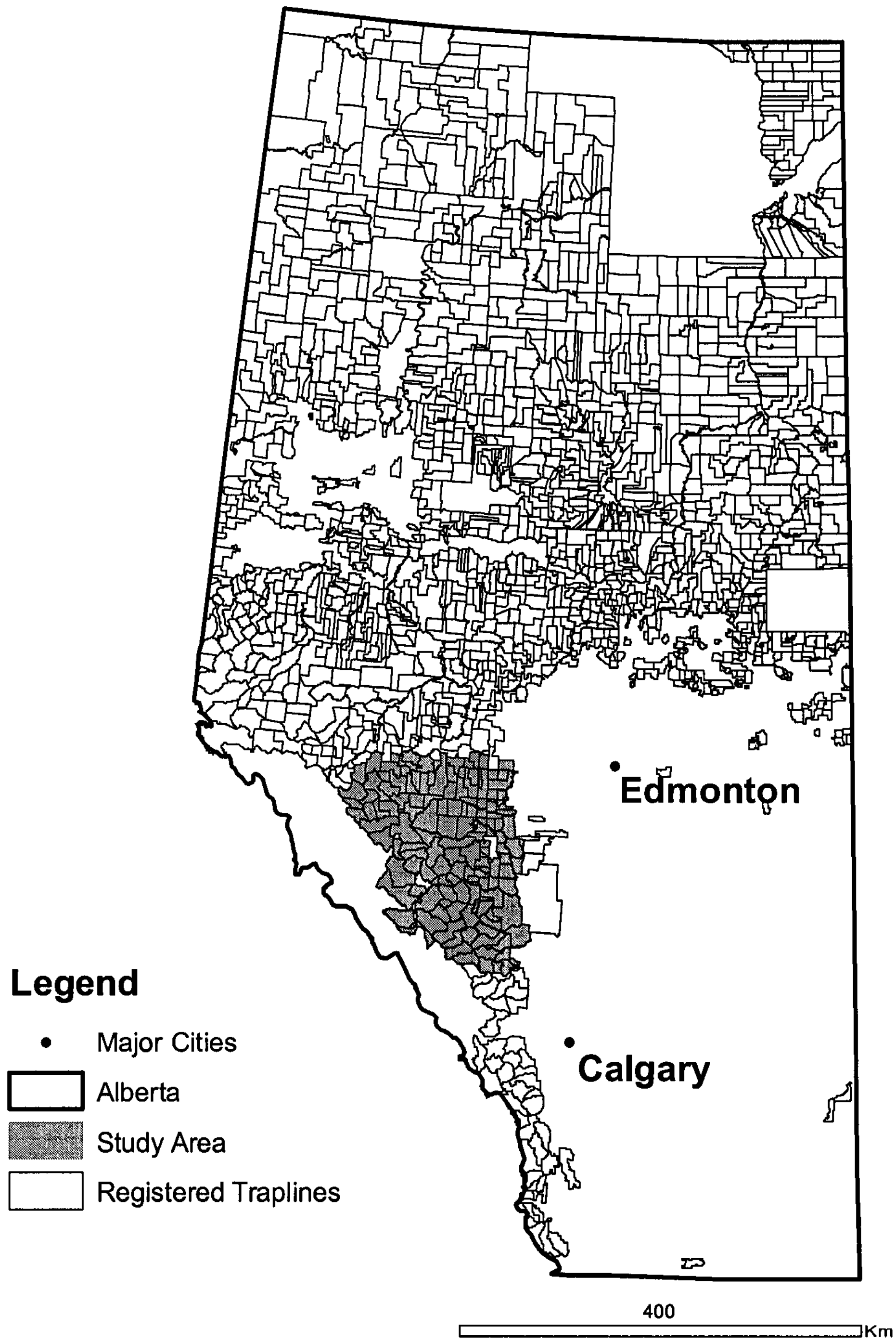

Figure 3.3. Marten harvests and landscape variables were collected for shaded registered traplines from 1970-2003 in west-central Alberta.

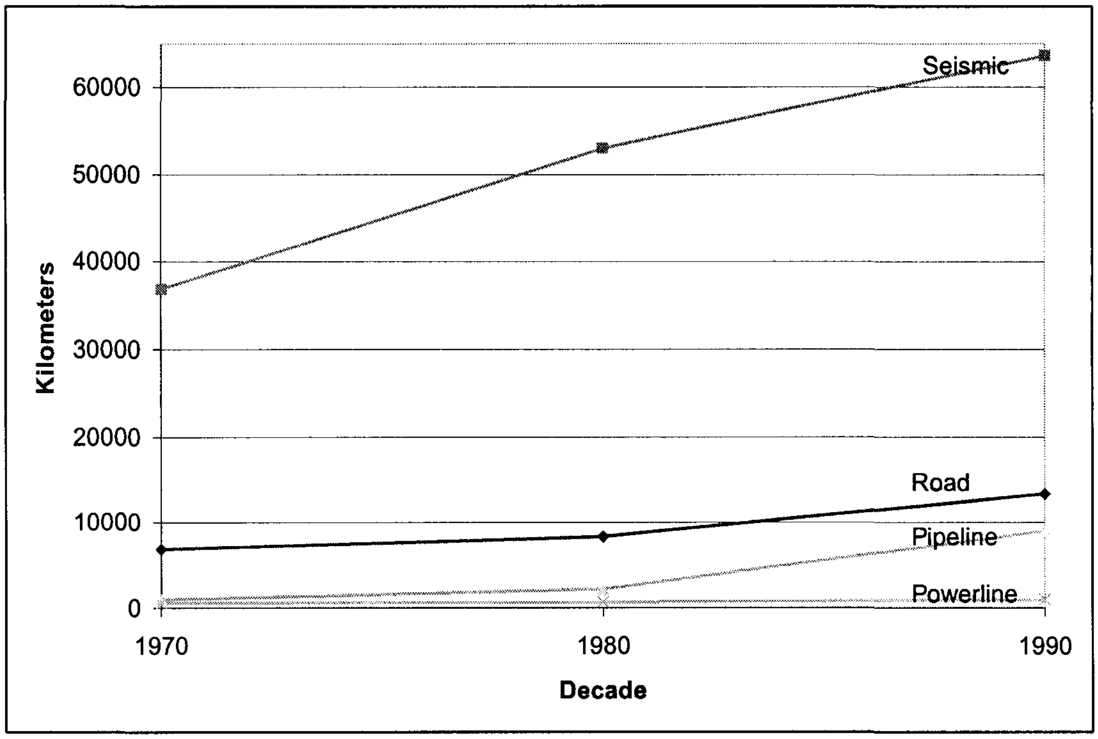

Figure 3.4. Landscape change trends for specific linear features by decade in the study area.

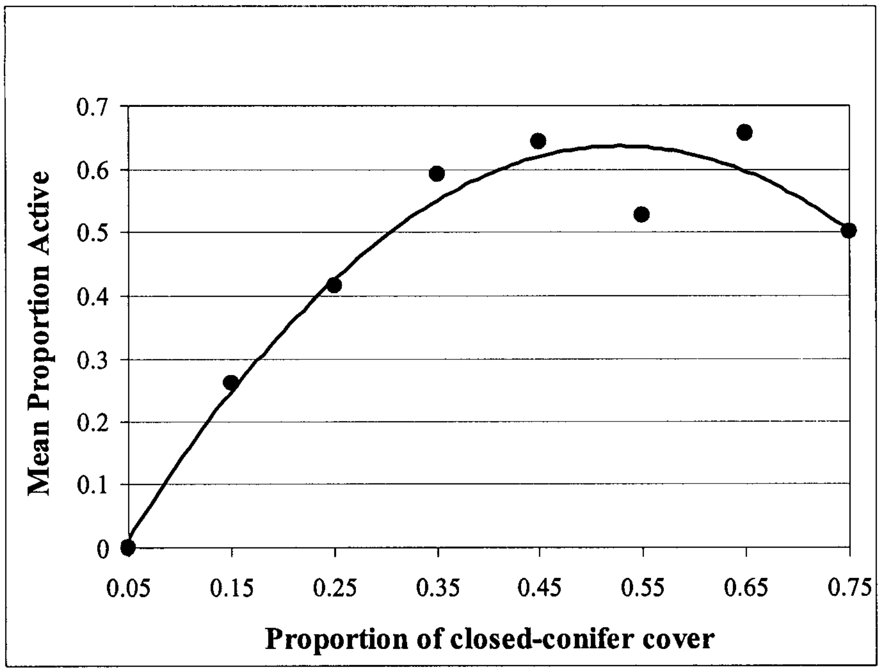

Figure 3.5. Proportion of active traplines versus the midpoint of each proportion of closed-conifer interval. For example, ~26% of traplines composed of 10-20% closed-conifer forest cover were active.

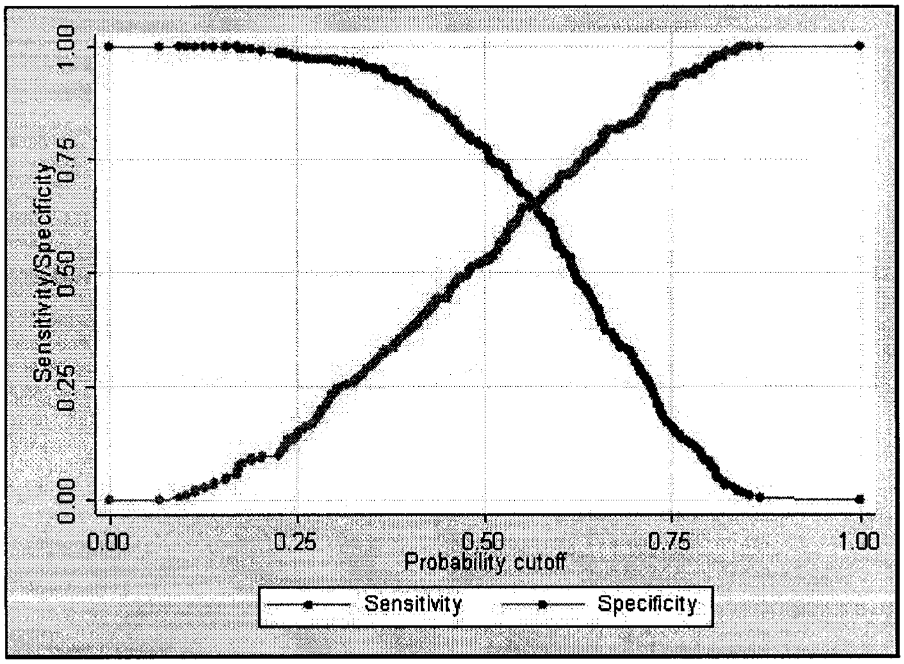

Figure 3.6. Sensitivity and specificity curves of the top ranked AIC model used to predict the probability of a trapline being active illustrate a statistical threshold where the 2 curves intersect (in this case, probability equals 0.57).

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CHAPTER 4

GENERAL CONCLUSIONS

Trapping data can provide managers with a general idea of furbearer distribution and status. Without trapping records, it would be costly to monitor elusive species like marten that can be used as bio-indicators of highly complex forests. The response of marten to habitat loss, primarily via forestry, has been well documented (Thompson 1994, Chapin et al. 1997, Huggard 1999); but it is unclear how other industrial features might affect them. Even more so, the effects of industrial activity on trapper attitudes and behaviour are not well understood. The relationship between trappers and habitats is an important component to understanding how fluctuating furbearer harvests may be linked to population trends. I examined fur harvests, habitat types, and land-use activities, to gain a better understanding on the effects of industrial development on trappers and fur harvest trends. Knowledge of the relationships between trapper behaviour, landscape change, and fur harvests will improve furbearer management. However, the use of these data does not come without a few caveats and recommendations for improvements.

Understanding the socioeconomic and cultural importance of trapping is complex but imperative to the management of harvested species. I interviewed trappers on active traplines to increase the reliability of trapper observations. There are many reasons why traplines could be inactive; I was more interested in the range in development on active traplines to determine how marten harvesting could coexist with industrial activity. Focusing on trappers who had telephone numbers also introduced bias because it reduced the opportunity to speak with native trappers. Surveying native trappers could have shed light on why several traplines adjacent to native reserves were inactive. It appears that the amount of access and mature coniferous forests on inactive native traplines were well within the range of active traplines, suggesting alternative motivations for not trapping. Many native traplines were sold to non-native trappers in particular districts (Nordegg) in recent decades. Another bias associated with the survey was that I interviewed only the most recent trapline owner. Change in trapline ownerships made it impossible to speak to every trapper who ever owned or trapped each trapline. Approximately 1/3 of the traplines were trapped for marten at least every other year from 1970-2000. This change-over affected harvest data because of the time that it takes for new trappers to learn about what furbearers are present and where they live; in the beginning, new trappers may report no or low harvests, which isn't necessarily a product of industrial activity but rather inexperience. However, I did not find any relationships between trapping experience or trapline ownership and number of marten harvested. I ended up using decade averages, partly, to clean up some of the noise associated with annual variation. Use of annual harvest data may be less useful in determining population fluctuations (Raphael 1994).

Documenting marten response to habitat loss was difficult because many trappers sold their trapline or stopped trapping when development was "too high" and/or they failed to observe marten sign. I only came across one true zero in the hard-copy affidavit records showing that a trapper set traps but caught 0 marten. Instead, there was an increasing trend in marten harvests through time despite increased habitat loss and a decline in pelt prices. On the surface, it would appear that there was a positive relationship between total number of marten caught and area logged, which is inconsistent with the literature. One explanation for an increase in harvests is a true increase in marten populations as a result of fire suppression and maturation of the forests. Andison (1998) determined that the current Weldwood FMA harvest practices have created an age-class distribution that falls within the natural range of variation based on fire modelling exercises. However, the lower foothills had a bi-modal age-class distribution with a greater percentage of older age classes (101-140 years old) currently than occurred prior to forestry and fire suppression. Andison's simulation results indicate that the foothills are highly dynamic and that some areas (i.e., lower foothills) may be overdue for disturbance. Furthermore, it has been suggested that marten may be more abundant today then they were historically in this area due to frequent fires. Marten population surveys, other than harvest records, are lacking to validate these theories.

My study focused on the response of trappers and marten to landscape change. Although I did not examine the relationships between other furbearers and habitat, it is important to mention that although marten were popular, trappers also caught a variety of other furbearers. One third of the registered traplines had no marten harvest data from 1970-2000. Traplines not actively trapped for marten could have been actively pursuing other furbearers. There was a general trend of inactive traplines in the northeastern part of the study area in the Drayton Valley/Evansburg District for marten where instead, I found coyotes were the most common furbearer caught. This district was the most disturbed and had the least amount of closed-conifer forests and it would make sense that trappers focused on habitat generalists, like coyotes. Although I did not collect data on aquatic furbearer harvests, based on telephone surveys, beavers were also an important animal in the catch in this area.

Lack of data and communication between trappers and industry has led to strife. My interviews identified that the majority of trappers were sensitive to habitat loss and as a result, many had negative attitudes towards forestry companies. But some companies had better relations with trappers than others because they integrated their management plans with the trappers and improved cutblocks for marten (e.g., large residual patches, structure retention). Although forestry is a major industrial player, the energy sector has a larger footprint and greater impact on landscape structure (Schneider 2002). Lack of concern specifically of energy development could be attributed to greater jobs, trapper compensation, or direct observations of marten sign around well sites, seismic lines, pipelines, and other infrastructure. Instead, many trappers targeted general industrial activity for reasons of concern. As expected, trappers with negative attitudes towards industry had significantly more access and well density, greater fragmentation and proportion of cutblocks, and less closed-conifer forest cover, thus quantifying their concerns. The number of marten harvested per unit area in the 1990-decade, however, did not vary between interviewed traplines which had negative or positive/neutral attitudes towards industrial activity. This could be a product of the biases associated with not being able to interview all traplines in the study area.

Using a modelling approach I was able to uncover important relationships that were not obvious at first glance. Although total marten harvests have increased, the spatial distribution of active traplines has changed in response to changes in habitat conditions and industrial development over time. Our data suggest that differences in the amount of industrial activity influence whether a trapline is active or not. Active traplines had significantly fewer wells and roads, quad-trails, and rights-of-ways, as well as greater amounts of mature coniferous forests. In addition, the probability of a trapline being active was best predicted by the proportion of closed-conifer and logged habitat, access and well density, and the size of a trapline. There was also evidence that harvests were influenced by habitat loss as a result of industrial activity. Marten harvests decreased as a result of increased disturbance and logging, and harvests increased with greater amounts of mixed and closed-conifer cover types. Similar trends were found when predicting the average number of marten harvested. Greater numbers of marten were harvested from traplines that were composed of less open habitat types (e.g., shrub, barren) but more closed-conifer and mixed habitats, and in areas that were less fragmented by industry. Furthermore, when accounting for differences in the frequency of years trapped, trappers caught more marten where there were more mature coniferous forests and fewer oil and gas wells per unit area. The combined importance of the amount of good quality habitat and the industrial footprint was able to describe up to 25% of the variation in the number of marten harvested. Cummings and Cartledge (2004) found that the density of wells could be used as a surrogate for the energy footprint because it was able to explain 30-50%, respectively, of the variation in the amount of roads, seismic, and pipelines in northeastern Alberta. Our results support Cummings and Cartledge's findings with the density of roads, seismic lines, and pipelines accounting for 94% of the variation in the density of wells on registered traplines.

Indirect measures of population abundance, such as harvest data, are usually less costly and more logistically feasible to collect over a long period of time, yet their ability to describe actual population dynamics is questionable (Raphael 1994). However, researchers have found success with inferring population trends and relative abundance from harvest data (Viljugrein et al. 2001, Cattadori et al. 2003), suggesting the value of maintaining long-term datasets. The cyclic population of lynx and snowshoe hares was discovered because of a wealth of historic trapping records (Quinn & Parker 1987), despite limited biological data. Previous research on fur harvest trends in Alberta recommended further study at the regional level; as a result, strong patterns emerged when studying furbearers on registered traplines and suggest that a trapline is an appropriate sampling unit. The results of our research demonstrate the strength of using an information-theoretic modelling approach in a multiple competing models framework to determine the level of support for different management scenarios. These models can be useful for understanding the relationships between wildlife and habitat and for predicting the effects of habitat loss on forest-dependent species so that land-use planning can incorporate trapping and development.

MANAGEMENT RECOMMENDATIONS

Managers

Currently, trappers submit fur affidavits to their local Fish and Wildlife District office when paying their renewal license fees. One copy of the affidavit remains with the trapper, one at the District office, and one gets sent to Edmonton to be entered into the electronic fur database. A hard-copy trapline file remains in the local district office and a trapline file also exists in an Edmonton ABSRD office. There is no verification of fur harvests such as a proof of fur sales receipt. To increase the accuracy of records, I recommend that trappers be required to show proof of sale of fur when signing annual affidavits for valuable furbearers (e.g., coyote, lynx, marten, etc.). Alternatively, Poole & Mowat (2001) suggest having fur dealers be responsible for submitting pelt counts organized by registered traplines to Fish and Wildlife. This would increase accuracy of records (especially when trappers may not submit affidavits if not trapping for the subsequent season) and ability to determine trapline status and distribution trends. I also uncovered many problems with the accuracy of the electronic fur records. This database must be checked for errors using hard-copy affidavits so that the records can be reliably used.

Most surveys have focused on registered trappers and no research has included resident trappers who trap on private lands in the white zone. A large number of coyotes are caught by resident trappers but there is no system in place to identify harvests by location like a registered trapline. Although resident trappers are required to report the number of animals taken on affidavits, it also would be helpful to include the townships trapped so that the regional distribution of the harvest could be documented. There are discrepancies between the export permits and Alberta SRD records, and the resident trapping records could explain the difference (Poole & Mowat 2001).

In addition, reporting age (adult or juvenile) and sex data would be particularly useful to monitor populations (Fryxell et al. 2001). Harvest alone is a weak indicator and would be a stronger signal of population trends if linked to effort, sex, and age data. Ontario trappers submit these types of data and as a result, much research has been able to take place to aid in the management of furbearers (Fryxell et al. 2001). Effort is a difficult metric to accurately measure but simply, the number of traps and number of days spent on the trapline in a given year, could be more useful than no information. At the decade level, we found that the proportion of years trapped was strongly associated with the average marten harvest.

The size of traplines was originally allocated based on the amount of productive land. Traplines that have a lot of rock or wetlands tend to be larger in size. We found that more marten were caught on larger traplines and that traplines were more likely to be active on larger traplines. There are some traplines in the study area that are inactive and could be amalgamated to adjacent traplines to give other trappers greater opportunity in areas that are heavily fragmented by industrial development. Fish and Wildlife should investigate the nature of inactive traplines (traplines without any harvest data for ≥5 years), so that there would be options for merging traplines in disturbed landscapes.

Trappers

Habitat loss and range contractions are major factors influencing wildlife population dynamics worldwide (Laliberte & Ripple 2004). Trappers can act as indicators of wildlife sensitive to habitat loss but data are necessary to build a case. Using short-term harvest data alone is not indicative of reality and instead, trappers need to collect more information. Currently there are some trappers who have a trapping notebook or journal to record how many animals they catch, condition, sex:age ratio, and effort. The Alberta Trappers Association supports a trapline management plan that allows trappers to have something at the table when meeting with industry. It is impossible to show the effects of industrial development when trappers stop trapping or do not record true zeros on their affidavits. The current harvest retrieval system is basic and would be more useful if teamed with additional information. I encourage trappers to speak with their regional biologists about collecting more data on affidavits. Although more time consuming, in the long run this information will prove to be more useful. In addition, many studies were possible because of trapper cooperation. Trappers are decreasing in numbers and support, and must stay active in research and other initiatives to continue the tradition of wise management and stewardship. Trappers must be proactive and communicate their concerns to industry and managers. Participating in research and the ATA, having a management plan, and keeping an organized, detailed journal will aid trappers during wildlife-habitat discussions.

Industrial Development

Trappers harvested marten under a range of anthropogenic activities, demonstrating that marten trapping can persist with development. There are many innovative ways to improve forestry practices by leaving larger retention blocks, snags, and structure (OMNR 1986, Stelfox 1995, Payer 1999, Kneeshaw et al. 2000). Our results indicate that maintenance of at least 20% mature coniferous forests on individual traplines by industry will ensure that trappers can continue a traditional lifestyle. Connected (e.g., via riparian corridors) forest patches that are at least 15 ha each in size that also maximize core area and minimize edge (round shapes) would best benefit marten (Bisonnette et al. 1989). Exploring alternatives to clearcutting practices is growing in popularity in response to changing public attitudes in the north-eastern U.S. and has the potential to reduce the negative effects of habitat loss on marten (Fuller & Harrison 2005). Soutiere (1979) found that the density of adult marten was not different between partially cut (20-25 m^2/ha basal area in pole stage and larger) and uncut forest stands. Maintenance of forest stands that have at least 18 m^2/ha basal area and 30% canopy cover during leaf-off season with partial harvesting satisfies marten cover requirements (Fuller & Harrison 2005). The arrangement of partial harvests or clearcuts that are adjacent to large mature forest stands is also important so that marten can shift their home ranges in response to habitat changes (Fuller & Harrison 2005). In addition to the configuration of cut stands, the amount of structure and debris (e.g., snags, downed logs) left after a cut is equally important so that regenerating stands can support future marten populations.

In addition to planning logging activities, access also can be created in such a way to minimize additional fragmentation. We found that access contributed the most to increased fragmentation in recent decades, suggesting the importance of coordinating road development by energy and forestry companies. Industry should exchange plans frequently, which should be quite feasible considering the use of geographic information systems and ease of making maps. Energy development could plan pipelines along road corridors, powerlines, and railways which are already devoid of trees. Dry, abandoned well sites need to be reclaimed and this reclamation requirement needs to be enforced by the government. Seismic line construction has improved during the past 3 decades, from a 10-m width cut by bulldozers in the 1970's, to hand-cut 2 m lines today (Schneider 2002). This change reinforces the ability to manage our forests better so that multiple activities (industry and trapping) can be maintained. Adaptive management can aid in better understanding of complex social, economic, and ecological issues so that current practices can be adjusted to promote, not degrade, ecosystem integrity.

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Appendix 1. Survey questions asked to registered trappers in west-central Alberta.

1. How many years have you been trapping?

2. How long have you been the leaseholder of your current RFMA(s)?

3. How many trappers on your RFMA? Junior trappers? If >1, do you record harvests separately on affidavits?

4. What furbearers do you catch on your trapline (other than marten)?

5. How would you describe landscape changes (new roads, trails, cutlines, clearcuts, etc.) over the time period you have been trapping on your line? No change, increase?

    - Forestry-
    - Petroleum-
    - Provincial Roads-
    - Other-

6. What factors, if any, are you most concerned about in relation to marten conservation on your trapline?

7. Please describe your marten trapping efforts. For example, do you generally set similar number of traps for similar number of days each year in the same location?

8. On average, how many traps do you usually set?

9. If your effort varies from year to year, what factors affect your decision to trap marten (e.g. free time, pelt prices of marten, pelt prices of other species, income, etc.)? Which factor is most important?

10. If marten pelt price affects your effort, what is the lowest dollar amount in which marten were worth that you would decide to stop trapping for marten?

11. What type of sets do you use to catch marten? Lure, bait? Conibears vs. snares?

12. Have these methods (from Q #11) remained constant?

13. Do you see a response in marten abundance and behaviour (from tracks in the snow or trapped individuals) on your trapline after logging operations? If so, please describe?

- Short-term:

- Long-term:

14. Are you notified by the FMA holder of areas that will be harvested on your line? If so, how does your trapping change for that specific area? (e.g. trap area hard with the assumption that marten will move out of area, discouraged to trap after cut?)

15. Do you see a response in marten abundance or behaviour (from tracks in the snow or trapped individuals) on your trapline after well sites, pipelines, and seismic lines are created?

- Short-term:

- Long-term:

16. How does your trapping change after new roads and trails are created on your trapline? Do you use these roads and trails to set traps from?

17. If more roads and trails are created, do you set more traps or do you set the same number of traps?

18. Do these new roads and trails provide access to areas that you would not otherwise trap?

19. What types of habitat or landscape features do you use to make decisions on trap placement? (e.g. tracks, structure, mature forest)

20. Compare SRD marten harvests with their memory of past harvests on their trapline.

21. Please share additional comments you may have about marten from your trapping experiences.

Appendix 2. Detailed methods used to collect and calculate landscape change from forest inventory maps (FIM), base layers, and Alberta Vegetation Index (AVI).

All modified forest stands (including burns, clearcuts, and clearings) 1950-present were used to calculate the amount of area logged from the Alberta Vegetation Index (AVI) for Weldwood and Weyerhaeuser (Edson) FMA's. AVI was initiated in 1987 to identify and characterize vegetation types using aerial photographs on Alberta Crown lands. For Sunpine and Weyerhaeuser (Drayton Valley) FMA's, I used the Central East Slopes Wolf and Elk Study (CESWES) cutblock layers (Contact: E.H. Merrill, University of Alberta, Edmonton, AB.) derived from AVI and satellite imagery. I also used Updated Phase III Forest Inventory Maps (FIM) to digitize and calculate total area of cutblocks in Sundance FMA. Forest inventory maps (with 3 phases, 1949-2000) preceded AVI to document wildfires, land-use activities, and descriptive forest-stand information from aerial photos. Closed-conifer was quantified using recent satellite imagery from Foothills Model Forest (FMF) (Franklin et al. 2001), which covered most of the study area, and also from CESWES habitat layers (Beyer et al. 2004).

Landscape change was quantified using historic hard copy forest inventory maps (Contact: L. Lyseng, ABSRD, Edmonton AB.), base layer features from satellite images, and AVI from forestry companies (Sunpine, Weyerhaeuser, and Weldwood). Because dates were not available for the majority of landscape variables, I used Original and Updated Phase III FIM's to backcast from current landscape. Original Phase III forestry maps were "blue-lined" from hard copy plastic maps onto paper for each township and were available from 1972-1983. Updated Phase III FIM's were available from 1983-2000 in an electronic format for the study area townships. Satellite images were used to geo-reference existing pipelines, powerlines, roads, and trails/cutlines on the landscape using images as recent as 2004 and AVI data updated to 1999. The western portion of the study area has had little industrial activity so aerial photos were not available for these areas and it is assumed that limited access in this area has not changed much over the past 3 decades. Most of the western slopes in the study area adjacent to national parks are Forest Land Use Zones (F.L.U.Z.) with strict access and motor-vehicle restrictions.

Limited dates were available on forestry maps and satellite images so features were grouped by relative decade of creation, based on the average between map dates. I used a geographic information system (GIS) to determine the quantity of each feature for each decade and trapline. AVI forestry data were incorporated into a GIS and grouped by modified stands and dates. Some stands did not have dates available and were grouped into the present landscape, so the 1990's decade clearcuts may appear inaccurately elevated due to unknown clearcut dates. Although most of the modified stands were clearcuts, other modifications were included in the quantification of clearcuts (e.g. burns and clearing), because they were an important contribution to land clearing. Weather data were averaged annually and monthly during trapping season (November-March) and summarized by trapline. Weather was one of the few variables with annual data so trends could be analyzed. Closed-conifer was only available for 1990-decade landscape so I subtracted the area in cutblocks in 1990 and 1980 from conifer stands to determine the relative amount of closed-conifer during the 1970 and 1980-decades. To determine approximate area of closed-conifer habitat in past decades, we assumed that forest stands harvested were softwood.

Dates were determined for access (roads, pipelines, seismic, powerlines) and facilities (plants, mines, gravel pits, etc.) because most clearcuts and well sites had date attributes. The first landscape change phase of the analysis involved comparing present landscape (from GIS base layers supplied by ABSRD) to Updated Phase III maps for every township. Features (e.g. roads, seismic, etc.) present on the current landscape but not on Updated Phase III map received a relative date (meaning that the feature was created sometime between the 2 dates of the maps), which was the average date of the Updated Phase III map and capture date from the GIS base layers. Features present on both maps received no date. The second landscape change phase compared Updated Phase III maps to Original Phase III maps. Again, each feature was compared between the two maps and features present on updated but not original map received a relative date based on the average dates between the two maps. All features without dates at this point were created prior to the study period of interest and received a 1970 relative date to create a base landscape to calculate change from. There was good agreement between forest maps so only a limited amount of digitizing was necessary. In addition, clearcuts were digitized from one small Forest Management Area (~420 km^2) and dates were present for most of these cuts on Updated Phase III maps. The amount of each access feature present in each decade was relative with some discrepancy due to replacement of seismic/trails by roads or rights-of ways. I focused on seismic, road, and rights-of-ways broadly as access features, rather than specific habitat loss from each access type, assuming that trappers used all types. Thus, the final landscape change product yielded spatial layers of all landscape features grouped by trapline and decade to be used later in analysis. Industrial features were summed and total landscape change was calculated to identify growth of individual features through time.

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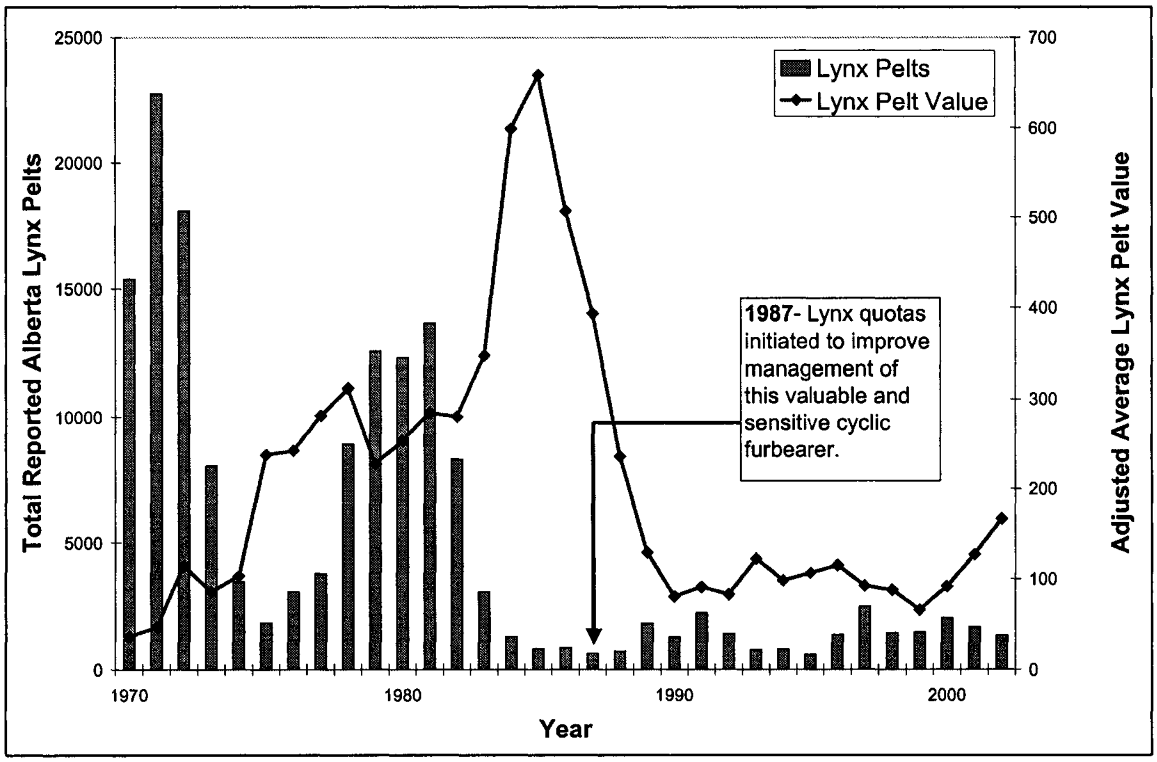
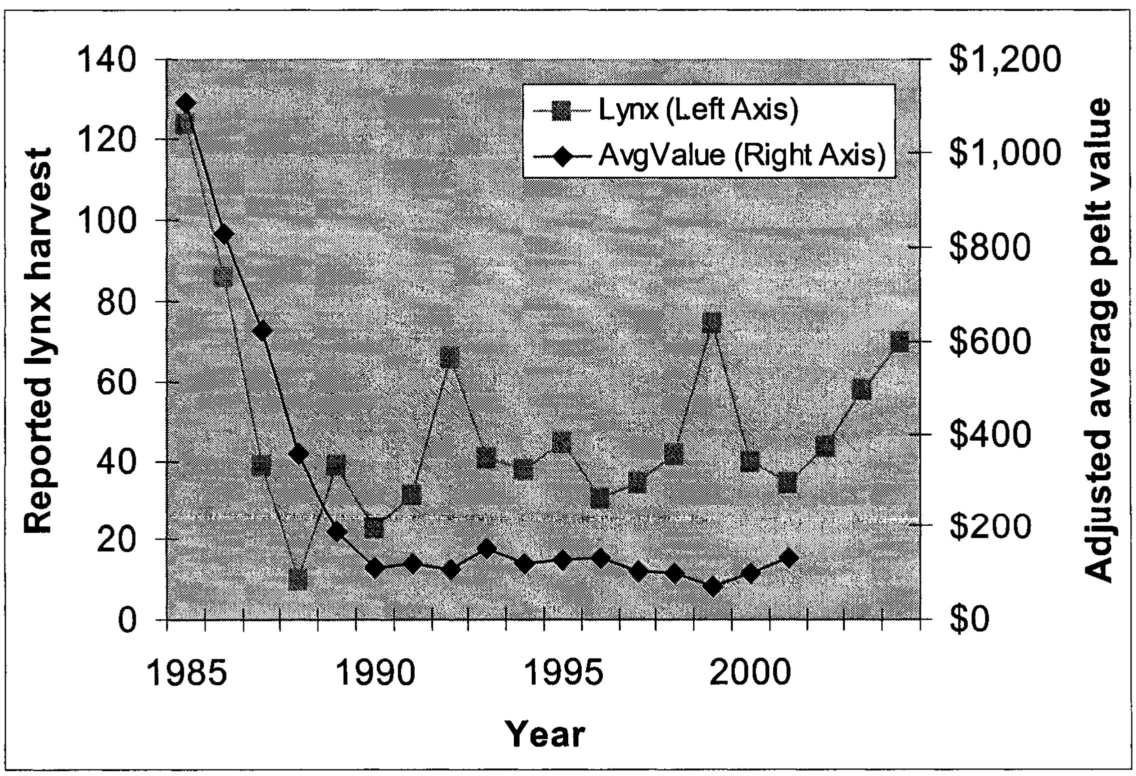
Appendix 3. Field measurements of linear features that were used to create a disturbance layer. The average width was used to buffer access features. In addition, wells were assumed to be 16,000 m^2 in size.

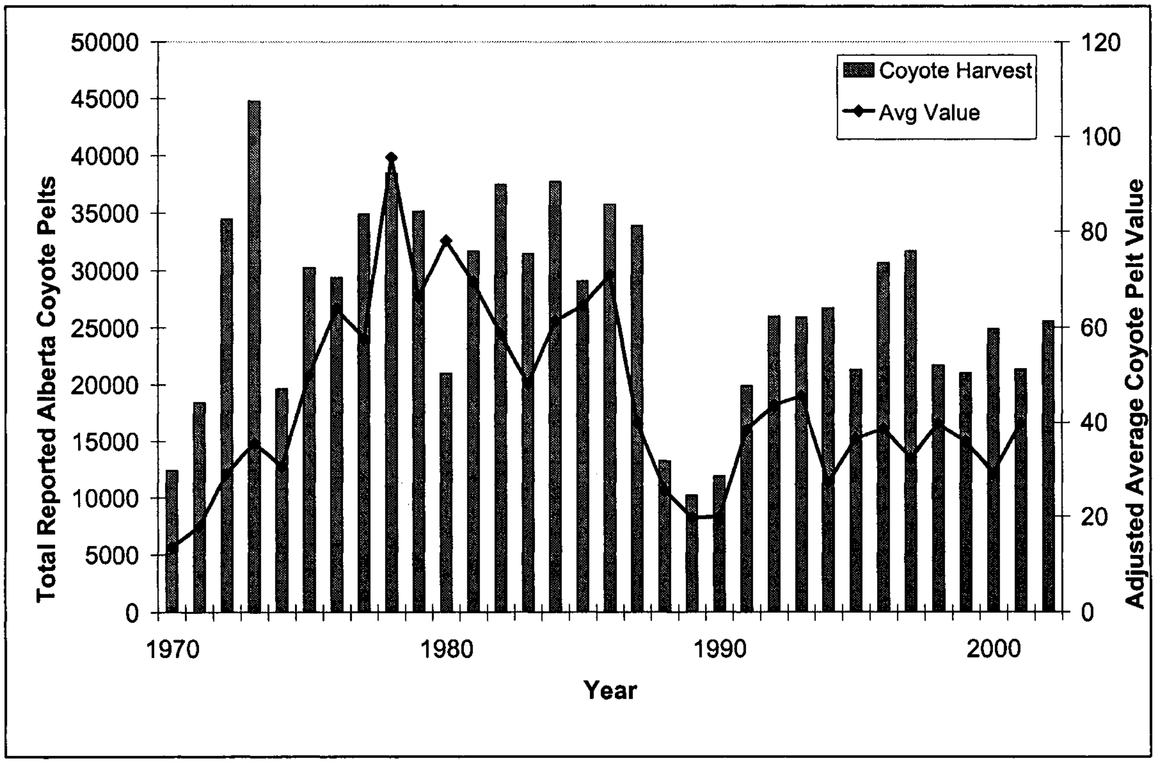
Access Feature	Average Width (m)	Range(m)
Pipeline	15	(10-40)
Powerline	10	(5-30)
Seismic lines	6	(2-9)
Roads		
Truck Trail	10	(5-30)
Road Unimproved	10	(5-30)
Road Paved-UNDIV-2L	60	(30-90)
Road Paved DIV	100	(50-150)
Road Gravel-2L	35	(20-50)
Road Gravel-1L	20	(15-35)

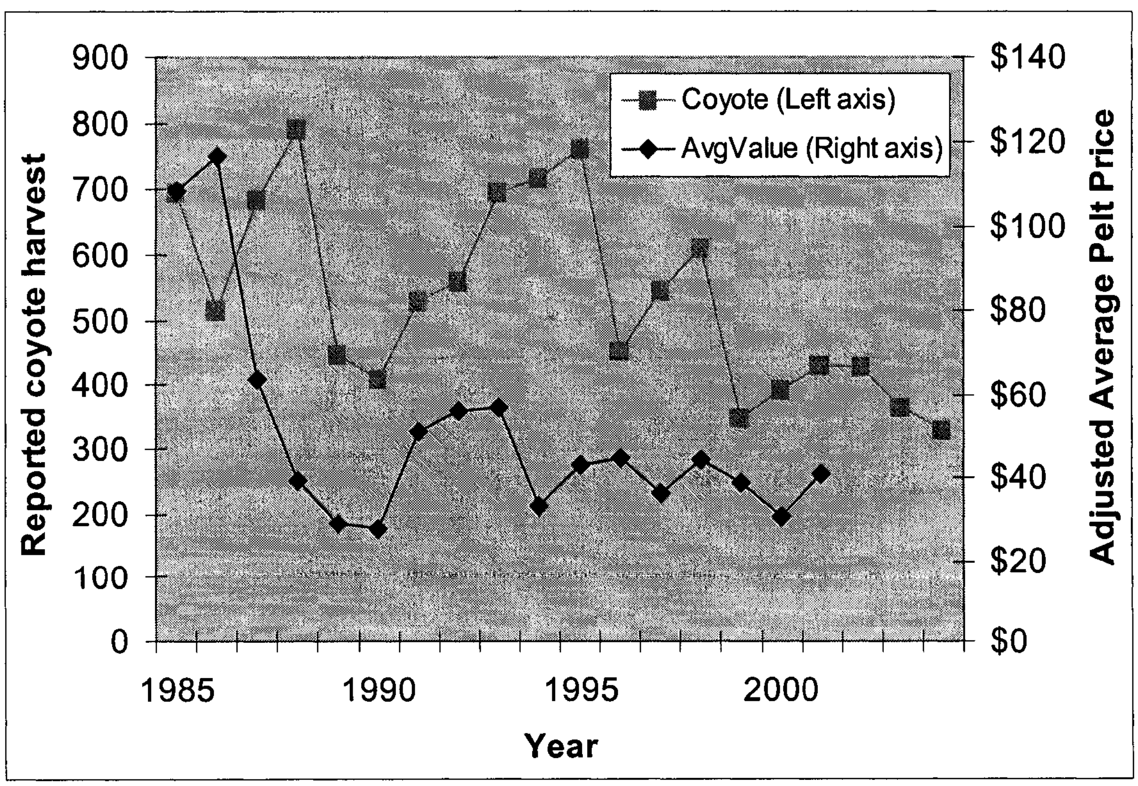
Appendix 4. Long-term lynx harvests and pelt price trends in Alberta (top) and in west-central Alberta (bottom) from 1970-2003. Note differences in the time scale. Prices are adjusted 2003 Canadian dollars.



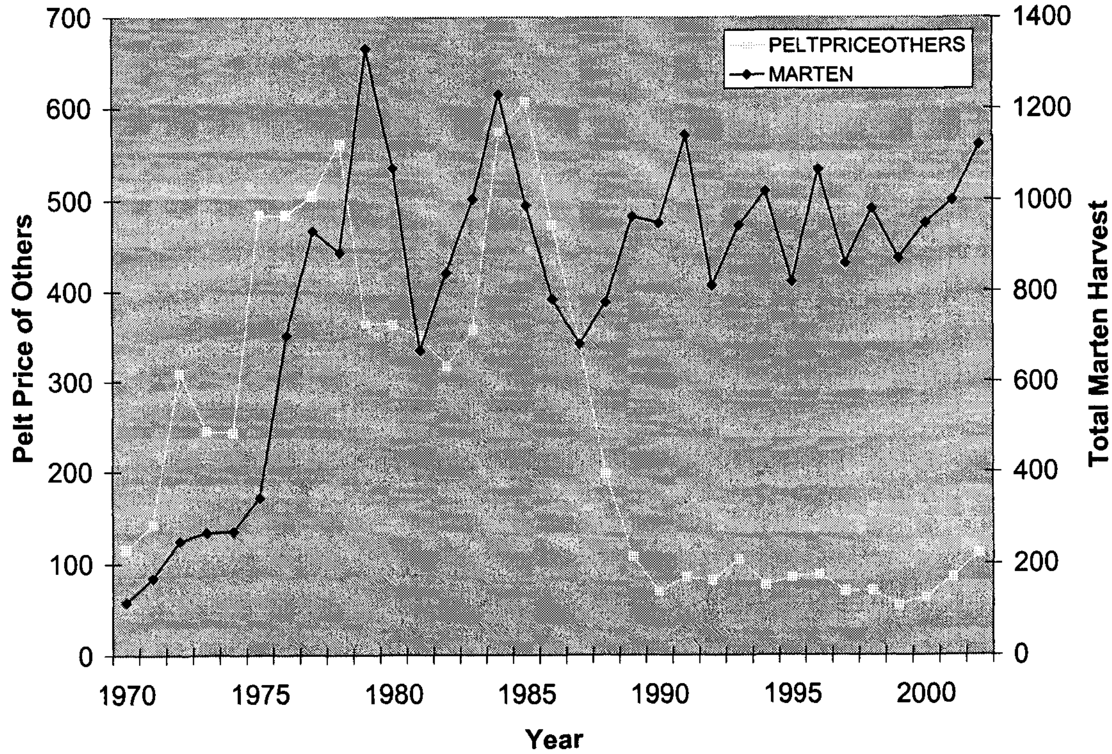


Appendix 5. Alberta (top) and study area (bottom) trends of coyote harvests and pelt values from 1970-2003. Note differences in the time scale. Prices are adjusted 2003 Canadian dollars.





Appendix 6. Provincial trends of marten harvests and average pelt value of coyote and lynx combined from 1970-2003. Prices are adjusted 2003 Canadian dollars.



Appendix 7. Provincial trends of marten, coyote, and lynx pelt value from 1970-2003. Prices are adjusted 2003 Canadian dollars.