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A Description and Analysis of Wildlife Mortality on Transportation Corridors in Jasper National Park, Canada.

by ©

Jim Bertwistle

A thesis submitted to the Faculty of Graduate Studies and Research in partial fulfillment of the requirements for the degree of Master of Science

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The undersigned certify that they have read and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled A Description and Analysis of Wildlife Mortality on Transportation Corridors in Jasper National Park, Canada submitted by Jim Bertwistle in partial fulfillment of the requirements for the degree of Master of Science in Wildlife Ecology and Management.

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ABSTRACT

Wildlife collisions with vehicles and trains are examined in Jasper National Park, Alberta. There are a variety of variables that influence collision rates ranging from age class, sex, type of wildlife, vehicle volumes, vehicle type, season, time of day and transportation category. From 1980 to 1999, collisions with wildlife averaged 149 large animals per year. For some species these collision rates are both statistically and biological significant. In addition, collisions on highways and the railway affect both local and regional wildlife populations. Using collision data as indicator of wildlife composition adjacent to transportation corridors shows changes have occurred in the wildlife composition adjacent to transportation corridors.

This thesis also includes an assessment of reduced speed zones. Reduced speed zones reduced the rate of collisions with elk and other wildlife but had a negligible affect on reducing bighorn sheep collisions. A brief description of mitigation measures that have been used in Jasper National Park is also provided including suggestions on improved mitigations.

ACHKNOWLEDGEMENTS

This thesis is dedicated to Jasper National Park Wardens. These men and women collected the data used in this thesis during the last half a century. I want to thank them for their efforts every time they, lugged, pulled, lifted, winched, shoveled and scraped roadkills off of the highways and railway in Jasper National Park.

Of particular note is Wes Bradford for ensuring that records were kept and for always stressing the importance of reducing roadkills. Paul Galbraith for his encouragement and support during the initial phase of this research. And Murray Hindle and Brian Wallace for continuing to support this research.

Last but not least my wife Patty Best. Without your patience and encouragement this thesis would not have been possible.

TABLE OF CONTENTS

List of Tables

List of Figures

CHAPTER 1

1.0 INTRODUCTION

Wildlife mortality on transportation corridors has been a recognised problem in National Parks (Damas and Smith 1982), (Poll 1989), (Woods and Munro 1996) (Shury 1996) for more than half a century (Parks Canada 1987). In Jasper National Park the Yellowhead Highway, the Canadian National Railway and a large wildlife population combine to make transportation related wildlife mortality an issue of concern.

From 1951 to 1999, (48 years) 4 143 animals have been recorded as killed by vehicles and trains in Jasper National Park. Two studies carried out in National Parks (Damas and Smith 1982, Poll 1989) estimated 18% to 30% of wildlife and vehicle collisions remain unreported. While species-specific population effects are not well understood, the impacts on wolves (*Canis lupus)* are believed to be significant (Parks Canada 2000).

Highways and railways are a source of wildlife mortality, they also cause;

- habitat fragmentation, highway and railways dissect contiguous habitat patches resulting in smaller patch sizes and higher edge to interior ratios (Andrews 1990);
- ecological stress, carnivores have certain biological traits that suggest vulnerability to highways, carnivores often exhibit ecological stress before other species (Ruediger 1996);
- disruption, highways and railways not only affect local populations but regional populations may be affected as well by disrupting animal movements (Paquet 1999) and causing direct mortality of individuals undermining the long-term viability of regional wildlife populations (Jackson 1999);

- wildlife habituation, highways and railways attract some species leading to habituation, attractants that cause habituation are varied ranging from roadside vegetation, to grain spills and carcasses resulting from collisions (Morgantini 1999).

The Yellowhead Highway and the Canadian National Railway form part of a national transportation corridor linking British Columbia with the rest of Canada. Traffic volumes on highways and the railway have increased during the last 20 years, during this period there has been a corresponding increase in wildlife collisions resulting in high rates of wildlife mortality. From 1980 to 1999 (20 years) yearly collision mortality on highways and the railway averaged 149 large animals per year. The majority of wildlife collisions on roads in Jasper National Park occur on the Yellowhead Highway. The ecological effects of this external source of wildlife mortality are not well documented.

One of the primary management goals of Jasper National Park is to protect and maintain the native biological diversity in Jasper National Park. Section 5(1)(1.2) of The National Parks Act states: "Maintenance of ecological integrity through the protection of natural resources shall be the first priority when considering park zoning and visitor use in a management plan" (Canada 1990). Parks Canada's management plan for transportation corridors states: "...corridors are managed in a way that supports Parks Canada's commitment to ecological integrity..." (Parks Canada 2000). The Canada National Parks Act defines ecological integrity as:".... a condition that is determined to be characteristic of its natural region and likely to persist, including abiotic components and the composition and abundance of native species and biological communities, rates of change and supporting processes" (Canada 1990). Parks Canada has established objectives to achieve ecological integrity. Two of the objectives are: to reduce the environmental impact of roads and the railway, including wildlife mortality caused by collisions and to maintain or to restore the compositional, structural and functional integrity of the montane (Parks Canada 2000). Wildlife is an integral part of the montane; therefore, this objective cannot be achieved without reducing vehicle and train collisions with wildlife.

1.1 PURPOSE

The purpose of this thesis is to describe, document and examine wildlife/vehicle and train collisions from 1951 to 1999 in Jasper National Park. Jasper National Park staff has accumulated a large collision database but have not analysed it. The analysis and description of this database is the first step in developing improved mitigations to reduce collisions. The extensive nature of this database also provides opportunities to analyse changes that have occurred in wildlife populations, the effects of collisions on wildlife and the relationship between traffic and wildlife collisions. In addition, because collisions with wildlife are a common problem in many other jurisdictions (Romin and Bissonette 1996), the results of this analysis are of interest to other agencies that are interested in reducing wildlife collisions.

1.2 OBJECTIVES

The objectives of this thesis are:

- to describe, document and examine wildlife collision data;
- to determine the type of highway vehicle responsible for most collisions;

- to analyse changes that have occurred in wildlife populations adjacent to transportation corridors based on collision data;
- to analyse temporal and spatial collision trends;
- to compare collisions on highways and the railway;
- to analyse collisions based on wildlife species, age class and sex;
- to assess the effect of collisions on the elk population adjacent to the Yellowhead Corridor;
- to assess mitigation that has been used to reduce collisions;
- to make recommendations to reduce collisions;
- to formulate a methodology to address the issue of wildlife mortality on transportation corridors that may be transferable to other locations and National Parks.

1.3 LITERATURE REVIEW

"The problem of wildlife/transportation mortality exists throughout Canada's National Park System, with the problem being most pronounced in the western mountain national parks" (Damas and Smith 1982). The State of the Parks Report (1997) stated: vehicle/animal collisions are causing significant ecological impacts in Jasper National Park. However, the report did not describe the extent or types of ecological impacts.

Transportation corridors can have an effect on large carnivores throughout North America. Although the literature varies with regard to the amount of displacement and other impacts, there is irrefutable evidence that roads and their associated disturbances reduce habitat effectiveness resulting in reduced fitness and increased risk of mortality (Diamondback 1990).

Ruediger (1996) stated the extirpation of carnivores in the lower 48 states is partially a factor of highway densities. Carnivores are particularly susceptible to highway mortality because of low biological productivity and the large areas required to sustain populations and individuals. Direct mortality is common. Wolf mortality caused by vehicle collisions has been reported in locales as diverse as Alberta, Idaho, Israel, Minnesota, Montana, Ontario, Wisconsin, and the Greater Yellowstone Ecosystem (Jalkotzy *et al.* 1997).

Highways could have an increasingly adverse effect on some black bear populations (Gilbert 1996). In British Columbia, black bears are the most frequent roadkills in the Columbia Valley (Woods and Harris 1989, Woods & Munro 1996). In Florida, black bear roadkills have increased since the 1970s. Highways provide a formidable impact to wildlife, particularly rare, wide-ranging carnivores (Ruediger 1998)

The effect of transportation corridors and the associated wildlife mortality on ungulates is also well documented. Romin and Bissonette (1996) estimated that at least 538 000 deer were killed along highways during 1991 in the United States of America.

In Florida, human-related mortality, primarily roadkills, is the greatest known source of key deer (*Odocoileus virginianus)* mortality (75-80% of all known deaths) (Hardin 1974, Silvy 1975, Drummond 1989). The Vermont Department of Transportation (unpublished data 1992) recorded 24,884 deer-vehicle accidents between 1981 and 1991; property damage occurred in 94% (n=23 285) of the collisions for a total estimated property damage of $31,141,777 or $1,881/accident. Additionally, vehicle collisions with wildlife cause an estimated 120 human deaths per year in the United States of America (Nationwide Insurance 1993).

In Newfoundland, 5 422 moose-vehicle collisions occurred between 1988 and 1994, resulting in 14 human and 4 800 moose fatalities (Joyce and Mahoney 2001). The yearly economic losses in initial health care are estimated at $500 000 and $2.25 million in vehicle damage (Newfoundland Wildlife Division 2000).

In Alberta, yearly collisions with animals increased 51% from 5 997 collisions in 1991 to 9 077 collisions in 1999. Alberta Infrastructure does not differentiate between animal collisions with wildlife and domestic animals. Human fatalities during this period averaged five deaths per year (Owens L. 2001 Pers comm.).

Vehicle and train collisions with small mammals and birds are generally poorly documented (Woods and Harris 1989). A notable exception is the mortality of pine siskins (*Carduelis pinus)* on the Trans Canada Highway during invasion winters in the Columbia Mountains (Van Tighem and Gyug 1984). At these times thousands of birds may be attracted to the road surface by salt and sand and hundreds may be killed by a single passing vehicle (Woods and Munro 1996). High mortality of the Florida Scrub Jay (*Aphelocoma coerulescens)* appeared to be a direct result of automobile traffic along a two-lane highway at Archbold Biological Station in Florida. Mortality was especially high for immigrants without previous experience living along the road (Mumme R. L. *et al.* 1995). In Banff National Park, Clevenger *et al.* (2001) recorded 183 tiger salamanders (*Ambystoma tigrinum*) killed during 1998 over an 8-day period on a 300-metre section of the Trans-Canada Highway.

Damas and Smith (1982) developed the following standards to estimate the effect of transportation related wildlife mortality in National Parks:

- significant- Average annual transportation mortality exceeds 50% of the population's estimated annual productivity;
- contributory- 25-49% of annual productivity;
- minor- Less than 25% of annual productivity;
- unknown- insufficient data for estimation.

Damas and Smith (1982) estimated the effects on eight species in Banff National Park (Table 1) and Jasper National Park (Table 2). This was based on 1 191 transportation related wildlife mortalities in Banff National Park from 1970 to 1980 and on 868 in Jasper National Park from 1970 to 1980. Damas and Smith (1982) listed the following major factors that influenced higher rates of highway mortality in Jasper National Park:

- fall concentrations of elk adjacent to highway corridors;
- possible use of road side vegetation by mule deer during the spring;
- bighorn sheep attraction to road salt on highways;
- general movements of moose close to roads;
- attraction of bears to the landfill adjacent to the highway and railway.

In Jasper National Park, highway and railway mortality accounted for 68% of ungulate mortality from 1945 to 1980 (n=2153) (Parks Canada 1987). Poll (1989) reviewed wildlife collisions on Highway 93 in Kootenay National Park and found that identifying the impact of mortality on large mammal populations was complicated by a lack of knowledge of the status and populations of most species. However, elk mortality caused by collisions was considered contributory to the observed decline in the park elk population.

Table 1. Estimated effect of wildlife collisions in Banff National Park 1970-1980 from Damas and Smith (1982)

Species	**Significant**	**Contributory**	**Minor**	**Unknown**
Elk (*Cervus elaphus*)	X			
Mule deer (*Odocoileus hemionus*)	X			
Bighorn sheep (*Ovis canadensis*)	X			
Moose (*Alces alces*)	X			
Whitetail deer (*Odocoileus virginianus*)				X
Black bear (*Ursus americanus*)			X	
Grizzly bear (*Ursus arctos*)			X	
Coyote (*Canis latrans*)			X	

Table 2. Estimated effect of wildlife collisions in Jasper National Park 1970-1980 from Damas and Smith (1982)

Species	**Significant**	**Contributory**	**Minor**	**Unknown**
Elk	X			
Mule deer				X
Bighorn sheep (*)	X	X	X	
Moose	X			
Whitetail deer				X
Black bear				X
Grizzly bear				X
Coyote			X	

** (7 herds in the Main Athabasca Valley) significant, contributory, and minor, depending on the specific population.*

Shury (1996) completed a summary of wildlife mortality from 1981 to 1995 in Banff National Park. Based on 2 815 wildlife mortalities the greatest contributor to mortality was motor vehicle collisions. Predation and train collisions are also important causes of ungulate mortality, while highway collisions are the major cause of carnivore mortality. Wildlife road and rail kills are frequent throughout the Rocky Mountains on the Trans-

Canada Highway and are the best-documented conflict between transportation developments and wildlife (Woods and Munro 1996).

Highways and railways are sources of mortality that threaten wildlife populations. They also have the potential to undermine ecological process through fragmentation of wildlife population, restrictions of wildlife movement and the disruption of gene flow (Jackson 1999).

1.4 STUDY AREA

Jasper National Park (Fig.1) is located in the West-Central portion of the province of Alberta, Canada. The Park was established in 1907, and is the largest (11 220 square/kilometres) and most northerly of the four contiguous Canadian Rocky Mountain National Parks (Jasper, Banff, Kootenay and Yoho). These parks were collectively designated as a world heritage site in 1984 (Parks Canada 1988).

Jasper National Park is situated within the Continental Ranges of the Central Rocky Mountains, Eastern System of the Cordillera Region (Bostock 1967). The main ranges of the Canadian Rockies run along the West Side of Jasper National Park, with the front ranges along the East Side. The topography is mountainous with characteristic steep slopes and deep valleys (Parks Canada 1987).

Holland and Coen (1982) described Jasper National Park as having three ecoregions: the montane, the subalpine and the alpine. The montane ecoregion ranges from 1 000 metres elevation to approximately 1 350 metres with Douglas Fir (*Pseudotsuga menziesii)*, white spruce (*Picea glauca)*, and aspen (*Populus tremuloides)* as the dominant vegetation. The subalpine ecoregion extends from the upper montane to treeline (approximately at 1 900 metres in elevation). Predominant subalpine vegetation is

Engelmann spruce (*Picea engelmannii)*, subalpine fir (*Abies lasiocarpa)* and lodgepole pine (*Pinus contorta)*.

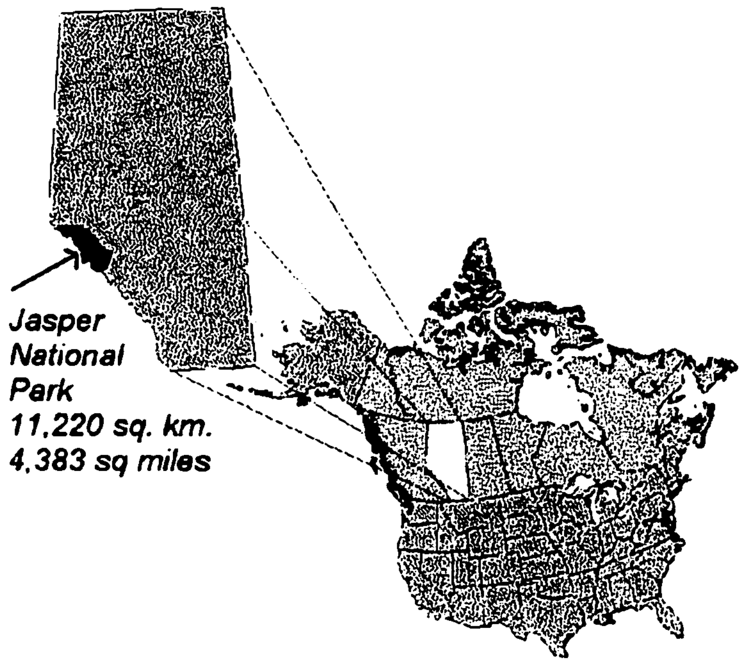

Figure 1. Jasper National Park

The alpine ecoregion occurs above the subalpine ecoregion and is dominated by yellow heather (*Phyllodoce glanduliflora)* and White Mountain heather (*Cassiope mertensiana)*. The subalpine ecoregion comprises 48.95% of the total Park area followed by the montane at 6.98% and the alpine at 5.66%. The remainder of the park (38.41%) is non-vegetated and is comprised mainly of rock landscapes.

The focus of the study area is The Yellowhead Corridor, which runs through the centre of Jasper National Park cutting through the montane ecoregion (Fig.2). The Yellowhead

Highway and the Canadian National Railway are each located within the Athabasca and Miette River valleys and together make up the Yellowhead Corridor. The Yellowhead Corridor makes up less than 1% of the total area of Jasper National Park but cuts through prime wildlife habitat in the montane ecoregion. The montane ecoregion encompasses a relatively small area, (7% of Jasper National Park), but is the most biologically diverse ecoregion in Jasper National Park (Parks Canada 2000). Consequently, the effect of the Yellowhead Corridor on wildlife is magnified because:

- the Yellowhead Corridor is located in prime wildlife habitat;
- the Yellowhead Corridor cuts through the centre of Jasper National Park and wildlife must cross the corridor to utilise habitat on each side of the corridor;
- the Yellowhead Corridor receives the highest level of human use in the park;

1.5 TRANSPORATATION NETWORK

1.5.1 The Yellowhead Corridor

The Yellowhead Corridor is made up of the Yellowhead Highway and the Canadian National Railway. The Yellowhead Corridor is one of two national transportation corridors connecting British Columbia to the rest of Canada (Parks Canada 2000). The second corridor is in Banff National Park 250 kilometres south of The Yellowhead Corridor. The Banff Corridor is made up of the Trans-Canada Highway and the Canadian Pacific Railway. Most of the Trans-Canada Highway in Banff National Park is twinned, where twinning occurs fencing mitigates wildlife collisions with large animals.

The Yellowhead Highway is located on the south side of the Athabasca and Miette Rivers and the railway is located on the north side of these two rivers (Fig. 2). Highway traffic volumes doubled from 1973 to 1997 to 1.2 million vehicles per year. Seventy-five percent of highway traffic does not stop in the park, but uses the Yellowhead Highway as a transportation link to other areas (Parks Canada 2000). Virtually all transport truck traffic uses the Yellowhead Highway for this purpose. This type of traffic is called through-traffic. Through-traffic drivers are not required to purchase a park pass.

Railway volumes average 33 trains per day, 97% of train traffic is freight trains the remainder is passenger trains. The average freight train length is 1 800 metres (Stenvold 1999). A minimum of 73% of collisions occurs on the Yellowhead Highway and the Canadian National Railway. Because 75% of highway traffic and all train traffic is through-traffic, it is probable that the majority of wildlife collisions are caused by through-traffic.

1.5.2 The Yellowhead Highway

The Yellowhead Highway extends from Winnipeg, Manitoba to Prince Rupert, British Columbia. The Jasper National Park portion of the highway is 77 kilometres in length, entering Jasper National Park at the East Boundary and exiting at the West Boundary (Fig.2). Eighty seven percent of all Jasper National Park traffic volumes are on the Yellowhead Highway. In 1997, Yellowhead Highway traffic volumes reached 1.2 million vehicles per year (Parks Canada 2000).

The Yellowhead Highway was upgraded (paved) to an all-weather road in 1966. From 1970 to 1978 the posted speed limit was 100 kilometres per hour. The current Yellowhead Highway is two lanes with a posted speed of 90 kilometres per hour. Traffic lane widths are 3.7 meters with 3 additional meters of shoulder. Good visibility exists along most of the highway with horizontal curvature described as excellent and a high percentage of the highway has passing sight distance available (Damas and Smith 1982). The number of vehicles on the Yellowhead Highway has increased by 3% annually since 1973 (Parks Canada 2000). In 1991, three, slow-down-for-wildlife zones were installed on the Yellowhead Highway, reducing the posted speed limit to 70 kilometres per hour. The length of reduced speed zones is 15.5 kilometres or 22% of the total highway length.

1.5.3 The Canadian National Railway

Information on Canadian National Railway volumes was provided by the Canadian National Railway for the year 1998. The Canadian National Railway is the main northern railway across Western Canada connecting British Columbia to the rest of Canada. The Grand Trunk Railway was constructed through Jasper National Park in 1911 and became part of the Canadian National Railway sometime between 1918 and 1923 (Stenvold 1999). In 1981, the Canadian National Railway was upgraded to a twin track. The Jasper National Park portion of the Canadian National Railway is 75.5 kilometres in length, entering at the East Boundary and exiting at the West Boundary (Fig.2).

In 1998, 11 900 freight and 331 passenger trains passed through Jasper National Park or an average of 33 trains per day. Train traffic is evenly spread from month to month. Freight train speed zones range from 40 kilometres per hour to 88 kilometres per hour (Stenvold 1999). Train speeds are monitored by railway staff using three methods: conventional traffic radar, monitoring train movement between signal locations and event recorders on locomotives (Pimblett 2000).

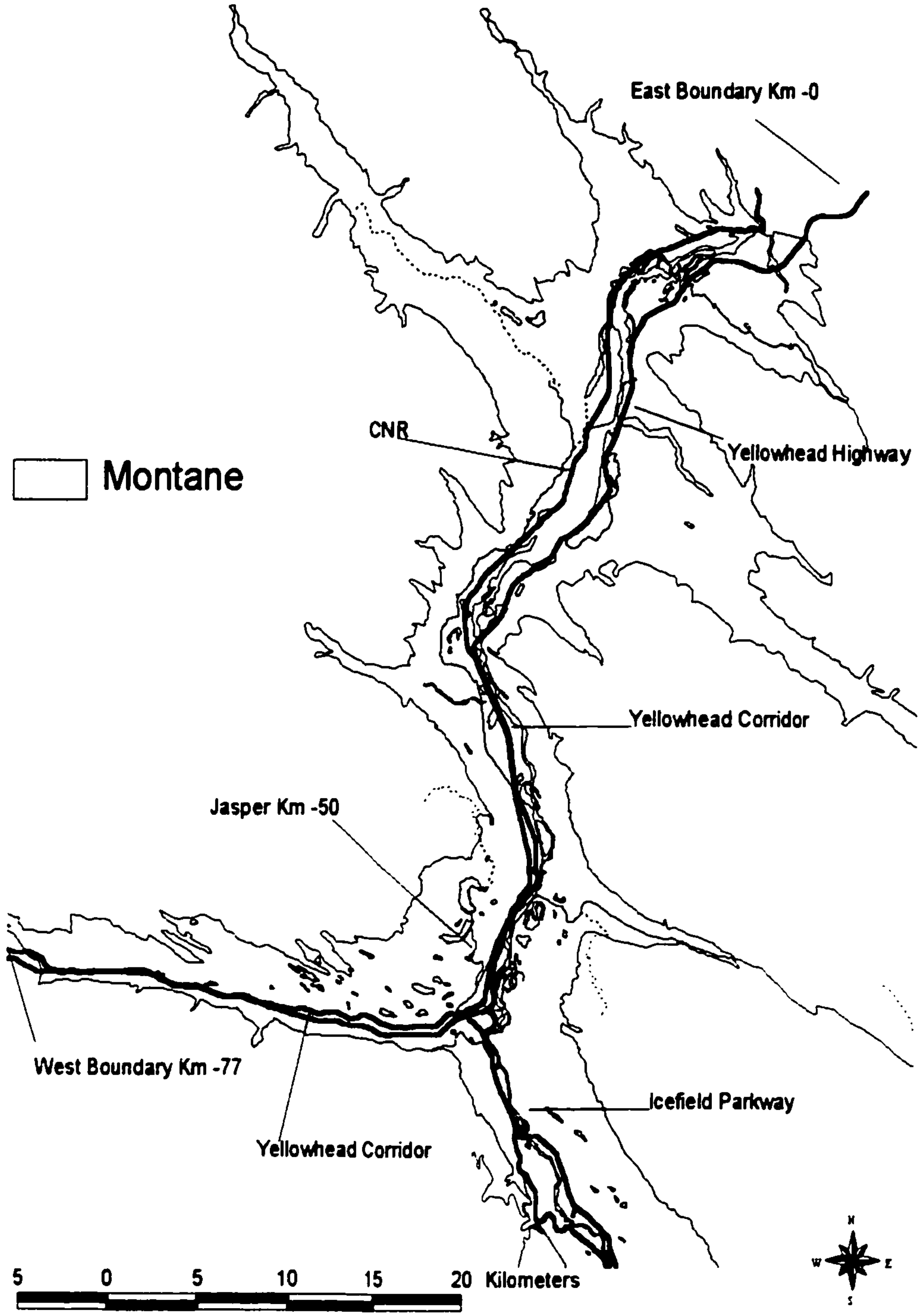

Figure 2. The Yellowhead Corridor

1.5.4 Other Roads in Jasper National Park

In addition to the Yellowhead Highway there are 258 kilometres of roads in Jasper National Park: the Maligne Lake Road (46 kilometres), the Miette Hotsprings Road (17 kilometres), the Icefield Parkway (105 kilometres) and secondary roads (90 kilometres) (Jasper National Park Management Plan 2000). The Icefield Parkway and the Yellowhead Highway are the only through roads in Jasper National Park. The Icefield Parkway has a commercial vehicle weight restriction of 4.5 tonnes, which excludes transport trucks with the exception of trucks making local deliveries. From 1973 to1997 Jasper National Park traffic volumes increased 100% from 600,000 to 1.2 million vehicles per year (Fig.3). Sixty-five percent of traffic volume occurs during a five-month period from May to September (Fig.4).

1.5.5 Yellowhead Highway Traffic Profile.

Seventy-percent of wildlife collisions in Jasper National Park occurs on the Yellowhead Highway. Therefore, a more complete description of traffic data on the Yellowhead Highway is presented.

The majority of vehicles travelling on the Yellowhead Highway are passenger vehicles. From September 18, 1994 to August 23, 1995, passenger vehicles accounted for 80% (747 944 vehicles), transport trucks 12% (110 198 vehicles), mid-sized vehicles 5% (5^{th} wheel trailers, small trucks, and motor-homes, 45 142 vehicles) and buses 3% (24 789 vehicles) of vehicles travelling on the Yellowhead Highway (Fig.5). Transport truck traffic is seasonally consistent relative to passenger vehicles however transport truck volumes fluctuate from a high of 14 000 to a low of 9 000 trucks per month (Fig. 6). Temporal differences between transport truck and passenger vehicle volumes also occur daily and hourly (Fig. 7 and Fig.8).

Data collected during August 1995 and September 1994 is incomplete, (7 days in August and 13 days in September are missing) consequently, daily totals for August and September were averaged and extrapolated to compensate for missing data.

From September 18, 1994 to August 23,1995, 78% (681 614 vehicles) of passenger vehicles and 81% (107 345) of transport trucks exceeded the posted speed limit of 90 kilometres per hour (Fig. 9).

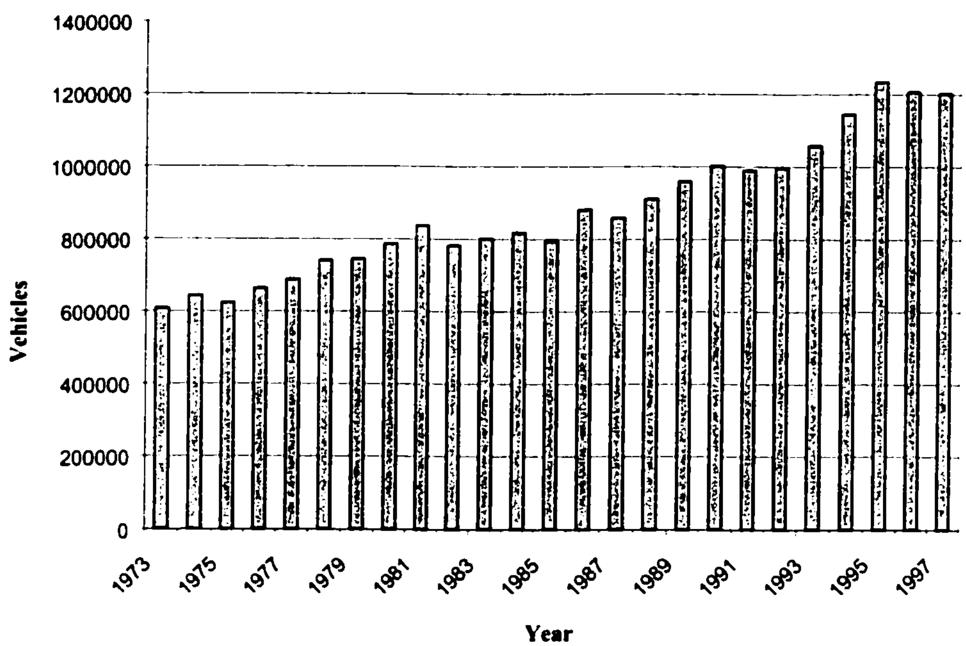

Figure 3. Traffic volumes Jasper National Park 1973-1997

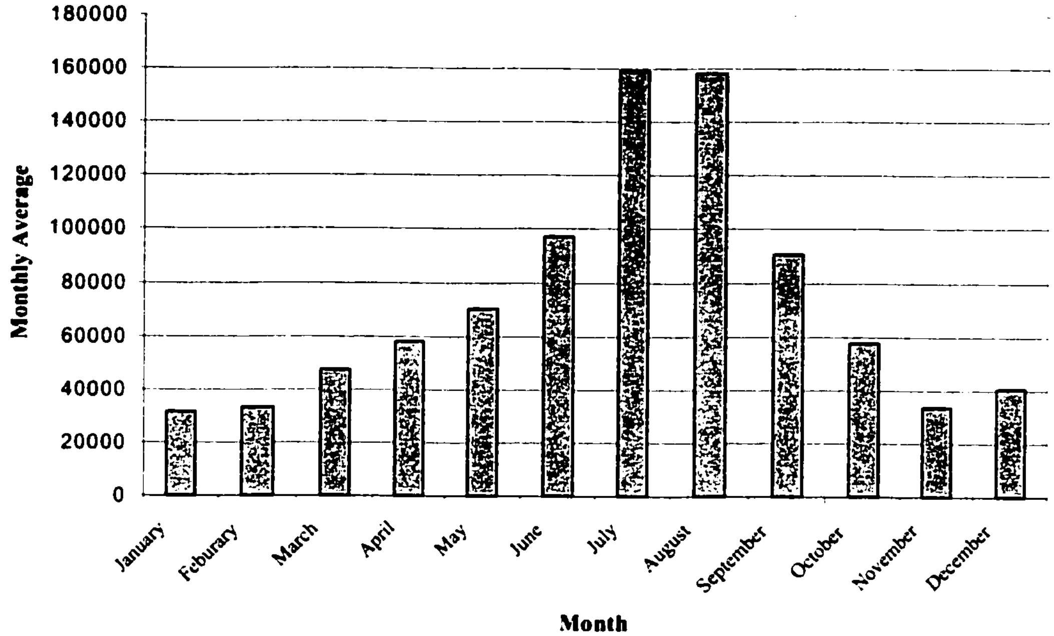

Figure 4. Average number of vehicles per month in Jasper National Park, 1973-1997

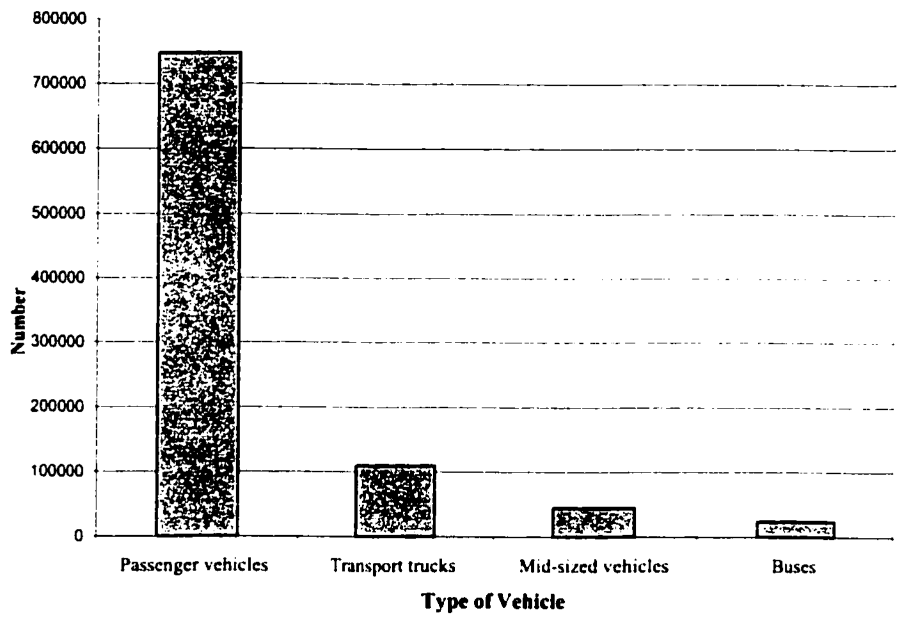

Figure 5. Breakdown of traffic types on the Yellowhead Highway, Sept/18/94-Aug/23/95

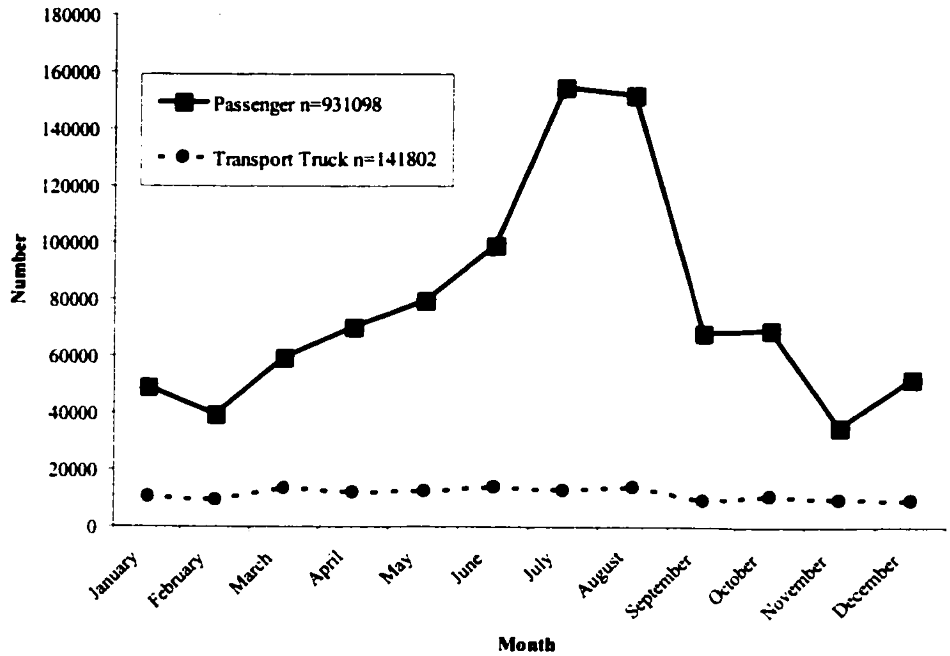

Figure 6. Monthly passenger & transport truck vehicle volumes on the Yellowhead Highway, Sept/01/94-Aug/31/95

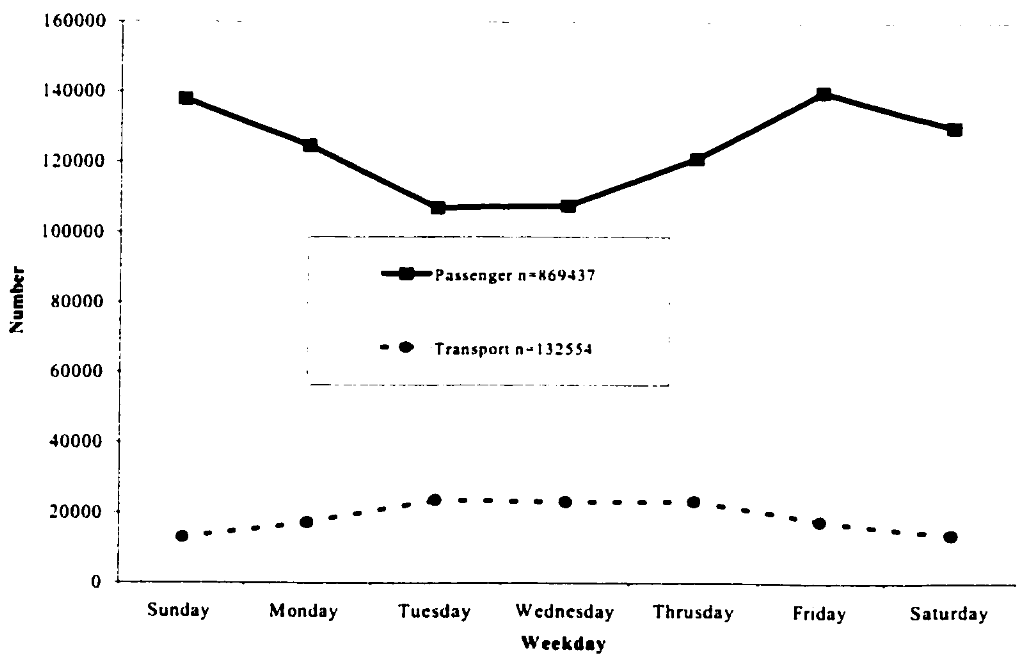

Figure 7. Daily passenger vehicle and transport truck volumes on the Yellowhead Highway, Sept/18/94-Aug/23/95

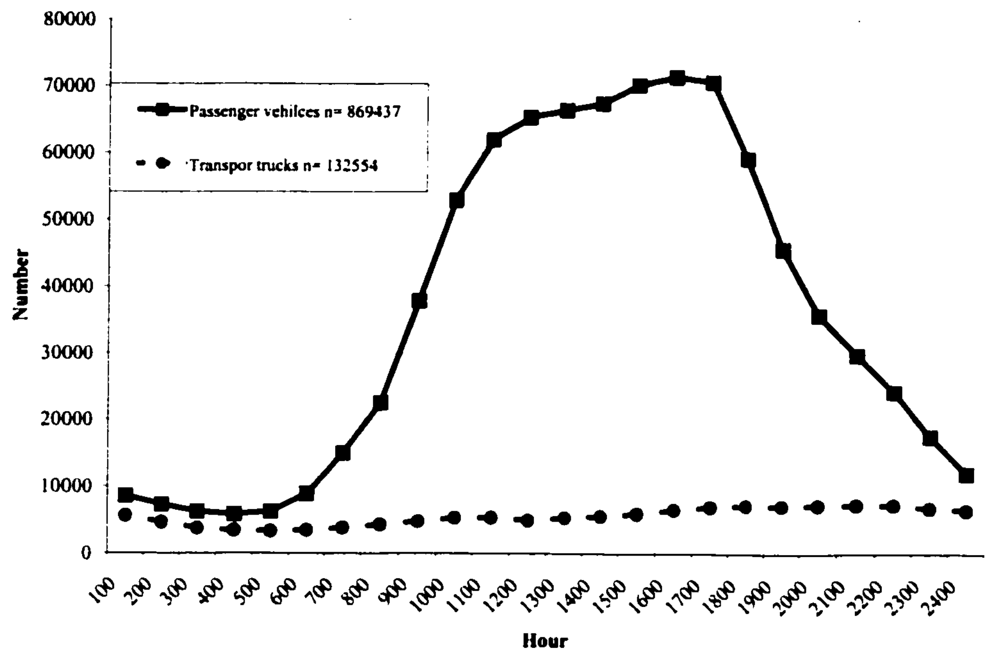

Figure 8. Hourly passenger vehicle and transport trucks volumes on the Yellowhead Highway, Sept/18/94-Aug/23/95

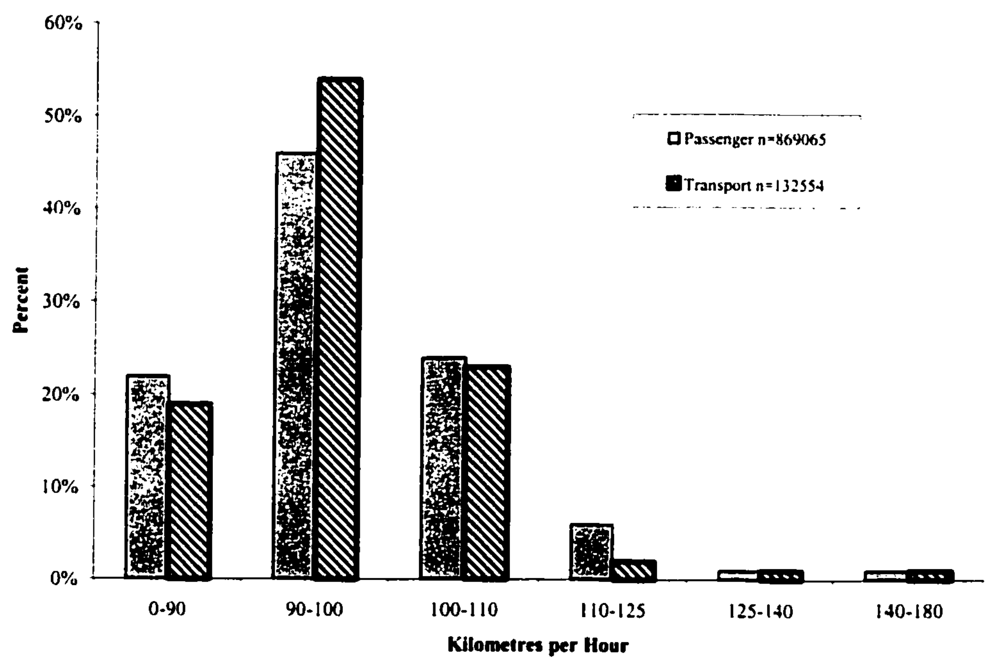

Figure 9. Average passenger vehicle and transport trucks speeds in a 90 kilometre per hour area, Yellowhead Highway, Sep/17/94-Aug/24/95

1.6 JASPER NATIONAL PARK WILDLIFE

The wildlife of Jasper National Park is a complex array of mammals, birds, amphibians, reptiles and fish whose numbers and diversity are reflective of the park's evolutionary and ecological past, and the diversity of habitats within the park (Parks Canada 1987). Soper (1970) noted that wildlife environments and distribution in the park are strongly effected by the region's physiography. Vegetation, habitats, seasons and climate vary with altitude. Consequently, to describe park wildlife Soper (1970) suggested the use of faunal life zones. Four life zones have been identified in Alberta: the Transitional, the Canadian, the Hudsonian and the Arctic-Alpine. The last three zones are present in Jasper National Park.

Parks Canada (1987) completed a wildlife description of these life zones in Jasper National Park. The Canadian life zone occupies the lowlands, hills and benches of the park between 915 and 1 281 metres in altitude. It is rich in both plant and animal life and provides suitable habitat for most of the park's carnivores and ungulates. Typical Canadian zone large mammals are elk, bighorn sheep, mule deer, whitetail deer, moose, mountain goat (*Oreamnos americanus*) coyotes, wolves, black bear, and lynx (*Lynx canadensis*). The Yellowhead Highway and the Canadian National Railway are each within this life zone. The Hudsonian life-zone lies roughly between altitudes of 1 281 metres and 2 135 metres. Typical Hudsonian zone large mammals are wolves, grizzly bear, wolverine (*Gulo gulo*), bighorn sheep and mountain goat. The Arctic-Alpine life lies entirely above tree line. Few mammals are confined to this zone and most of those found here utilise life zones at lower elevations. Typical Arctic-Alpine zone large mammals are grizzly bear, wolves, wolverine, bighorn sheep, mountain goat, and caribou (*Rangifer tarandus*).

CHAPTER 2

2.0 METHODS

This thesis is based on data collected from 1951 to 1999. However, the majority (82%) of wildlife collisions recorded are from 1980 to 1999. The analysis of data is limited to the main species involved in collisions, namely: elk, bighorn sheep, mule deer, whitetail deer, moose, wolves, coyotes, black bears and grizzly bears.

When a wildlife collision is reported or found by the Warden Service, the animal is removed and the information is recorded on a Warden Service occurrence report. During the early part of the study period, this information was stored on the Canadian Soils Inventory System (CanSIS) and mortality reports. The preparation of this thesis included the transfer of CanSIS and mortality information to a digital wildlife mortality database. Each digital record contains the following information: collision number, date, time, map location, cause of mortality (vehicle or train), vehicle type, species, total number of animals per collision, age, sex class, common location name, and a Yellowhead Highway and Canadian National Railway block location. Some records do not contain complete information. The mortality database used in this thesis contains 3 399 records.

In 1999 a map of the Yellowhead Highway and Canadian National Railway was segmented into 500-meter blocks and plotted on a Geographic Information System. This was done to assess the distribution of collisions on the Yellowhead Highway and Canadian National Railway. The Yellowhead Highway contains 154 blocks (77 kilometres.) and the Canadian National Railway contains 151 blocks (75.5 kilometres). Collision locations were plotted based on field recordings using Universal Transvererse Mercator Grid (U.T.M) maps at a scale of 1-50,000, with an accuracy of 100 meters (plus or minus).

2.1 STUDY QUESTIONS

The following eight study questions guided this thesis:

Study Question 1. Do passenger vehicle and transport truck collision rates correspond to proportional volumes of each vehicle type?

Study Question 2. During the study period have changes in species composition occurred adjacent to transportation corridors?

Study Question 3. Are monthly vehicle volumes a significant factor in the number of monthly wildlife collisions?

Study Question 4. Is there a significant association between transportation category (highways or railway) and wildlife collisions?

Study Question 5. Is there a significant association between transportation category and sex of wildlife?

Study Question 6. Does transportation category influence collision rates based on age class of wildlife?

Study Question 7. Have collisions with elk significantly affected the number of elk counted adjacent to the Yellowhead Highway and the Canadian National Railway?

Study Question 8. Have reduced speed zones been effective in reducing wildlife collisions?

2.2 STUDY LIMITATIONS

The analysis of wildlife collisions is limited to the main ungulate and carnivore species involved in collisions. Current species population estimates are only available for elk. Elk survey information used in this analysis was collected from 1983 to 1998.

Smaller species such as birds, smaller mammals, amphibians and reptiles are not recorded as frequently as larger species. It is probable that the recording of these species does not accurately represent the frequency of collisions with these species. This may be a result of a number of factors such as, lack of recorder effort, failure to report collisions (smaller species do not cause significant damage to vehicles and motorists may not report these collisions) and smaller species are quickly removed by scavengers.

The recording of daily collision times on the railway may not be as accurate as recorded collision times on highways. Recovery of carcasses is logistically more difficult on the railway than on highways because the Warden Service does not have easy access to all areas of the railway. If an animal is reported as a railway collision in the evening in an area not easily accessible, it is not removed until the next morning. In some of these cases, the time is recorded when the carcass is removed versus the actual collision time. In addition, carcasses located off the highway and the railway surface are less visible during lowlight periods and at night. Therefore, some collisions recorded during the morning (0800 to 1200 hours) may be incorrectly recorded as the time the collision was reported or the carcass picked up by the Warden Service rather than the actual collision time.

Spatial information in this thesis is confined to the Yellowhead Highway and Canadian National Railway because:

- the majority (73%) of collisions occur on the Yellowhead Highway and the Canadian National Railway;

- seventy-five percent of the montane landscape in Jasper National Park is adjacent to the Yellowhead Highway and the Canadian National Railway;
- maintaining and restoring the montane is a park management objective;
- the Yellowhead Highway and the Canadian National Railway receives the highest levels of use;
- increasing use of the Yellowhead Highway will create demands to upgrade the highway.

Each dot on the collision location maps may represent more than one collision. Because of the high number of collisions, plotting each collision would require a smaller scale and could not be concisely presented in the text of this thesis. Consequently, collisions per kilometre are also charted in a cross section view and presented in a Table format. The analysis of non-spatial information (temporal, species etc.) is taken from all recorded collisions.

Traffic profile information is based on one year's data collected during 1995 on the Yellowhead Highway. The description of vehicle traffic is limited to passenger vehicles and transport trucks because other traffic types (mid-sized vehicles and buses) comprise less than 1% of wildlife collisions (n=1 103) when the vehicle type was determined.

CHAPTER 3

3.0 RESULTS

3.1 TYPE OF VEHCILE INVOLVED IN A WILDLIFE COLLISION

Passenger vehicles and transport trucks are the most frequent vehicles involved in wildlife collisions. During the study period, other vehicles such as mid-sized vehicles and buses, were responsible for less than 1% of collisions. For the purpose of this study, vehicle types are divided into 3 categories: passenger vehicles, transport trucks and undetermined vehicles. When an unreported collision occurs and the animal is found by the Warden Service, an attempt is made to determine vehicle type by on-site investigation. Tire marks and grill pieces are assessed and if enough information is gathered a determination of vehicle type is made.

3.1.1 Study Question 1. Do passenger vehicle and transport truck collision rates correspond to proportional volumes of each vehicle type?

Passenger vehicles accounted for 80% and transport trucks 12% of vehicles travelling on the Yellowhead Highway from September 1,1994 to August 31,1995. During this period passenger vehicles accounted for 48, transport trucks for 48, and undetermined vehicles for 43 wildlife collisions (n=139) (Table 3).

Table 3. Proportion of vehicle volumes and number of wildlife collisions September 1,1994 to August 31,1995

Vehicle type	**Proportion of vehicle volume**	**Proportion of collisions**	**Number of wildlife killed**
Passenger vehicles	80%	34%	48
Transport trucks	12%	34%	48
Undetermined	-	31%	43
Total	-	99%	139

When the vehicle type was determined there was 1 wildlife collision every 18 113 passenger vehicles and 1 wildlife collision every 2 716 transport trucks. During this period, passenger vehicle and transport truck collision rates did not correspond to proportional volumes of each vehicle type. Transport trucks accounted for a greater number of collisions relative to transport truck volumes. Additionally, passenger vehicles accounted for a lesser number of collisions relative to passenger vehicle volumes.

Because transport trucks and passenger vehicles accounted for 99% of determined vehicles involved in a collision it is reasonable to conclude that undetermined vehicles are either a transport truck or a passenger vehicle. From 1980 to 1999, the number of highway collisions in each vehicle category was, 552 passenger vehicles, 329 transport trucks and 1130 undetermined vehicles (n=2011). During this period passenger vehicles accounted for 62% and transport trucks for 37% of determined collisions (n=881).

3.1.2 Discussion

Differences in the speed of transport trucks and passenger vehicles are likely not a factor in higher transport truck collision rates because the speed of transport trucks and passenger vehicles is similar. Average vehicle speed data collected in a 90 kilometre per hour area during 1995 shows the average speed of passenger vehicles and transport trucks is similar (Fig. 9).

Stopping distances increase as vehicle speed increases increasing the distance and time it takes for a vehicle to stop (Sowers 2000). The reasons for disproportional greater collision rates for transport trucks are probably related to the general design of transport trucks compared to passenger vehicles. Based on identical road conditions the stopping distance of a transport truck travelling at 100 kilometres per hour is 86 metres compared to the stopping distance of a passenger vehicle travelling at the same speed which is 56 metres (Sowers 2000). The main reasons for this difference is weight shift and brake lag. Weight shift occurs when the brakes are applied and brake lag occurs in transport trucks between the time the brakes are applied and when they actually lock up. The weight shift and brake lag on transport trucks is greater than passenger vehicles because of the general design of transport trucks (Sowers 2000). Consequently, transport truck drivers are less able to avoid collisions compared to passenger vehicle drivers because of the greater stopping distance and time required to stop a transport truck.

The data shows a relationship between traffic volumes and collisions however, predicting collisions based on traffic volumes should include an analysis of traffic type and should not be based entirely on total traffic volumes.

3.2 WILDLIFE INVOLVED IN COLLISIONS

From 1951 to 1999, 3 984 large animals (main species) and 159 other species were recorded as killed in collisions with vehicles and trains in Jasper National Park. This does not include animals involved in collisions that are not reported or found. Ungulates make up 90% of the main species recorded in collisions (Fig.10). Eight-two percent of collisions occurred from 1980 to 1999. The average yearly mortality during this period was 149 animals per year (Fig. 11). Seventy percent of collisions occurred on highways and 30% occurred on the Canadian National Railway. Three thousand and twenty six or 73% of all confirmed wildlife collision locations occur on the Yellowhead Highway or the Canadian National Railway.

Yearly collisions on highways and the railway show similar trends with the exception of the 1990's when highway collisions decreased and railway collisions stabilised. In 1966, the Yellowhead Highway was paved and collisions began to show an upward trend. In 1981, a second track was added to the Canadian National Railway and collisions also began to show an upward trend. The decrease in highway collisions during 1975 was likely an indirect affect of a record high snowfall during the 1973/74 winter which caused high levels of ungulate winter kill, reducing the number of animals adjacent to transportation corridors during the following year.

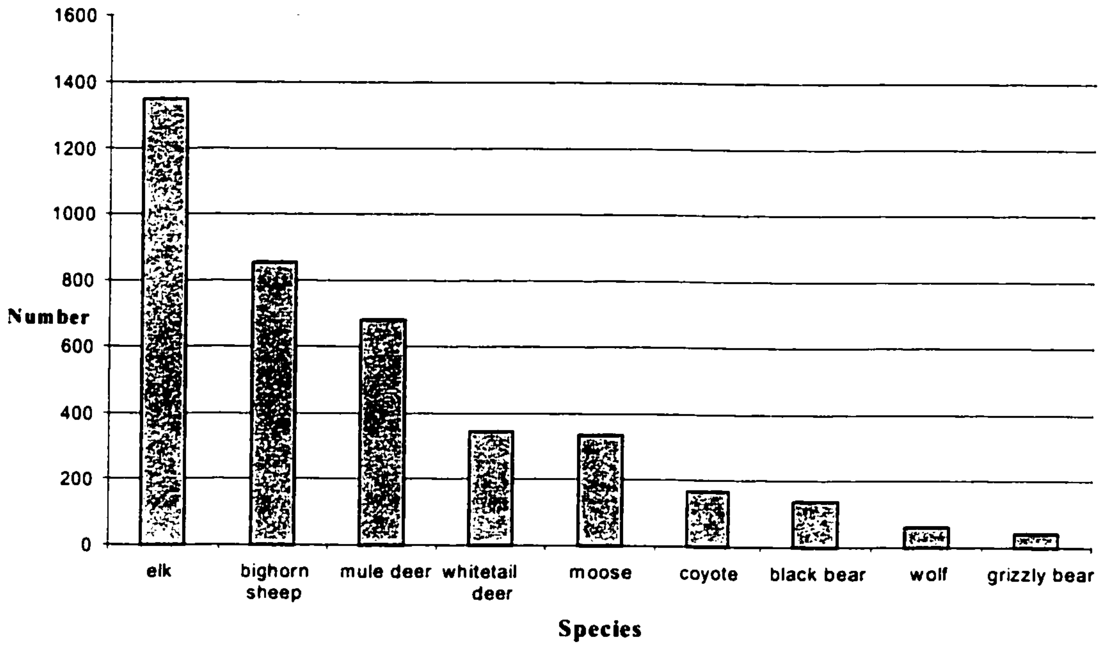

Figure 10. The main wildlife species involved in collisions 1951 to 1999

The main large animal species involved in collisions are elk (32.7%), bighorn sheep (20.7%), mule deer (16.5%), whitetail deer (8.3%), moose (8.1%), coyote (4.0%), black bear (3.3%), wolf (1.5%) and grizzly bear (1.0%). These species have been involved in 96% (n= 4143) of all collisions. The analysis of wildlife collisions is limited to these species. Wildlife collision data presented in this section is influenced by elk and bighorn sheep collisions because these two species comprised 53% of collisions during the study period.

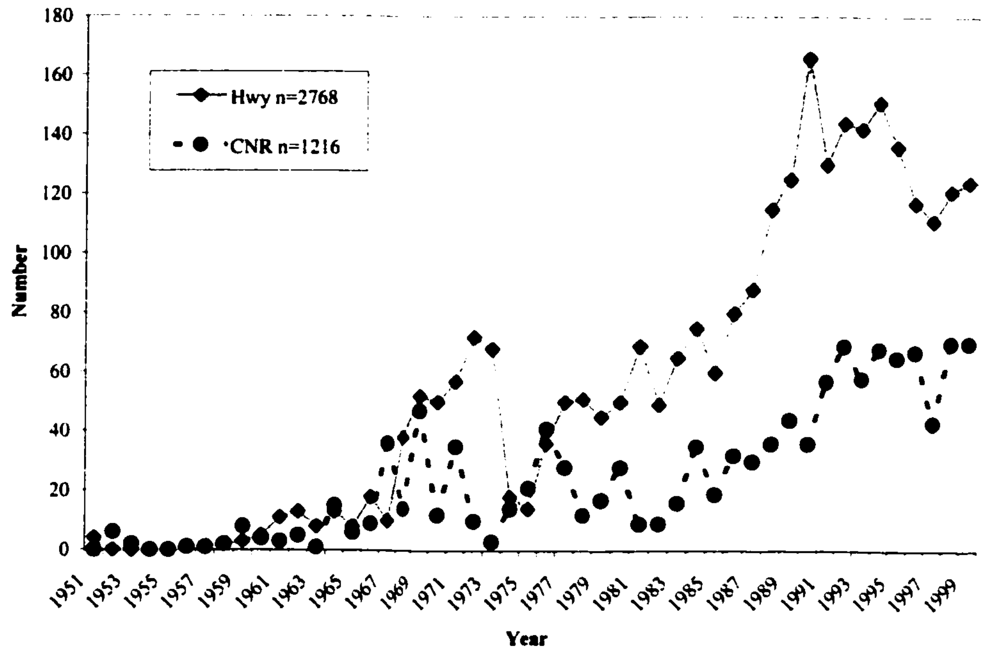

Figure 11. Yearly highway and railway mortality, Jasper National Park - 1951-1999

3.2.1 Discussion

Damas and Smith (1982) estimated that total wildlife/vehicle mortality in National Parks is underestimated by 20% to 30%. In Kootenay National Park wildlife collisions averaged 18% higher than observed (Poll 1989).

An increase in wildlife collisions during the study period, is most likely a result of increased traffic volumes and an increasing elk population adjacent to highways and the railway. However, the reasons for the decrease in highway collisions during the 1990's are not well understood. In 1986, large wildlife warning signs in the form of elk silhouettes were installed on park highways. In addition in 1991, reduced speed zones were installed at three locations on the Yellowhead Highway. A decrease in highway collisions during the 1990's may be a result of the combined affects of wildlife warning signs and reduced speed zones. Similar mitigation to reduce collisions has not been implemented on the railway.

Based on yearly collision rates, highway paving in 1966 and the associated change in traffic patterns (increased vehicle speed and volumes) had a greater effect on wildlife collision rates than the addition of a twin track in 1981 on the Canadian National Railway.

3.2.2 *Study Question 2. During the study period, have changes in species composition occurred adjacent to transportation corridors?*

During the study period, collisions with wildlife increased. In some cases, this is result of an increasing wildlife population, an example is elk. However, it would be incorrect to state wildlife populations have increased or decreased based simply on collision trends because of the influence of a variety of variables such as traffic volumes, vehicle speed, vehicle type and wildlife behaviour (an example is habituation). However, assuming the influence of these variables is evenly spread within species groups, collision data may be used to show relative changes in species groups over time. Consequently, collision rates can be used to determine if changes have occurred in the composition of different groups of wildlife over time.

Collision rates during the study period were analysed to determine if changes have occurred in the relative composition of species based on collision data. This was done by categorising collision data into three wildlife groups: ungulates, canids and bears and into three periods. Period 1 contains 19 years (1951-1969); period 2 15-years (1970-1984); and period 3 15 years (1985-1999). Each species is presented relative to the total number of species killed in its group for each period (Table 4).

3.2.3 Ungulates

Based on collision data, changes in the relative ungulate composition have occurred. Whitetail deer experienced the greatest increase in relative collision rates followed by elk. Mule deer and moose experienced the greatest decrease in relative collision rates. Relative collision rates remained stable for bighorn sheep (Fig. 12). In addition, whitetail deer are not represented in the collision data during period 1.

Table 4. Wildlife collisions listed as a percentage of each total during three periods, 1951-1999

Species	Period 1	Period 2	Period 3	Total
Elk	27%	39%	38%	1353
Bighorn sheep	25%	25%	24%	857
Mule deer	30%	25%	15%	684
Whitetail deer	0%	3%	13%	346
Moose	18%	8%	9%	334
Total	100%	100%	100%	3574
Wolf	10%	21%	31%	63
Coyote	90%	79%	69%	167
Total	100%	100%	100%	230
Black bear	60%	62%	89%	138
Grizzly bear	40%	38%	11%	42
Total	100%	100%	100%	180

Changes to the ungulate composition adjacent to transportation corridors have occurred during the study period. To determine if these changes in relative collision rates between periods are significant a chi-squared goodness of fit test was carried out on each wildlife group. A chi-squared test showed there was a highly significant association between periods 1, 2, 3 and ungulate collisions ($\chi 2$ 43.93, d.f.=8, P=0.00043).

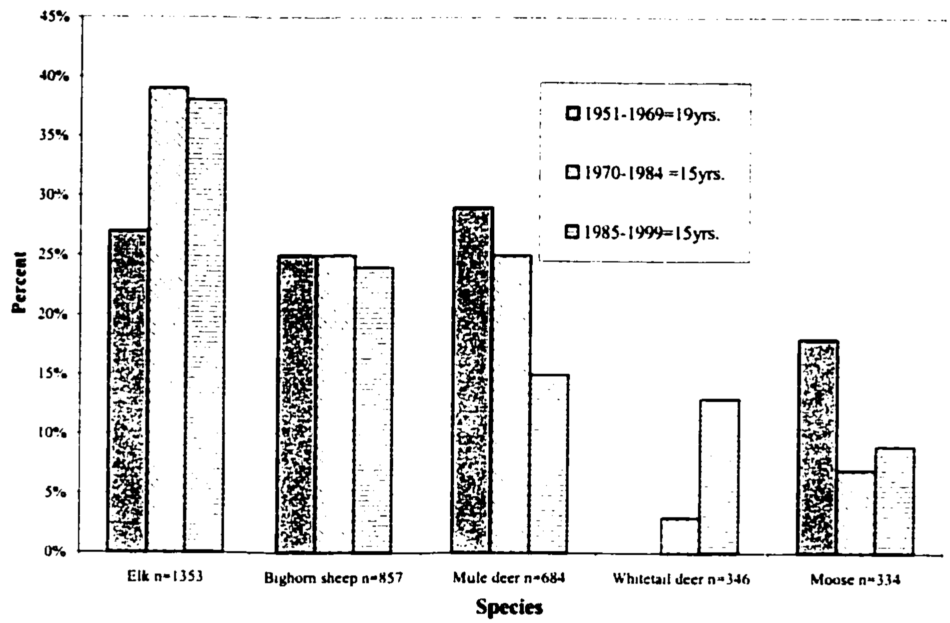

Figure 12. Relative percentage of ungulate kills during three periods, 1951-1999

3.2.4 Discussion

Changes in the ungulate composition adjacent to transportation corridors in Jasper National Park have occurred during the study period. Data analysis shows these changes are statistically significant.

Relative elk and whitetail deer populations have increased and relative mule deer and moose populations have decreased. From 1983 to 1998 (period 3) the elk population adjacent to the Yellowhead Corridor increased from 400 to 928 elk. This increase had a major influence on relative collision rates. Additionally, collision rates for whitetail deer indicate this species was uncommon adjacent to transportation corridors during period 1.

The first recorded observation of whitetail deer in Jasper National Park was in 1943 (Holroyd & Van Tighem 1983). Today whitetail deer are common in Jasper National Park in a variety of habitats. Recorded collisions with whitetail deer began in 1970. During this decade, 13 whitetail deer were recorded as killed in collisions. During the 1980's and 1990's whitetail deer collisions increased to 332.

Displacement of mule deer by whitetail deer is well documented (Geist 1991). Mule deer have showed sharp declines in the Prairie Provinces of Canada where whitetail deer replaced mule deer within a few years (Geist 1991). Holroyd and Van Tighem (1983) concluded whitetail deer populations in Jasper National Park were increasing and may be invading mule deer habitats. Collision data supports this conclusion adjacent to the Yellowhead Corridor.

Relative changes in moose collision rates are not as dramatic as mule deer collision rates. Between periods 2 and 3 moose collision rates are relatively stable.

Using collision data as an indicator of changes in species composition shows relative bighorn sheep populations have remained stable while whitetail deer and elk populations have increased. In addition, relative mule deer and moose collisions have decreased. The most noteworthy changes are the relative increase in elk and whitetail deer collisions and the relative decrease in mule deer collisions.

3.2.5 Carnivores

Relative collisions for wolves and coyotes have also changed during the study period (Fig.13). To determine if changes in relative collision rates are statistically significant, a chi-squared goodness of fit test was carried out on wolf and coyote collisions. A chi-squared test showed there was no significant association between periods 1, 2, 3 and wolf and coyote collisions ($\chi 2$ 4.34, d.f.=2, P=0.11). Relative collision rates for black and grizzly bears have also changed during the study period (Fig.14). To determine if changes in relative collision rates are significant a chi-squared goodness of fit test was carried out on bear collisions.

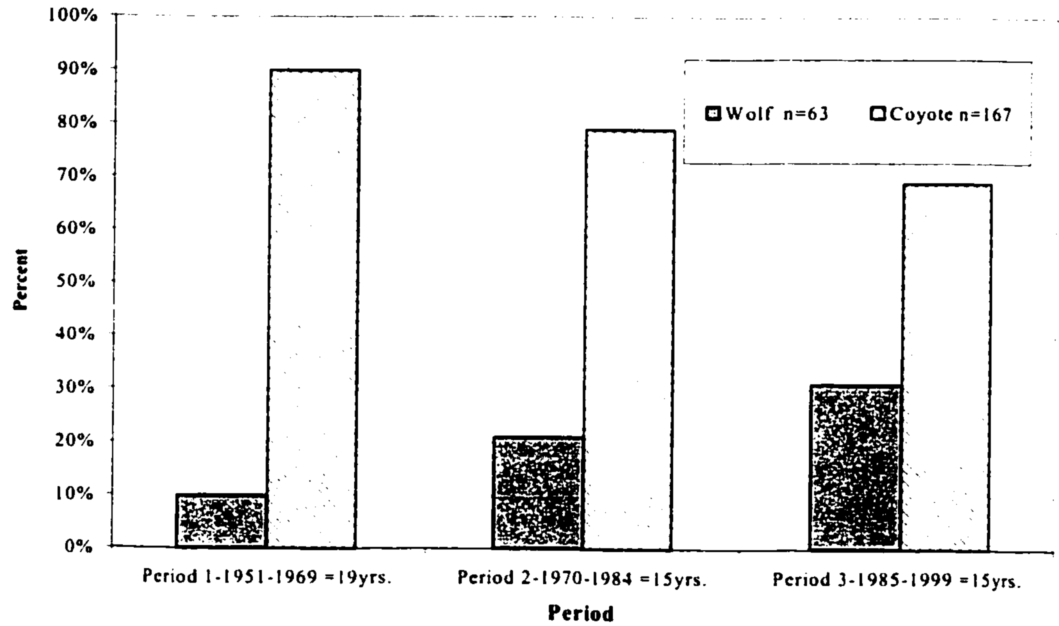

Figure 13. Relative percent of wolf & coyote kills during three periods, 1951-1999

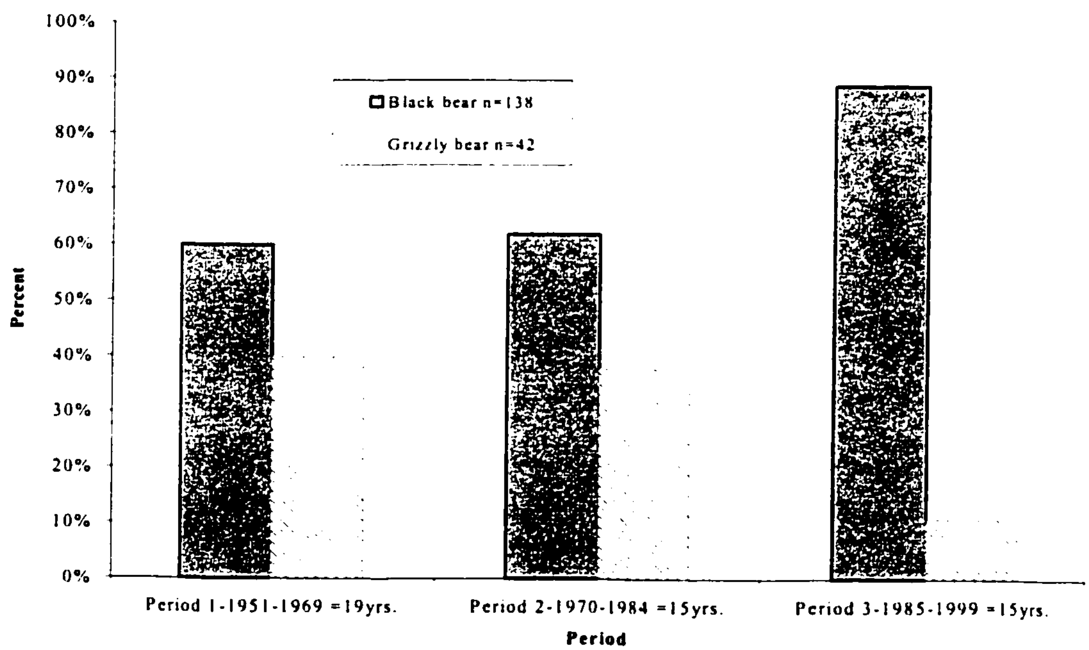

Figure 14. Relative percent of black and grizzly bear kills during three periods, 1951-1999

A chi-squared test showed there was a significant association between periods 1, 2 and 3 and bear collisions ($\chi 2$ 23.95, d.f.=2, P=0.00006). However, a chi-squared test showed no significant association between periods 1 and 2 ($\chi 2$ .017, d.f.=1, P=.89).

3.2.6 Discussion

Wolf and black bear collision data indicates a relative increase in collisions and a relative decrease in coyote and grizzly bear collisions. Data analysis shows these changes are not statistically significant with the exception of period 3 for bears.

Wolf displacement of coyotes has been documented in Jasper National Park (Bowen 1978). This may account for the relative decrease in coyote collisions. Additionally, increased collision rates for wolves may be a result of an increased wolf population.

During periods 1 and 2, major attractants for bears existed adjacent to the Yellowhead Corridor. These attractants were the Jasper National Park landfill and garbage containers in and around the Jasper area. By 1986 the landfill and garbage containers in Jasper National Park were bear proofed, removing a major attractant and dispersing grizzly bears. An indirect effect of bear proofing the landfill and garbage containers has been the dramatic reduction in grizzly bear collisions during period 3. Park staff had observed up to 15 grizzlies at one time at the landfill before bear proofing (Bradford 2000). Today, black bear observations along the Yellowhead Corridor outnumber grizzly bear observations by 9-1 (n= 30) (Jasper National Park 2000).

Herrero (1985) found that black bears will expand their range into areas vacated by grizzlies. This may account for the relative increase in black bear collisions compared to grizzly bear collisions during period 3 (1985-1999).

Major attractants for black bears still exists in the Canadian National Railway yard (spilled grain) and adjacent municipal sewage lagoons. Black bears are attracted to this area, which is reflected in the higher collision rates on the Yellowhead Highway and railway in this area. Grizzly bears are not commonly observed in this area which is reflected in the low grizzly bear collision rates.

3.3 MONTHLY WILLDIFE COLLISIONS

Monthly highway and railway collisions were plotted to determine if differences existed between monthly collisions on highways and the railway and to identify monthly collision trends on highways and the railway. Wildlife collisions on highways and the railway show similar monthly collision rates from January through September. From October to December these rates change; collisions increase on highways and decrease on the railway (Fig.15).

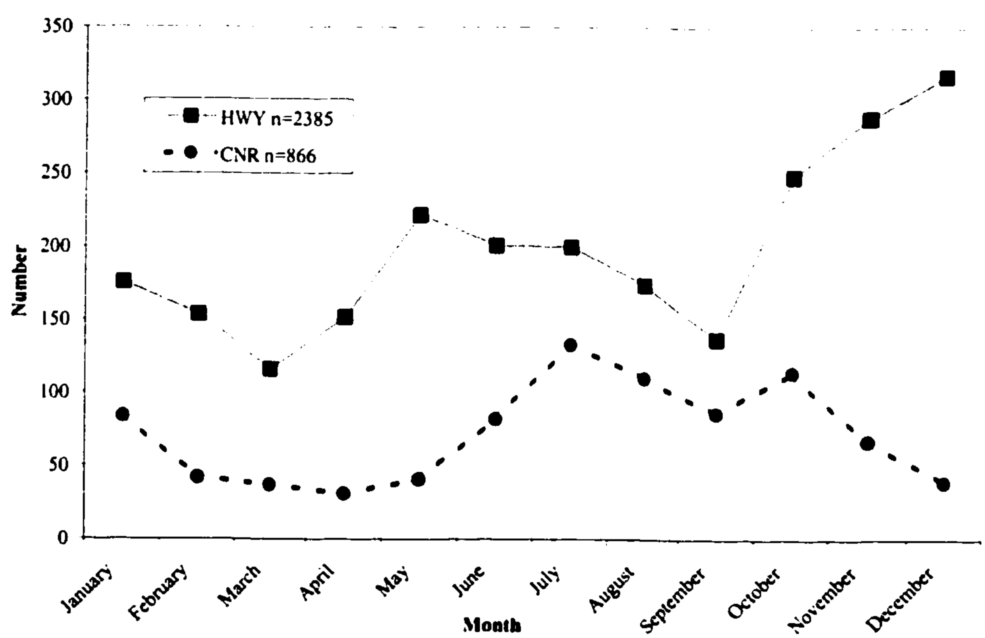

Figure 15. Monthly wildlife collisions on highways and the railway from 1951-1999

During this, 3-month period 36% of all highway collisions occur compared to 25% on the railway for this same period.

3.3.1 Discussion

Wildlife collisions are not consistent from month to month. Two major factors influencing collisions are traffic volumes and seasonal movement of wildlife. Both the Yellowhead Highway and the Canadian National Railway are located in prime winter range for most ungulates. Wildlife establishment on winter range occurs from October through December increasing wildlife exposure to highway and train traffic. Road salt applications also begin during this period. Ungulates, particularly bighorn sheep, are attracted to highways to lick road salt increasing their exposure to traffic. Conversely, during the summer season, a high traffic volume period, increased traffic volumes increases the probability of wildlife collisions.

Collision rates increase on highways during the October through December period despite relatively low traffic volumes and decrease on the railway where traffic volumes are consistent. The reason this difference does not occur on the railway is unknown. During the later part of the winter from January through March highway traffic volumes remain low and wildlife remain adjacent to transportation corridors. However, wildlife collisions decrease on both highways and the railway during this period. The reasons for divergent collision rates and traffic volumes during the October through December may be caused because wildlife is unaccustomed to highway traffic during establishment on winter range. As wildlife become more accustomed to traffic (January through March) collision rates and traffic volumes become more similar. Wildlife may develop collision avoidance strategies based on their increasing familiarity with traffic. Consequently, collision rates may be reduced because of the increased familiarity with traffic during this period. Mumme *et al.* (1995) found traffic mortality of the Florida Scrub Jay was especially high for immigrants without previous experience living along the road.

Average daily traffic volumes (1973-1997) during the October through December period were 1 467 vehicles per day or on average 61 vehicles every 60 minutes. If wildlife maintained a flight response each time they encountered a vehicle they would be expending a significant amount of energy unnecessarily. Familiarisation with traffic reduces the magnitude and frequency of flight response thereby conserving energy. An alternative explanation is selective mortality of individual animals that lack innate wariness.

3.3.2 Monthly collision rates by species

Monthly collisions for each species were plotted to provide monthly collision data that can be used to develop mitigation for individual species. Monthly ungulate collisions are plotted on two separate charts. Elk, bighorn sheep and moose each show similar monthly collisions trends (Fig. 16).

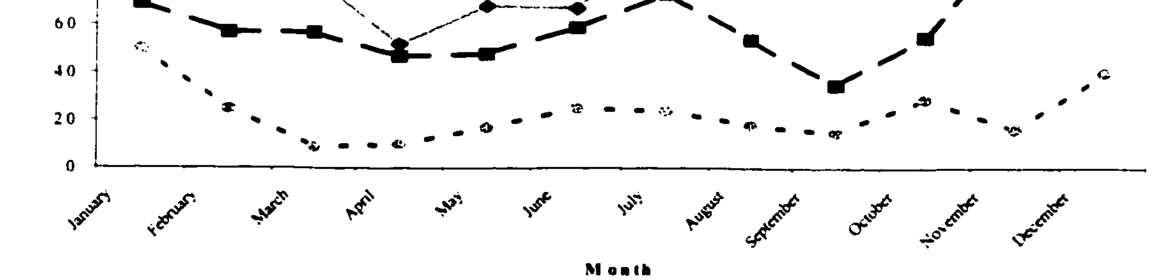

Figure 16. Monthly elk, bighorn sheep and moose collisions, 1951-1999

Maximum collisions occur during the months of October to January. Monthly whitetail deer collisions are also similar to elk, bighorn sheep and moose. Monthly mule deer collisions are notably different from other ungulates peaking during April and May (Fig.17).

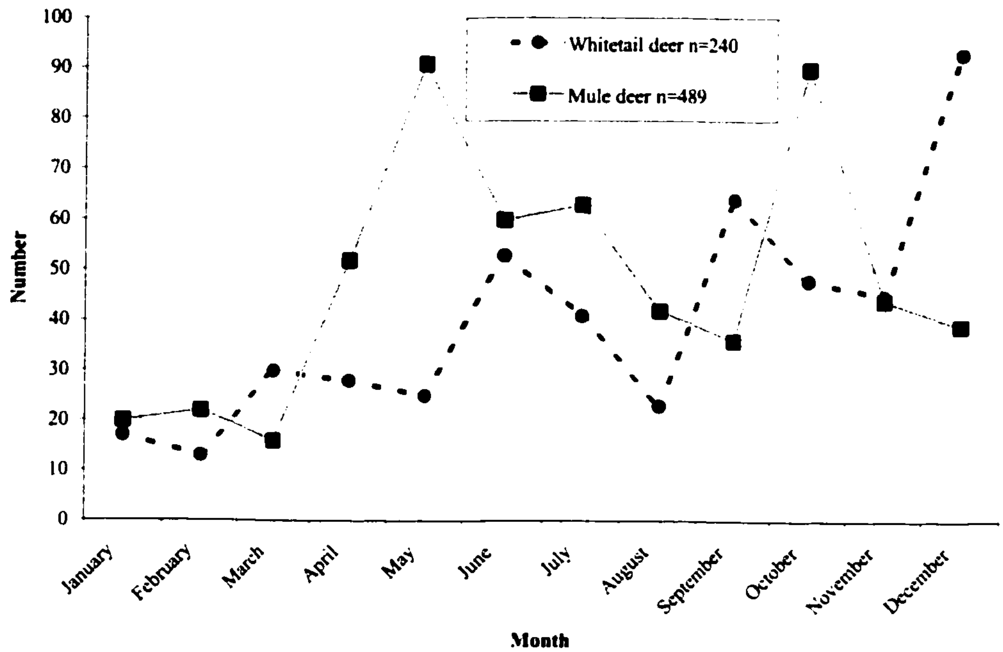

Figure 17. Monthly mule deer and whitetail deer collisions, 1960 -1999

Monthly wolf and coyote collisions show similar trends from January trough June. From July through December there are slight differences between these two species (Fig. 18). Monthly black and grizzly bear collision trends are similar (Fig. 19) and only cover the months of April to October when bears are not hibernating

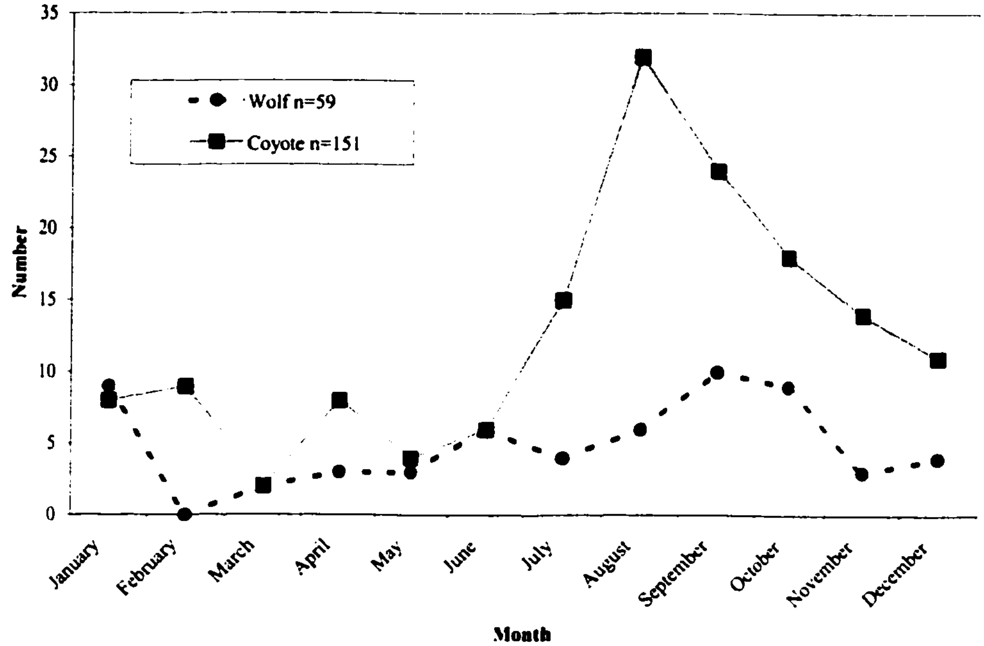

Figure 18. Monthly wolf and coyote collisions, 1962-1999

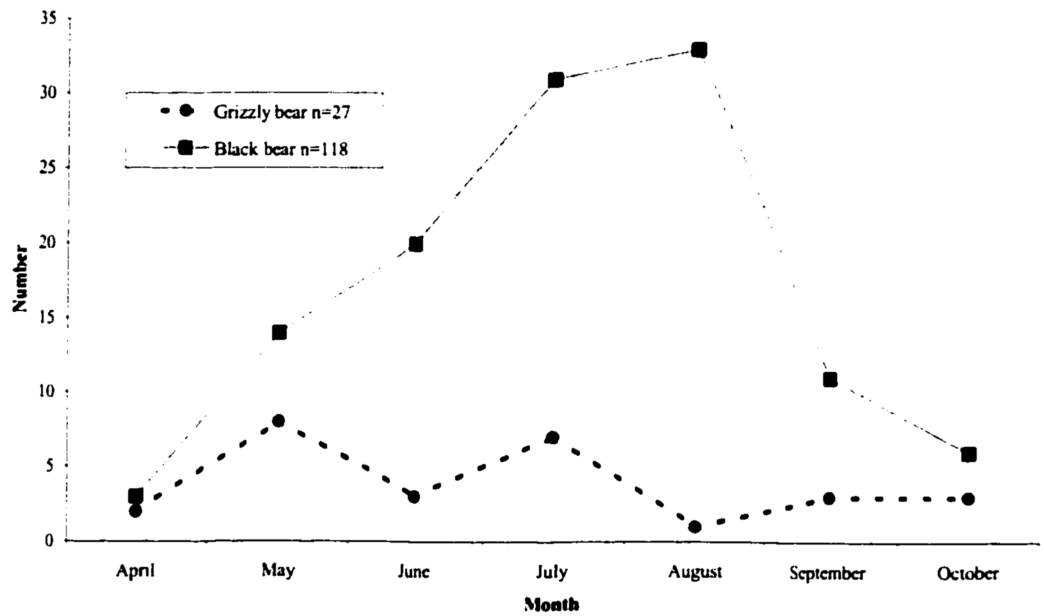

Figure 19. Monthly black bear and grizzly bear collisions, 1968-1999

Wolves, coyotes, black bears and grizzly bears show similar monthly collision trends. With the exception of mule deer, ungulates also show similar monthly collision trends. The reasons for this difference may be explained by differences in mule deer behaviour. Spring green-up occurs in May along the Yellowhead Corridor. Mule deer collisions also peak during May. Spring green-up in ditches may create a greater attractant for mule deer than other ungulates. Consequently, mule deer are exposed to traffic to a greater extent than other ungulates, increasing mule deer collisions during the green-up period. Damas and Smith (1982) noted this as a possible factor contributing to mule deer collisions.

3.3.3 Study Question 4. Are monthly highway vehicle volumes a significant factor in the number of monthly wildlife collisions?

Monthly collisions and traffic volumes are plotted in figure 20. To determine if there was a significant relationship between monthly traffic volumes and wildlife collisions a linear regression test was carried out. Regression analysis was carried out on 384 collisions recorded during a three-year period from 1994 to 1996. This period was chosen because it is believed that 1994 and 1996 are representative of traffic volumes recorded during 1995.

Weekday collisions are used in this analysis because weekdays do not influence wildlife behaviour. A linear regression analysis showed that there is no significant relationship between monthly vehicle volumes and wildlife collisions on highways (n=384, R squared=.14, P=0.22) The small R squared value shows a weak relationship.

Monthly collisions and vehicle volumes show similar trends from January through August. This shows that traffic volumes had a major influence on collision rates during this period. From September through December, other factors, a major one is establishment on winter range, influence collision rates to a greater extent than traffic volumes.

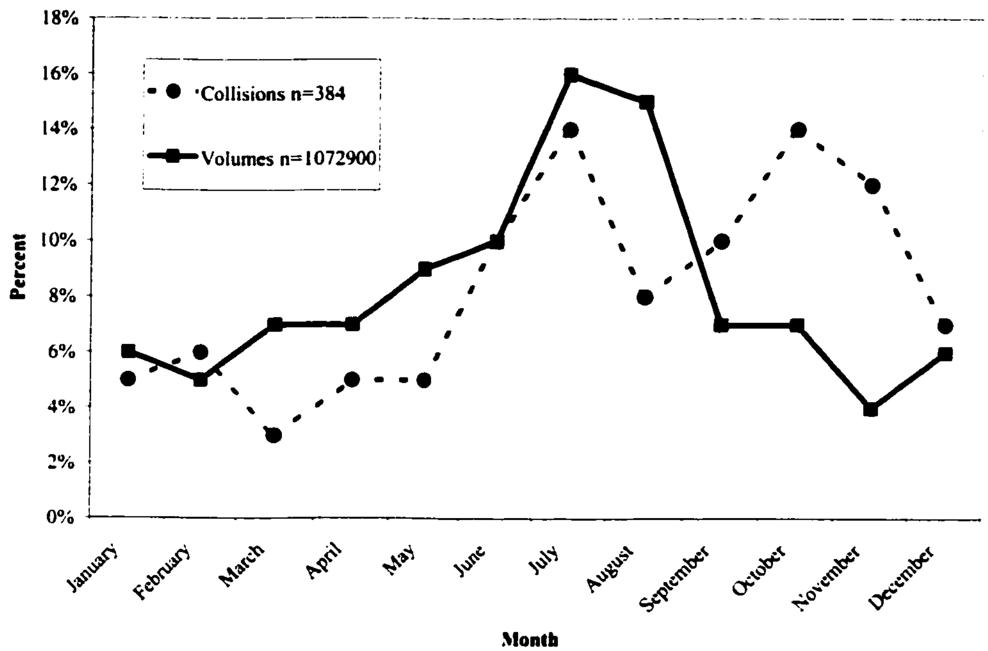

Figure 20. Monthly wildlife collisions and traffic volumes plotted as percentage of each total 1994 to 1996

Linear regression analysis was also carried out on individual species using 1994 to 1996 data to determine if a relationship existed for individual species during this period. Regression tables are listed in appendix 1. Carnivores (wolves, coyotes and black bears) were grouped for this analysis because of small individual sample sizes.

A significant relationship between monthly highway traffic volumes and elk, bighorn sheep, moose and whitetail deer collisions was not shown. A significant relationship between monthly highway traffic volumes, mule deer and carnivores was shown. Regression analysis for mule deer and carnivores suggests collisions are influenced by monthly traffic volumes. However, it should be noted these tests are unplanned comparisons and consequently the P values may be underestimated. If this is the case monthly, traffic volumes are not the single greatest contributor to collision rates for all species, including mule deer and carnivores. Other factors also influence collision rates, a major factor is establishment on winter range.

3.4 HOURLY WILDLFIE COLLISIONS

Hourly collision trends for individual species are identified on highways and the railway to assist park managers in developing mitigation for these species. In addition, hourly highway and railway collisions were examined to determine if differences existed between hourly collisions on highways and the railway.

On highways 73% of collisions occur during two peak periods, 0600 hours to 1200 hours and 1800 hours to 2400 hours. On the railway, 74% of collisions occur during a 12-hour period from 0900 hours to 2000 hours (Fig. 21).

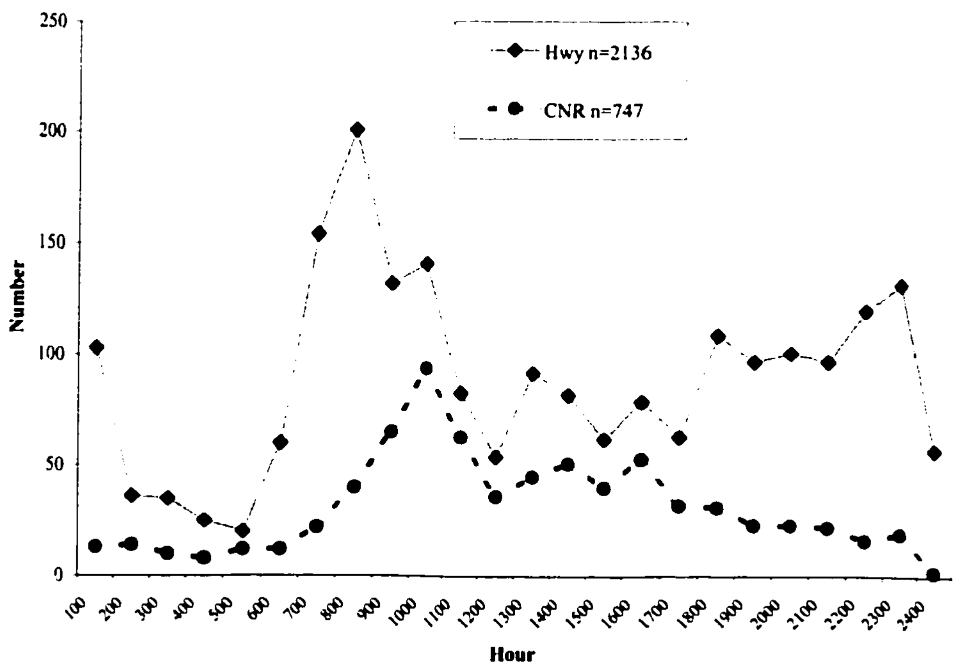

Figure 21. Hourly wildlife collisions on highways and Canadian National Railway, 1975-1999

Collisions are not spread evenly over a 24-hour period and occur to greater extent during specific periods particularly on highways.

3.4.1. Discussion

The recording of hourly collisions is predisposed toward daylight hours. The reason for this is carcasses that are not on the road surface and railway are less visible during crepuscular periods and at night than during daylight periods. In these cases, carcasses are not reported until the following day. Consequently, some collisions recorded as daylight collisions are incorrectly recorded as the time the collision was reported or the carcass picked up by the Warden Service rather than the actual collision time. The number of collisions where this error occurs is unknown.

Mercer (2000) identified 0600 hours to 1200 hours and 1800 hours to 2400 hours as peak wildlife movement periods in the Jasper townsite area (n=379). Each of these periods corresponds to collision times on highways. Hourly wildlife collisions on highways and the railway show similar peaks from 0600 to 1200 hours. The increased movement of wildlife during these periods increases the probability of collisions.

The second peak collision period (1800 hours to 2400 hours) identified by Mercer (2000) corresponds to wildlife collision periods on highways but not on the railway. The reasons for this difference may be a result of collision reporting by railway crews and the Warden Service rather than wildlife movement. If an animal is reported as a railway collision in the evening in an area not easily accessible, it is not removed until the next morning. In some of these cases, the time of collision is recorded when the carcass is removed rather than the actual collision time.

Hourly collisions for each species were plotted to provide hourly collision data that can be used to develop mitigation for individual species and to determine if differences existed between hourly collisions for individual species. Hourly ungulate collisions are plotted on two separate charts (Fig.22 & 23). All hourly ungulate collision trends are similar with the exception of bighorn sheep.

Wolf and coyote hourly collision trends are charted in Fig. 24, grizzly and black bear hourly collision trends are charted in Fig.25. There is a relatively small sample size for grizzly bears. However, grizzly bear data is similar to hourly collision trends for black bears. Hourly collision times are similar for the majority of species analysed. These species are elk, moose, mule deer, whitetail deer, wolves and coyotes. Generally, each of these species shows two peak collision periods between 0600 hours to 1100 hours and 1800 hours to 2300 hours. These times are similar to peak wildlife movement times noted by Mercer (2000) where the majority of observations were ungulates.

Hourly bighorn sheep, grizzly bears and black bears collision trends are distinctly different, peaking between 1100 hours and 1900 hours. This period also coincides with peak traffic volume periods. These collision hours are consistent with collision hours noted by Damas and Smith (1982).

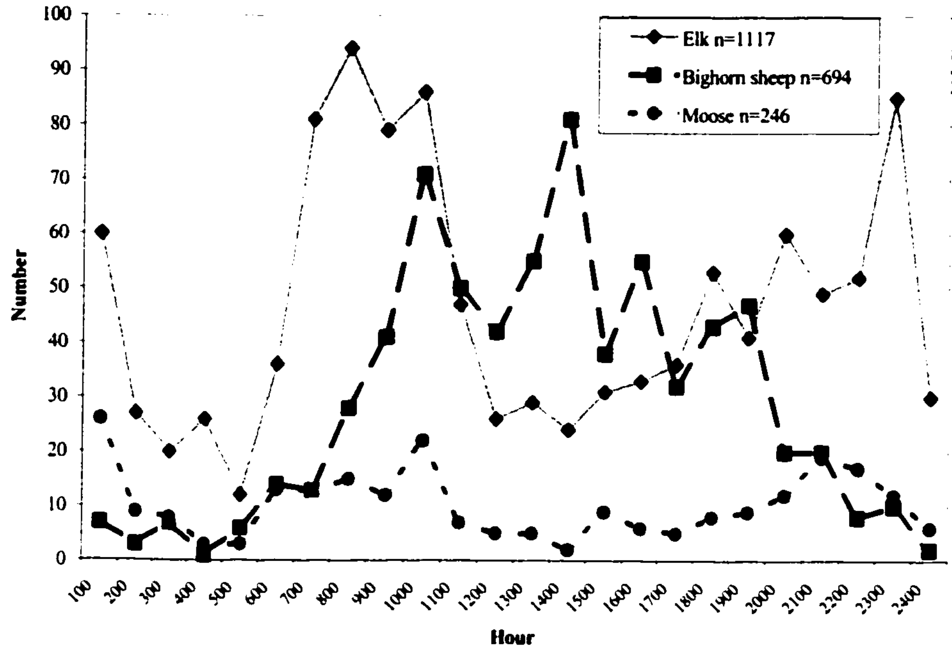

Figure 22. Hourly elk, bighorn sheep and moose collisions 1951-1999

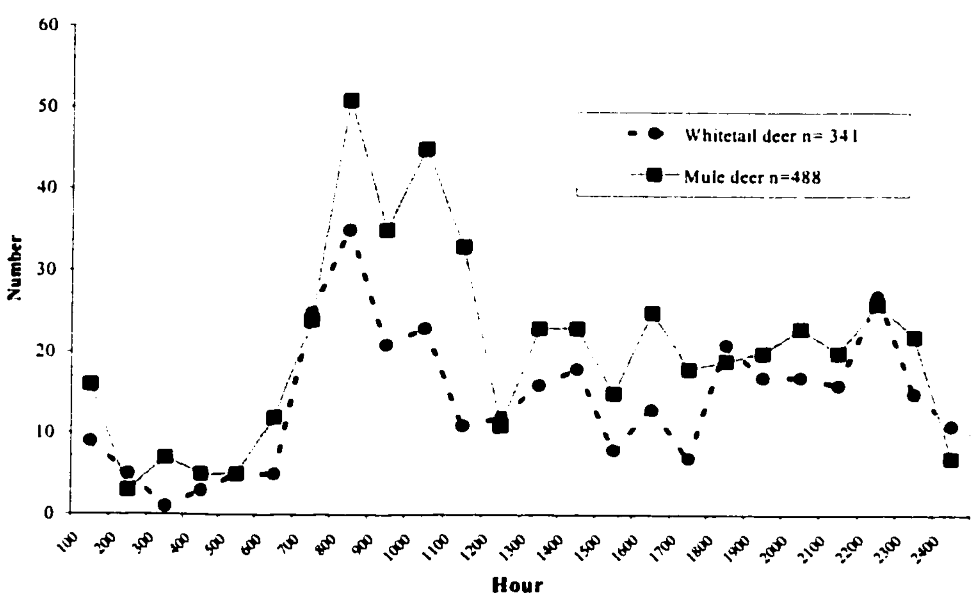

Figure 23. Hourly mule deer and whitetail deer collision 1956-1999

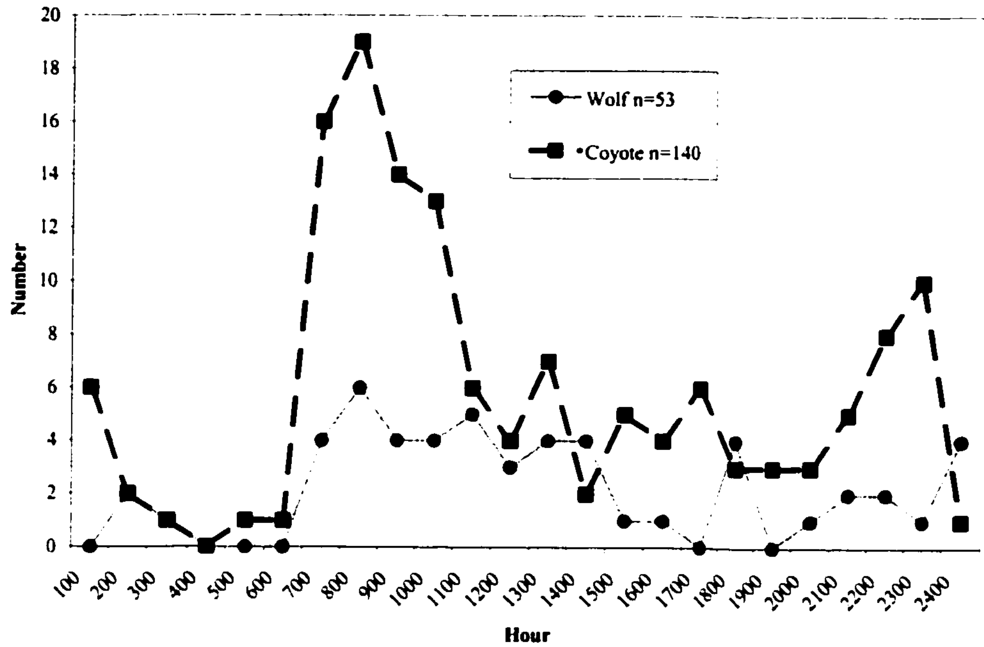

Figure 24. Hourly wolf and coyote collision 1962-1999

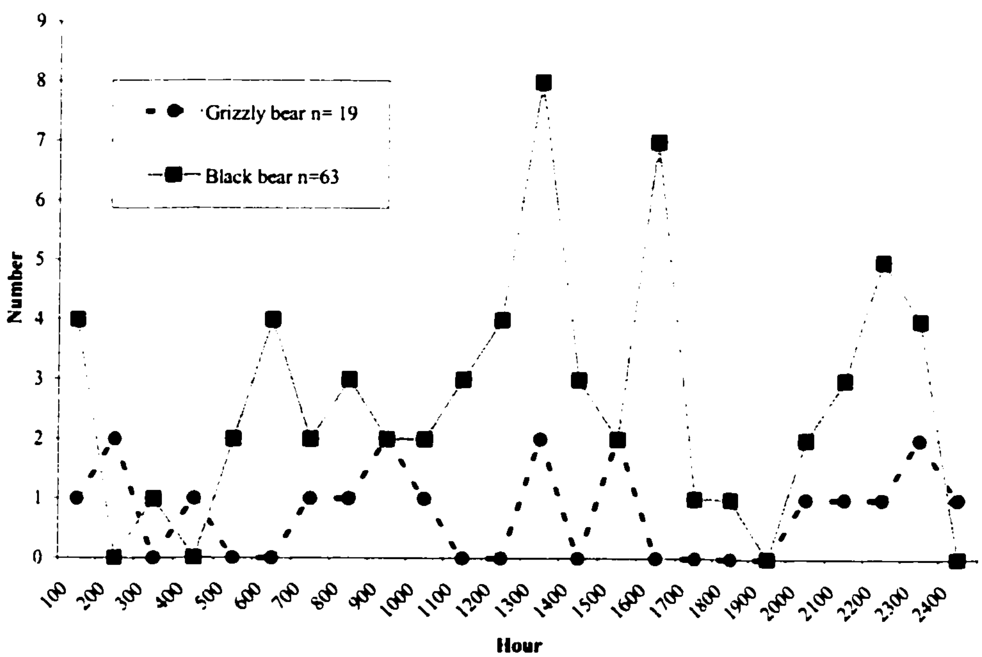

Figure 25. Hourly grizzly and black bear collision 1968-1999

3.5 COLLISIONS ON HIGHWAYS AND THE RAILWAY BY SPECIES, SEX AND AGE CLASS

Collisions on highways and the railway were analysed to determine if differences existed between a number of factors (Table 5).

Table 5. Highway (Hwy) and railway (CNR) collisions by species, age and sex class 1951-1999

Species (Hwy and CNR)	Adult Male	Adult Female	Adult/ *?/Sex	?/Age ?/Sex	YOY	YLY	Total
Elk CNR	32%	37%	1%	9%	13%	7%	449
Elk Hwy	16%	39%	1%	9%	12%	22%	904
Bighorn sheep CNR	31%	35%	1%	11%	12%	10%	409
Bighorn sheep Hwy	28%	42%	.7%	5%	8%	16%	448
Mule deer CNR	29%	30%	2%	12%	10%	16%	121
Mule deer Hwy	29%	35%	1%	18%	7%	10%	563
Whitetail deer CNR	70%	-	-	-	10%	16%	20
Whitetail deer Hwy	49%	35%	1%	1%	7%	6%	326
Moose CNR	27%	20%	-	36%	8%	8%	117
Moose Hwy	22%	41%	1%	9%	12%	15%	217
Coyote CNR	16%	33%	16%	33%	-	-	6
Coyote Hwy	21%	12%	14%	18%	4%	31%	161
Wolf CNR	40%	13%	13%	-	-	33%	15
Wolf Hwy	27%	23%	8%	14%	-	27%	48
Black bear CNR	32%	21%	8%	17%	13%	6%	46
Black Bear Hwy	44%	25%	9%	7%	10%	5%	92
Grizzly bear CNR	16%	26%	6%	39%	10%	3%	31
Grizzly bear Hwy	45%	36%	9%	-	-	9%	11
* Unknown						Total	3 984

Comparisons were made between total numbers on highways and the railway and differences in collision rates based on species, sex, and age class. YOY and YLY represent (Young-of-year and yearling age classes respectively). During the study period 70% of collisions occurred on highways. Highway collisions were greater than railway collisions for each species with the exception of grizzly bears. For some species very few collisions occur on the railway compared to highways. An example is whitetail deer where 6% of total whitetail deer collisions occurred on the railway compared to 94% on highways (n=346).

The species with the most similar collision rates on highways and the railway is bighorn sheep. In this case, 48% of bighorn sheep collisions occurred on the railway and 52% of collisions occurred on highways. These proportions are notably different than for other species.

3.5.1 Study Question 4. Is there a significant association between transportation category (highways or railway) and wildlife collisions?

To determine if transportation category (highways or the railway) influences wildlife collisions, a chi-squared goodness of fit test was carried out on all wildlife collisions and individual species from 1980 to 1999. Whitetail deer are excluded from individual analysis and carnivores are grouped because of the small sample sizes (collisions) of these species on the railway. Weekday collisions are used in this analysis because days of the week do not influence wildlife behaviour and weekdays are systematically spread through the year.

A chi-squared test showed that there was a significant association between transportation category and daily wildlife collisions ($\chi 2$ 15.18, d.f.=6, P=0.018). A similar result was returned for elk ($\chi 2$ 23.14, d.f.=6, P=0.00017). A chi-squared goodness of fit test showed no significant association between transportation category and the following species, bighorn sheep ($\chi 2$ 4.63, d.f.=6, P=0.59), mule deer ($\chi 2$ 7.78, d.f.=6, P=0.25), moose ($\chi 2$ 7.87, d.f.=6, P=0.35) and carnivores ($\chi 2$ 6.68, d.f.=6, P=0.24).

3.5.2 Discussion

Collisions on highways exceed collisions on the railway for all species with the exception of grizzly bears. The reason for this may be caused by the higher frequency of traffic on highways. This may cause a greater disturbance for a wary species such as the grizzly bear. Daily traffic volumes on the railway averaged 34 trains per day during 1998. Daily traffic volumes on the Yellowhead Highway during 1995 averaged 2 744 vehicles per day. Daily traffic frequency on the railway is considerably less than highways. It is possible wildlife may become de-sensitised to highway traffic compared to train traffic, putting wildlife more at risk of a collision on highways. Also, trains are considerably larger than highway vehicles and disturbance created by trains and or the warning of an approaching train may be greater on the railway than vehicles on highways. An alternative explanation is grizzly bears may be scavenging carcass from train collisions that are not removed.

On the railway only 6 coyote (3%) collisions have been recorded (n=167) (Table 5). The low collision rate for coyotes on the railway is unlikely. This is probably a result of a lack of reporting by train crews rather than actual collisions. This may also affect the low number of YOY wolves and bear collisions reported on the railway because of a similar body size for this age class. Therefore, on the railway, collisions with smaller animals (coyotes, young of year wolves and bears) are likely greater than is reported.

Most collisions with wildlife occur at the front of the train. It is more difficult for train engineers to see a collision with a smaller bodied animal because of the engineer's position in the cab of the train (Kennedy 2001). Also, there is less visible evidence of a collision with a smaller bodied animal. Additionally, the Warden Service carries out regular patrols on highways but not on the railway. Patrol duties include looking for roadkills. Damas and Smith (1982) found that a large proportion of collisions on the railway go unreported. An estimate of the proportion not reported is not included in their analysis.

Because elk make up 34% of wildlife collisions, this species has a major affect on chi-squared test results carried out on all wildlife. Habitat preference of elk is not an influencing factor in these test results because the majority of elk collisions occur where the highway and the railway are within 100 to 200 meters of each other (kilometre 30 to 60). These test results suggest elk collision rates are influenced by transportation category (highway vs. railway). In addition, collision rates for other species are not significantly influenced by transportation category (highway vs. railway). These tests suggest elk are at a greater risk of collisions on highways than on the railway.

3.5.3 Ungulate sex collision rates

Fifty-seven percent of collisions on highways and the railway are female ungulates and 43% are males (n=2299). On highways 60% of collisions with ungulates are females and 40% are males (n=1580). On the railway 52% of collisions with ungulates are females and 48% are males (n=719). These percentages are influenced by the larger number of elk collisions, because elk make up 35% of adult male and female collisions.

On the railway female collisions range from 37% for elk to 13% for wolves. Male collision rates on the railway range from 70% for whitetail deer to 16% for coyotes and grizzly bears. On highways female collision rates range from 42% for bighorn sheep to 12% for coyotes. Male collision rates on highways range from 49% for whitetail deer to 16% for elk.

3.5.4 Study Question 5. Is there a significant association between transportation category and sex of wildlife?

On highways, collisions with adult female ungulates are greater than collisions with adult males. An exception to this is whitetail deer where male collision rates exceed female rates. Total adult male whitetail deer collisions peak during November at 18% (n=173) compared to 5% for females (n=122), indicating male breeding behaviour increases male collision rates.

To determine if male ungulate collisions are greater during the rut, male and female ungulate collisions during the rut were compared. Average conception dates for ungulates are: elk, September (Flook 1970), moose, September and October (Grossenheider and Burt 1976), bighorn sheep, mid-November to mid-December (Geist, 1993), mule deer, November (Geist,1991) and whitetail deer, November (Geist,1991). Male and female collision rates during rutting periods are listed in Table 6.

Table 6. Ungulate male and female collisions during the rut 1951-1999

Species	Male collisions	Male collisions % of each total	Female collisions
Elk	24	44%	30
Moose	18	56%	14
Bighorn sheep	102	54%	87
Mule deer	15	47%	17
Whitetail deer	31	84%	6

Male collisions exceeded female collisions during the rut for moose, bighorn sheep and whitetail deer. Female collision rates during the rut were greater for elk and mule deer. The difference between male and female collision rates for moose and bighorn sheep are not large. Differences between male and female collision rates during the rut are greatest for whitetail deer. Eight-four percent of the whitetail deer killed in collisions during November are males compared to 16% for females. This suggests male whitetail deer breeding behaviour increases the probability of collisions with male whitetail deer during the rut. Minimal differences exist between male and female collision rates for other ungulates during rutting periods.

To determine if there is an association between transportation category and ungulate sex collision rates a chi-squared goodness of fit test was carried out on individual species collisions from 1951 to 1999. Whitetail deer are excluded from this analysis because of the small sample sizes on the railway. A chi-squared test of association showed there is a significant association between transportation category and sex of elk ($\chi 2$ 20.54, d.f.=1, P=0.00006), and moose ($\chi 2$ 8.64, d.f.=1, P=0.003) collisions (greater on highways). A chi-squared test of association showed there is no significant association between transportation category and sex of bighorn sheep ($\chi 2$ 2.97, d.f.=1, P=0.084) and mule deer ($\chi 2$ .38, d.f.=1, P=0.53). This analysis suggests transportation category significantly influence sex collision rates of elk and moose and not bighorn sheep and mule deer. This analysis also suggests female elk and moose are more of risk of collisions on highways compared to the railway.

3.5.5 Carnivore sex collision rates

Sixty-percent of collisions on highways and the railway are male carnivores and 40% are females (n=198). On the highways 62% of collisions with carnivores are males and 48% are females (n=149). On the railway 55% of collisions with carnivores are males and 45% are females (n=49). To determine if there is an association between transportation category and carnivore sex collision rates, a chi-squared goodness of fit test was carried out on individual species collisions from 1951 to 1999. Coyotes are excluded from this analysis because of the small sample sizes on the railway. Black and grizzly bears are grouped because of the small grizzly bear sample sizes. A chi-squared test of association showed there is no significant association between transportation category and the sex of wolves ($\chi 2$ 1.01, d.f.=1, P=0.29) and black/grizzly bears ($\chi 2$ 1.00, d.f.=1, P=0.31).

3.5.6 Study Question 6. Does transportation category influence collision rates based on age class of wildlife?

To determine if transportation category is associated with age class collisions, a chi-squared goodness of fit test was carried out on individual species collisions from 1951 to 1999. Whitetail deer and coyotes are excluded from this analysis because of the small sample size on the railway. Additionally, black and grizzly bears are grouped because of the small sample sizes on highways and the railway. Yearling and young of year age classes are grouped into one category and adult male and female are grouped into the second category, with the exception of wolves where only collisions with young of year wolves are used. Yearling wolves have not been recorded. This is probably a result of the difficulty in distinguishing yearlings from adults rather than the lack of yearling wolf collisions.

A chi-squared test of association showed there is a significant association between transportation category and elk ($\chi 2$ 19.91, d.f.=1, P=0.0008) (greater on highways) and mule deer ($\chi 2$ 3.92, d.f.=1, P=0.04) (greater on the railway) collisions by age class. A chi-squared test of association showed there is no significant association between transportation category and bighorn sheep ($\chi 2$ .05, d.f.=1, P=0.80), moose ($\chi 2$ .44, d.f.=1, P=0.50), wolves ($\chi 2$ .01, d.f.=1, P=0.90) and black/grizzly bears ($\chi 2$ .39, d.f.=1, P=0.52) collisions by age class. This analysis suggests that transportation category significantly influences age class collisions for elk (greater for YOY and YLY elk on highways) and mule deer (greater for YOY and YLY mule deer on the railway). In addition, age class collision rates for bighorn sheep, wolves, moose, black and grizzly bears are also not influenced by transportation category.

Train collisions involving adult female ungulates range from 37% for elk (n=449) to 20% for moose (n=117). Collisions involving adult males range from 32% for elk to 22% for moose. Train collisions involving YOY ungulates range from 10% for mule deer (n=121) to 7% for elk. Highway collisions involving adult female carnivores range from 36% for grizzly bears (n=11) to 12% for coyotes (n=161). Collisions involving adult males range from 46% for black bears (n=92) to 20% for coyotes (n=161). Highway collisions involving YOY carnivores range from 30% for coyotes (n=161) to 5% for black bears (n=92). Of particular note is the relatively high collision rate for YOY coyotes at 30%

(n=167) and wolves at 27% (n=48). Although not statistically significant these age classes may be at greater risk of collisions than adults may.

Train collisions involving adult female carnivores range from 26% for grizzly bears (n=31) to 13% for wolves (n=15). Collisions involving adult males range from 40% for wolves to 16% for grizzly bears. Train collisions involving YOY carnivores range from 33% for wolves to 3% for grizzly bears. Coyotes have been excluded from this analysis because of the small sample size on the railway. YOY carnivore mortality on the railway is greatest for wolves and is similar to levels recorded on highways.

3.5.7 Discussion

Collision rates vary by, species, sex and age class and transportation category. In some cases, these differences are statistically significant. Examples are yearling and young of year collision rates for elk (on highways) and mule deer (on the railway) that are notably higher than adult collisions. And female collision rates for elk and moose, which are notably higher on highways, compared to the railway. Reasons for differences in sex collision rates for elk and moose may be caused by sex based habitat selection. However, in the case of elk the majority of collisions occur where the highway and the railway are within close proximity and habitat selection is likely not a factor. Elk form large maternal herds made up of females and juveniles. The majority of collisions with female elk, and juveniles occur in close proximity to the Yellowhead Highway and the Canadian National Railway. Elk may become de-sensitized to vehicles on highways because of the frequency of traffic. In addition the disturbance created by trains (train size and length) may cause a greater flight response in elk than highway traffic. Reasons for the statistically significant differences in YOY and YLY collision rates for mule deer on the railway are not known.

Adult female mule deer collision rates are slightly higher for mule deer on highways compared to the railway (35% versus 30% respectively). An alternative explanation for differences in greater sex collision rates may be sex separation and associated seasonal habitat use adjacent to transportation corridors.

Although age class collision rates for carnivores are not statistically significant, they may be biologically significant because of lower carnivore reproduction, lower populations densities and larger home ranges, compared to ungulates. An example is YOY wolf collisions. Young of Year wolves accounted for 30% of wolf collisions on highways and the railway (n=53). Thirteen collisions with YOY wolves have occurred on highways, 10 of these collisions occurred in 1996 (4 collisions) and 1999 (6 collisions). In each year, the collisions were localised; (within 10 kilometres) suggesting these YOY wolves may have originated from individual packs during 1996 and 1999. Consequently, the effect of YOY mortality on individual wolf packs can be significant because virtually a complete age class is removed by an external source of mortality. A similar ratio exists for coyotes where 34% of all coyote collisions on highways are either YLY or YOY age classes. In addition, reporting of collisions with these age classes is underestimated because of the smaller body size of these age classes. Ruediger (1996) found that carnivores are particularly susceptible to highway mortality because of low reproductive rates, low population densities and the large areas required to sustain populations and individuals. Large home ranges require carnivores to regularly cross highways. Low reproductive rates and low population densities suggest that mortality will be additive rather than compensatory. The sex and age classes of each species are charted in Fig. 26 to 35.

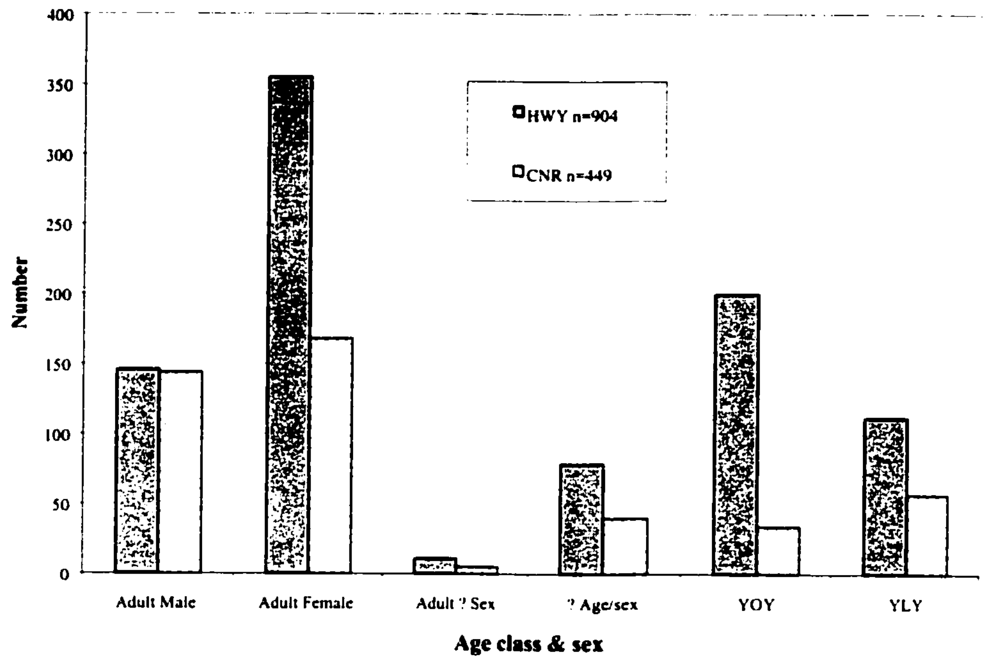

Figure 26. Elk collisions by age class & sex on highways and the railway, 1951-1999

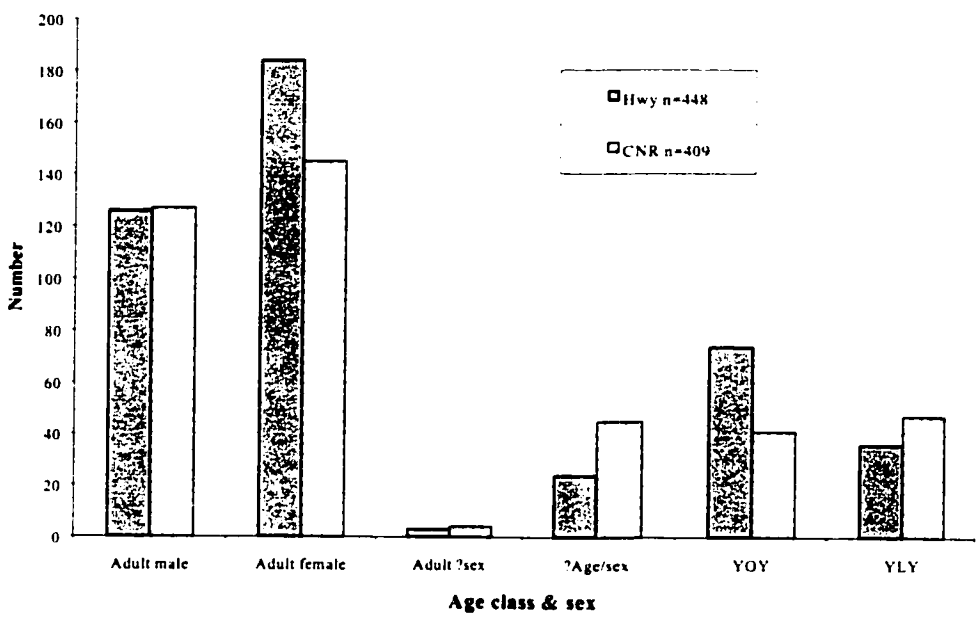

Figure 27. Bighorn sheep collisions by age class & sex on highways and the railway 1952-1999

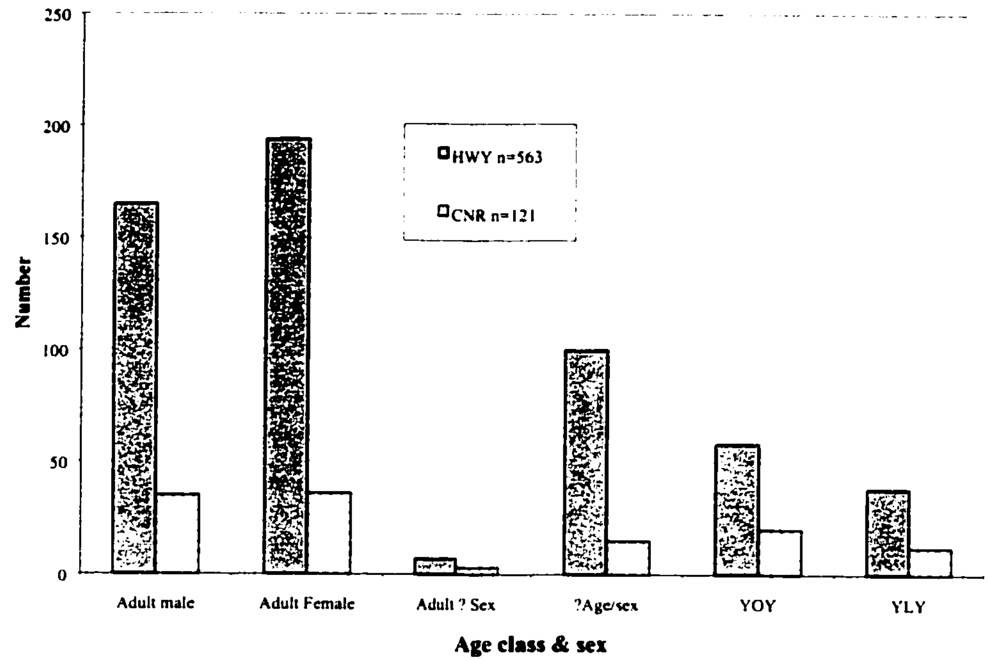

Figure 28. Mule deer collisions by age class & sex on highways and the railway, 1956-1999

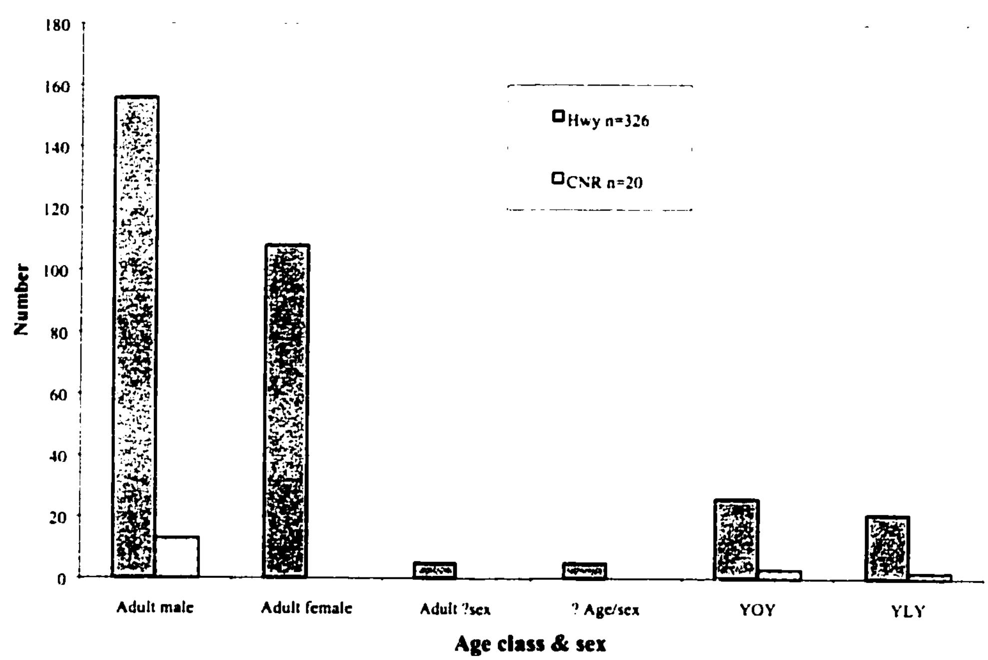

Figure 29. Whitetail deer collisions by age class & sex on highways and the railway, 1970-1999

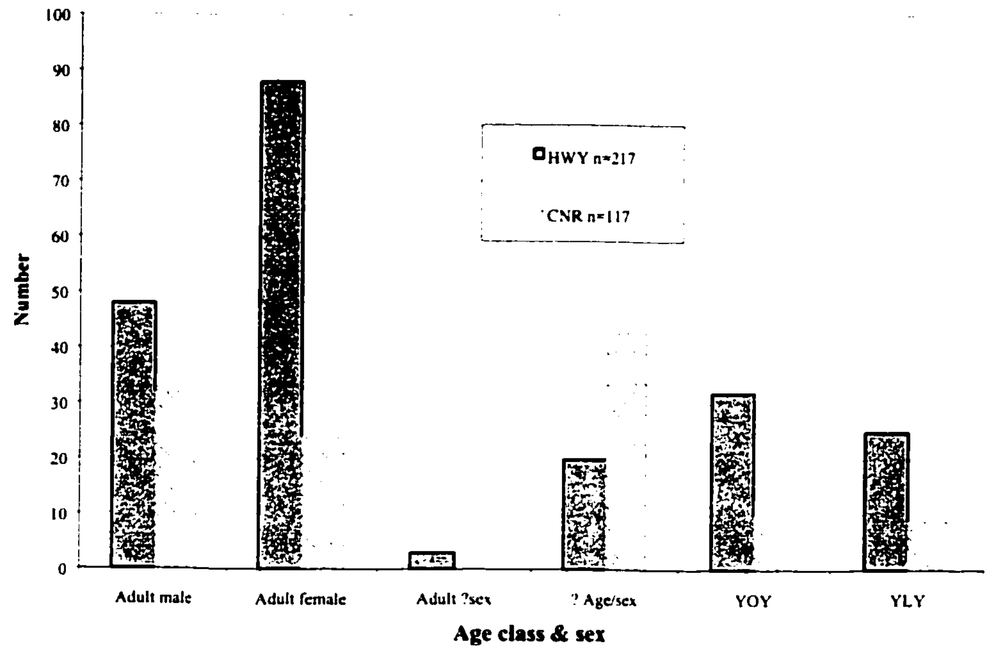

Figure 30. Moose collisions by age class & sex on highways and the railway, 1960-1999

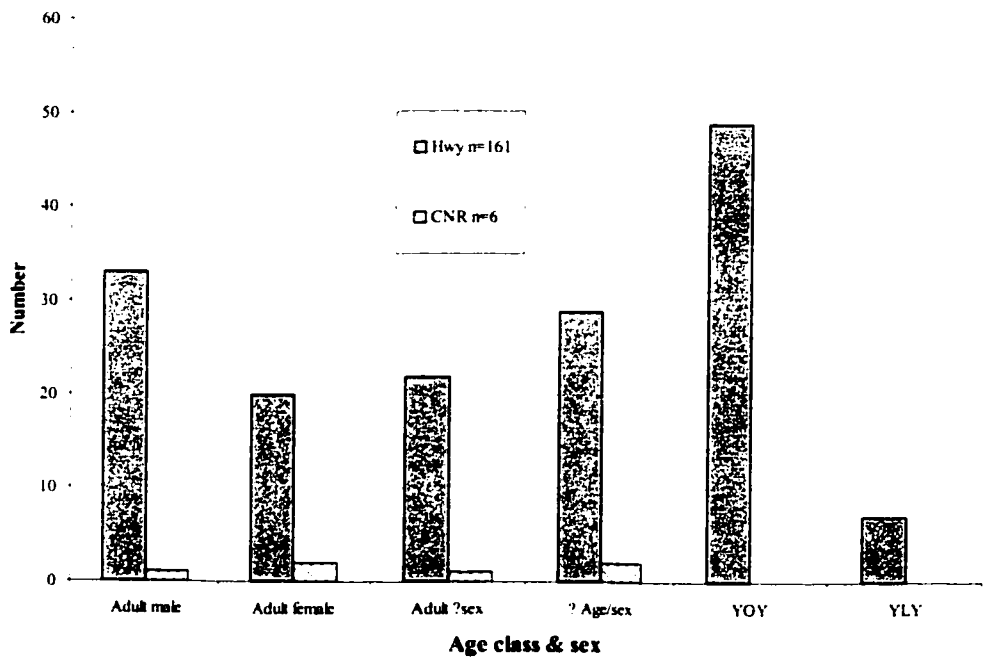

Figure 31. Coyote collisions by age class & sex on highways and the railway, 1962-1999

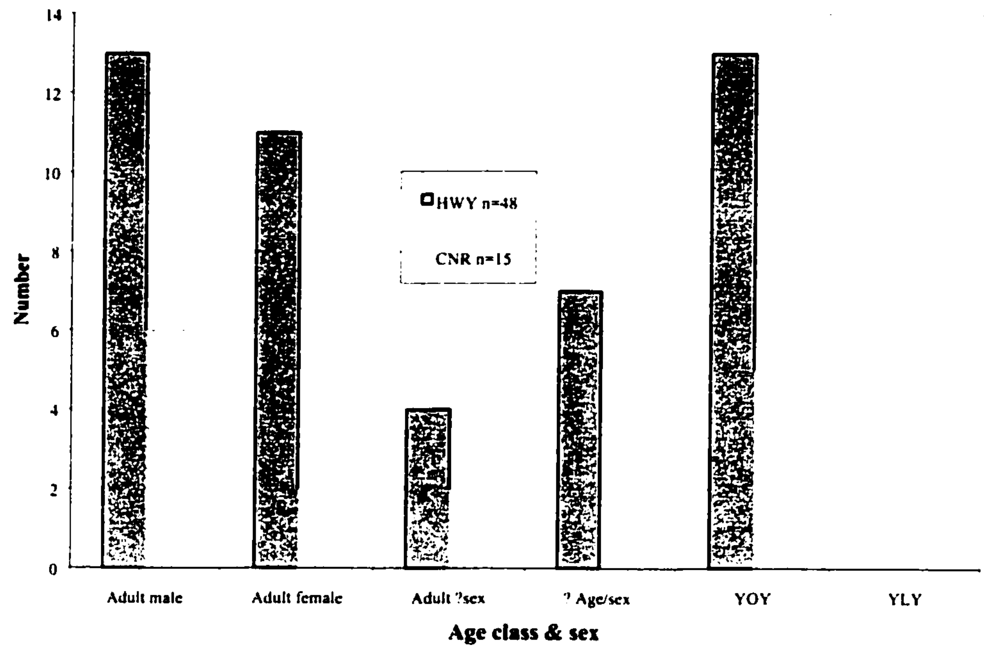

Figure 32. Wolf collisions by age class & sex on highways and the railway, 1968-1999

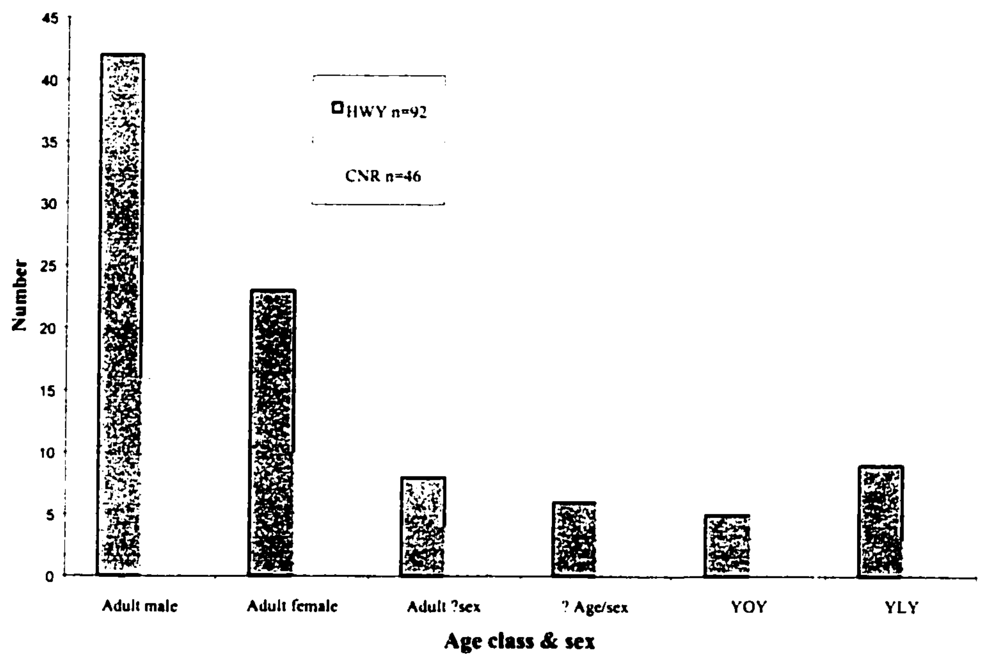

Figure 33. Black bear collisions by age class & sex on highways and the railway, 1969-1999

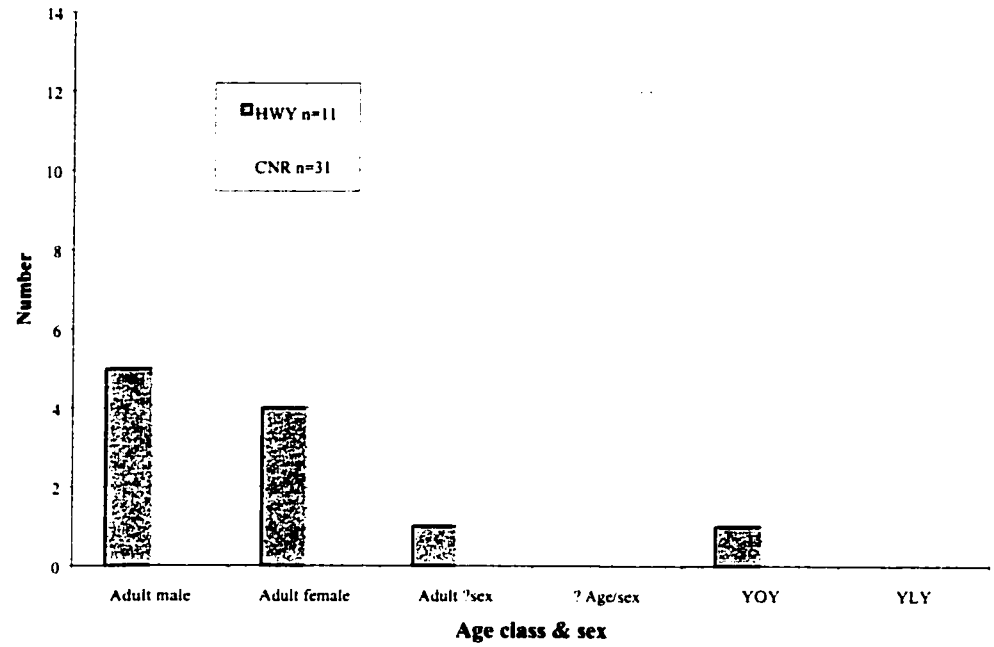

Figure 34. Grizzly bear collisions by age class & sex on highways and the railway, 1968-1999

3.6 WILDLIFE COLLISION LOCATIONS

Collision location data is vital in developing specific migration for individual species. Well-documented location data also minimises the costs of mitigation by focusing mitigations to high collision locations and minimises the effects of mitigation on human use of transportation corridors. Because of the importance of location data collision locations are presented in three formats, 1) in a map format showing collision locations in the montane, 2) in a table listing collisions per kilometre and 3) plotted as a cross section view beginning at the East Boundary (kilometre 1) and ending at the West Boundary. Only collision locations on the Yellowhead Highway and the Canadian National Railway are shown.

To accomplish this a map of the Yellowhead Highway and Canadian National Railway was segmented into 500-meter blocks and plotted on a Geographic Information System. This was done to assess the distribution of collisions on the Yellowhead Highway and Canadian National Railway. The Yellowhead Highway contains 154 blocks (77 kilometres.) and the Canadian National Railway contains 151 blocks (75.5 kilometres). Collision locations were plotted based on field recordings using Universal Transvererse Mercator Grid (U.T.M) maps at a scale of 1-50 000, with an accuracy of 100 meters (plus or minus).

During the study, period 1 642 collisions were recorded on the Yellowhead Highway and 697 were recorded on the Canadian National Railway. On the Yellowhead Highway 53% of collisions occur on a 31-kilometre section from kilometre 30 to 60, on the Canadian National Railway 50% of collisions occur along a 29-kilometre section from kilometre 25 to 53 (Fig.35 & 36). Table 7 contains the same location data listed in a table format. Collision locations for each species on the Yellowhead Highway and the Canadian National Railway are charted in figures 37 to 54. Collision locations are also presented in a Table format in Tables 8 through 16. From kilometre, 61 to 77 collisions decrease to the lowest numbers on each corridor. There are only two 1-kilometre sections on the Yellowhead Highway and the Canadian National Railway where collisions have not occurred. Kilometre 1 begins at the east entrance to Jasper National Park for both the Yellowhead Highway and the Canadian National Railway.

3.6.1 Discussion

Collisions occur with greater frequency in specific areas on the Yellowhead Highway and the Canadian National Railway. Collisions with individual species are localised. However, within these localised areas collisions are evenly distributed. Generally, collision locations correspond to habitat preferences of individual species and in some cases may identify locations where wildlife cross transportation corridors. However, the concept of corridor or wildlife crossing may be more of a human innovation that may not always be an accurate portrayal of high collision locations. Corridor implies a passageway or narrow strip of land used to access features on each side. Corridor also implies smallness compared to the description of larger land areas such as habitat requirements of larger species. Both the Yellowhead Highway and the Canadian National Railway are located in prime wildlife habitat and high collision locations may simply reflect the importance of specific habitat features. In most cases, the linear extent of these habitat features is extensive. Wildlife collision locations vary depending on the species. Because elk and bighorn sheep comprise the majority (53%) of collisions, high wildlife (Fig. 35 & 36) collision locations are influenced by habitat preferences of these species. Habitat preferences of elk and bighorn sheep reflect the high wildlife collisions in these areas. Most collisions occur near the Jasper townsite and east to kilometre 0. Exceptions are moose collisions, which peak west of the Jasper townsite (kilometre 53-75), and wolf and coyote collisions, which occur along the length of each corridor. Collision locations for wolves are the most widespread. High collision locations may also identify areas where transportation features influence collision rates an example is road alignment (curves) where sight lines for both drivers and wildlife are reduced.

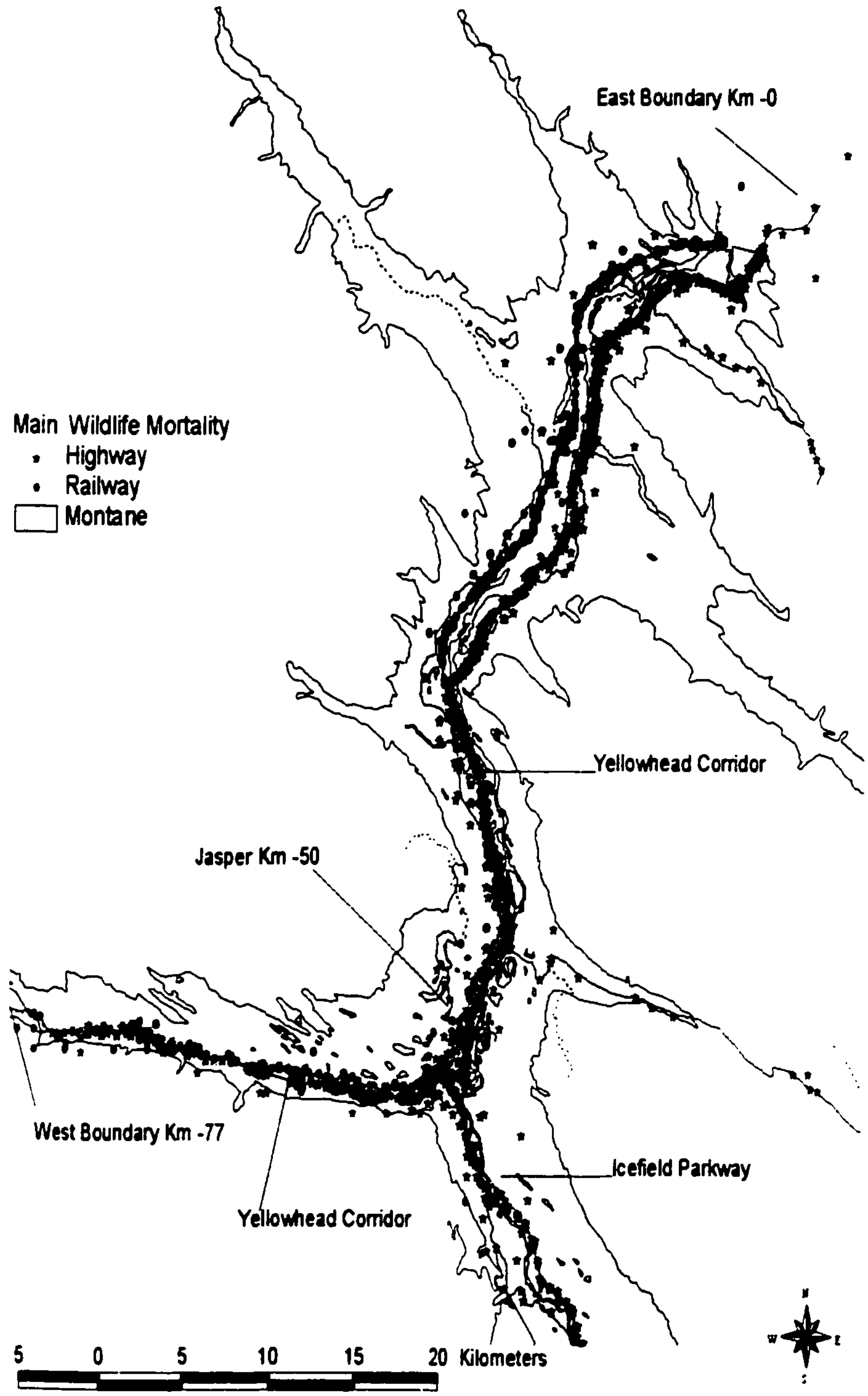

Figure 35. Wildlife collision locations on the Yellowhead Highway and the Canadian National Railway, 1951-1999

Table 7. Number of wildlife collisions by kilometre on the Yellowhead Highway (YH) and the Canadian National Railway (CNR), 1951-1999

Km	YH	CNR	Km	YH	CNR	Km	YH	CNR
1	51	63	*27*	16	4	*53*	29	14
2	22	9	*28*	26	11	*54*	26	5
3	30	5	*29*	25	7	*55*	33	6
4	15	3	*30*	41	11	*56*	17	3
5	14	2	*31*	93	5	*57*	11	3
6	28	7	*32*	15	4	*58*	17	4
7	15	6	*33*	27	4	*59*	15	4
8	22	9	*34*	13	10	*60*	22	3
9	28	7	*35*	13	14	*61*	8	8
10	15	6	*36*	20	17	*62*	5	3
11	20	1	*37*	16	17	*63*	1	5
12	27	7	*38*	14	8	*64*	7	2
13	40	2	*39*	12	12	*65*	12	5
14	17	3	*40*	35	18	*66*	0	3
15	36	7	*41*	39	3	*67*	2	11
16	23	17	*42*	14	19	*68*	2	4
17	15	13	*43*	15	8	*69*	6	2
18	33	11	*44*	37	5	*70*	11	6
19	15	7	*45*	30	11	*71*	5	12
20	13	12	*46*	25	25	*72*	11	4
21	22	19	*47*	60	14	*73*	3	6
22	15	14	*48*	38	6	*74*	7	1
23	19	9	*49*	69	9	*75*	9	1
24	35	7	*50*	22	10	*76*	1	0
25	20	19	*51*	25	12	*77*	6	2
26	9	21	*52*	37	30	*Total*	1642	697

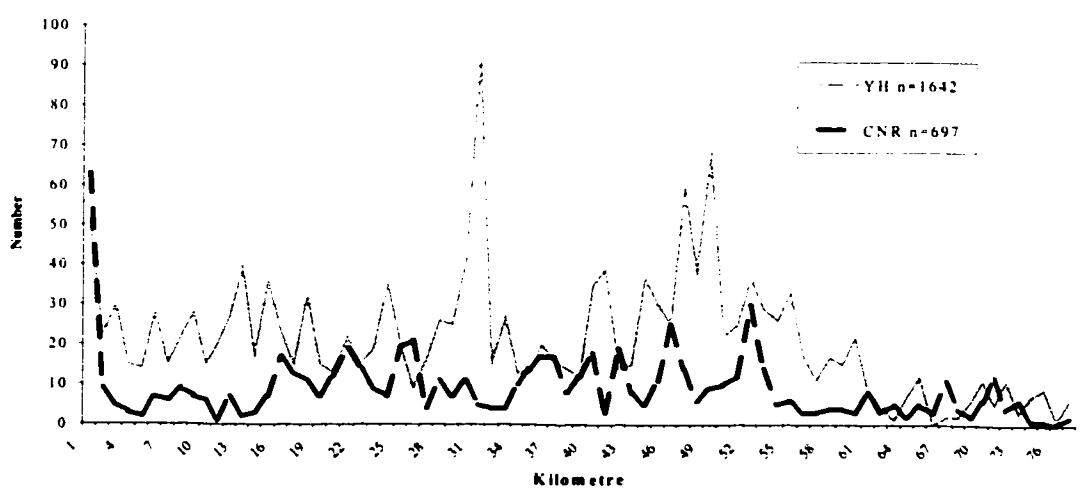

Figure 36. Number of wildlife collision by kilometre on the Yellowhead Highway (YH) and the Canadian National Railway (CNR), 1951-1999

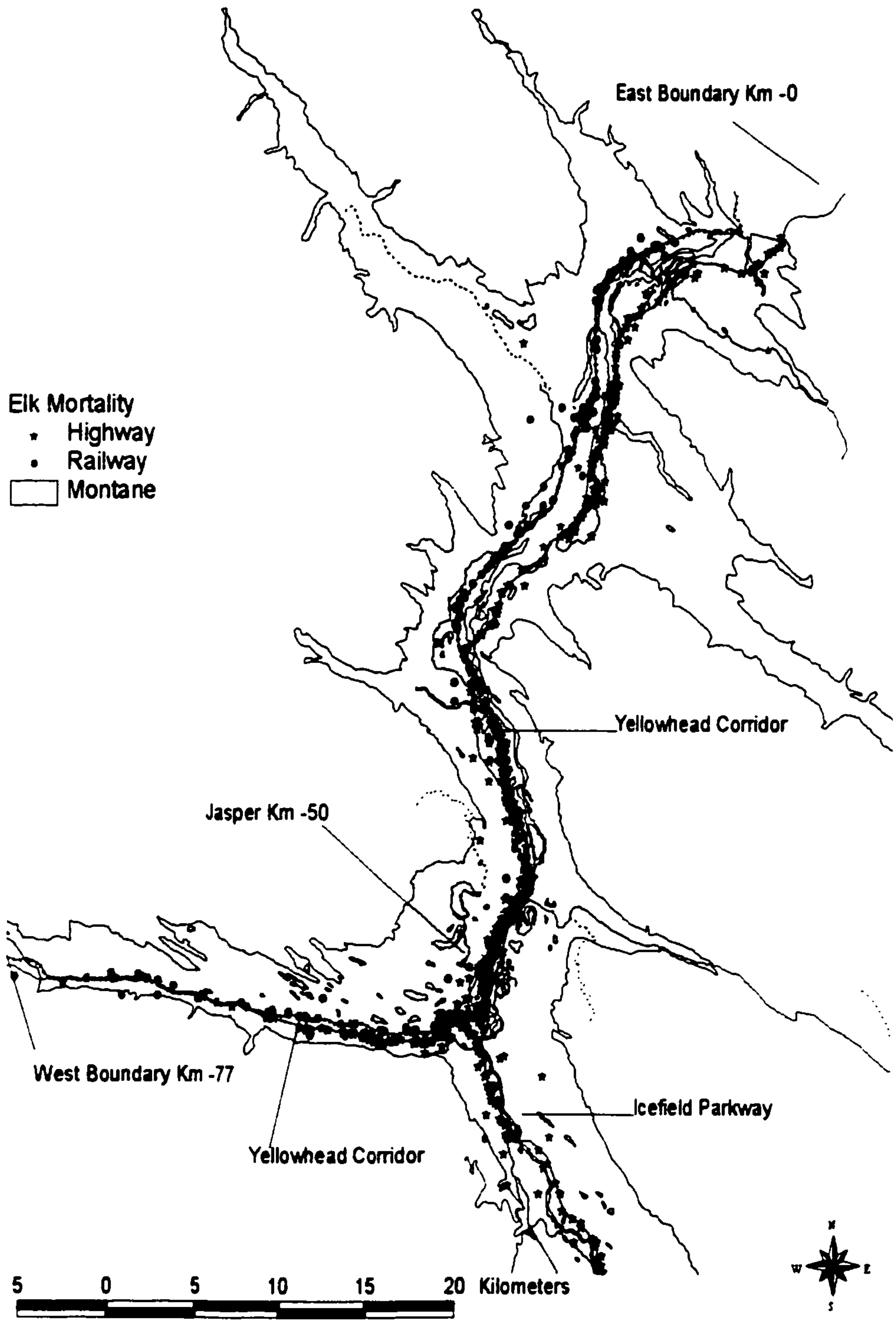

Figure 37. Elk collision locations on the Yellowhead Highway and the Canadian National Railway, 1951-1999

Table 8. Number of elk collision by kilometre on the Yellowhead Highway (YH) and the Canadian National Railway (CNR), 1951-1999

Km	YH	CNR	Km	YH	CNR	Km	YH	CNR
1	5	0	*27*	1	3	*53*	10	10
2	2	0	*28*	5	5	*54*	9	2
3	3	0	*29*	5	4	*55*	15	3
4	1	1	*30*	4	3	*56*	7	3
5	0	2	*31*	2	1	*57*	5	0
6	2	4	*32*	3	2	*58*	8	2
7	4	3	*33*	7	2	*59*	7	1
8	3	6	*34*	2	5	*60*	7	1
9	1	6	*35*	5	13	*61*	2	5
10	2	4	*36*	13	15	*62*	4	2
11	4	0	*37*	10	16	*63*	1	3
12	3	2	*38*	11	8	*64*	1	1
13	2	0	*39*	6	7	*65*	2	2
14	1	2	*40*	27	15	*66*	0	1
15	12	5	*41*	28	3	*67*	1	4
16	6	12	*42*	4	3	*68*	0	1
17	5	8	*43*	7	1	*69*	2	0
18	8	2	*44*	23	2	*70*	0	0
19	6	5	*45*	20	4	*71*	0	3
20	6	0	*46*	13	3	*72*	0	0
21	11	2	*47*	23	4	*73*	0	2
22	4	3	*48*	23	1	*74*	2	1
23	11	2	*49*	49	0	*75*	0	0
24	1	2	*50*	10	1	*76*	0	0
25	2	7	*51*	13	3	*77*	2	0
26	0	5	*52*	23	21	*Total*	527	275

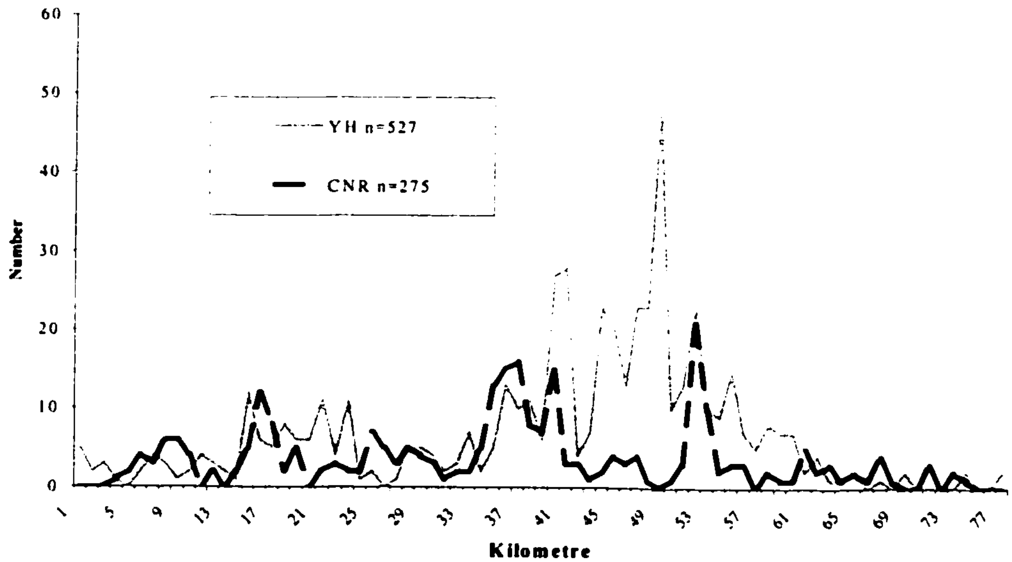

Figure 38. Number of elk collisions by kilometre on the Yellowhead Highway (YH) and the Canadian National Railway (CNR), 1951-1999

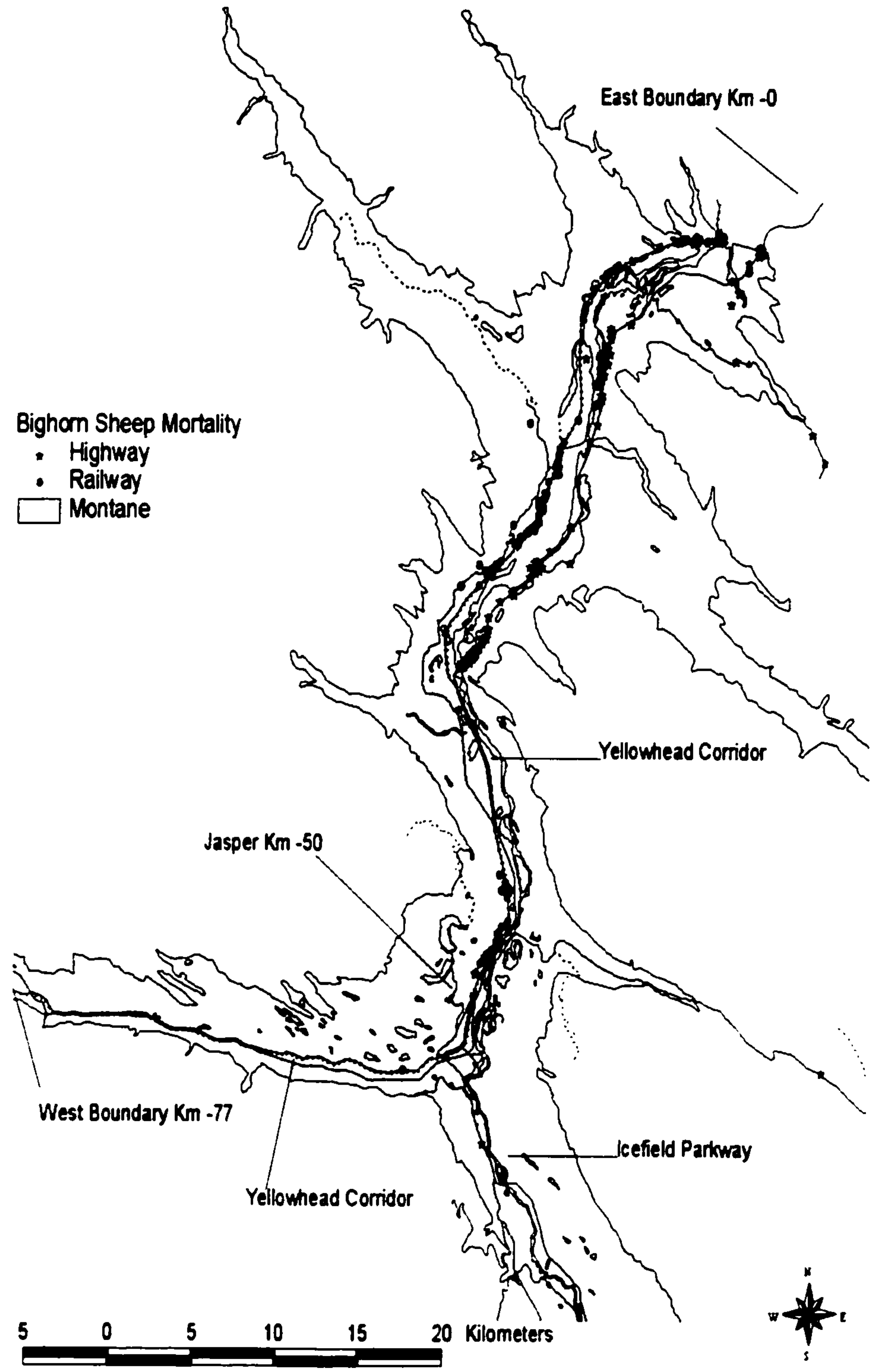

Figure 39. Bighorn sheep collision locations on the Yellowhead Highway and the Canadian National Railway, 1952-1999

Table 9. Number of bighorn sheep collisions by kilometre on the Yellowhead Highway (YH) and the Canadian National Railway (CNR), 1952-1999

Km	YH	CNR	Km	YH	CNR	Km	YH	CNR
1	20	60	*27*	1	0	*53*	0	0
2	0	7	*28*	1	0	*54*	0	0
3	2	5	*29*	11	0	*55*	0	1
4	0	1	*30*	29	0	*56*	0	0
5	0	0	*31*	81	0	*57*	0	0
6	0	1	*32*	0	0	*58*	0	0
7	0	0	*33*	2	0	*59*	0	0
8	0	0	*34*	1	0	*60*	0	0
9	0	0	*35*	0	0	*61*	0	0
10	1	0	*36*	0	0	*62*	0	0
11	3	0	*37*	0	0	*63*	0	0
12	11	0	*38*	0	0	*64*	0	0
13	31	0	*39*	0	0	*65*	0	0
14	12	0	*40*	0	0	*66*	0	0
15	7	0	*41*	0	0	*67*	0	0
16	1	1	*42*	0	12	*68*	0	0
17	1	3	*43*	0	6	*69*	0	0
18	0	8	*44*	0	3	*70*	0	0
19	0	2	*45*	1	7	*71*	0	0
20	0	12	*46*	2	20	*72*	0	0
21	1	17	*47*	24	2	*73*	0	0
22	0	11	*48*	4	1	*74*	0	0
23	1	7	*49*	1	0	*75*	0	0
24	26	2	*50*	0	0	*76*	0	0
25	9	9	*51*	0	0	*77*	0	0
26	3	5	*52*	0	0	*Total*	287	203

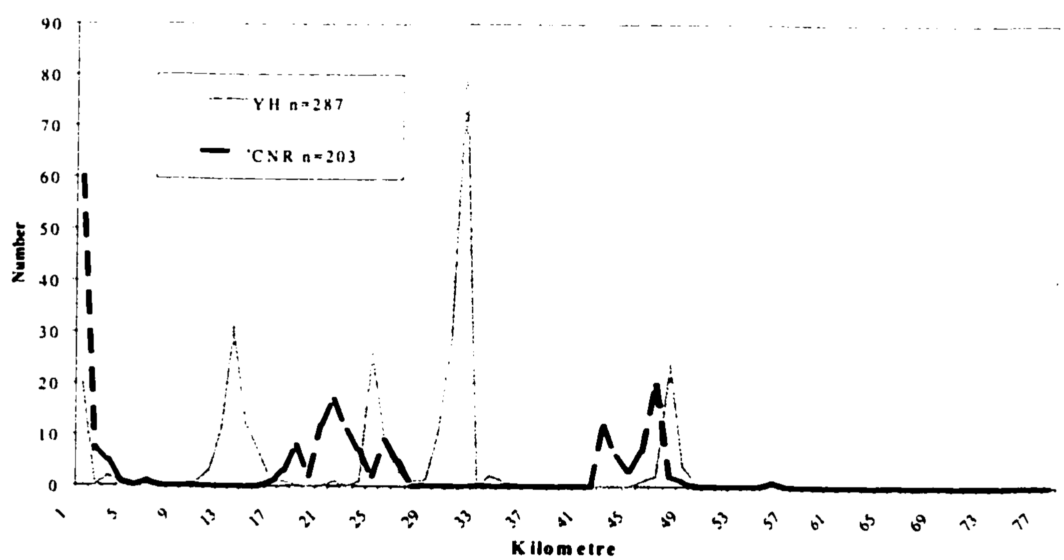

Figure 40. Number of bighorn sheep collisions by kilometre on the Yellowhead Highway (YH) and the Canadian National Railway (CNR), 1952-1999

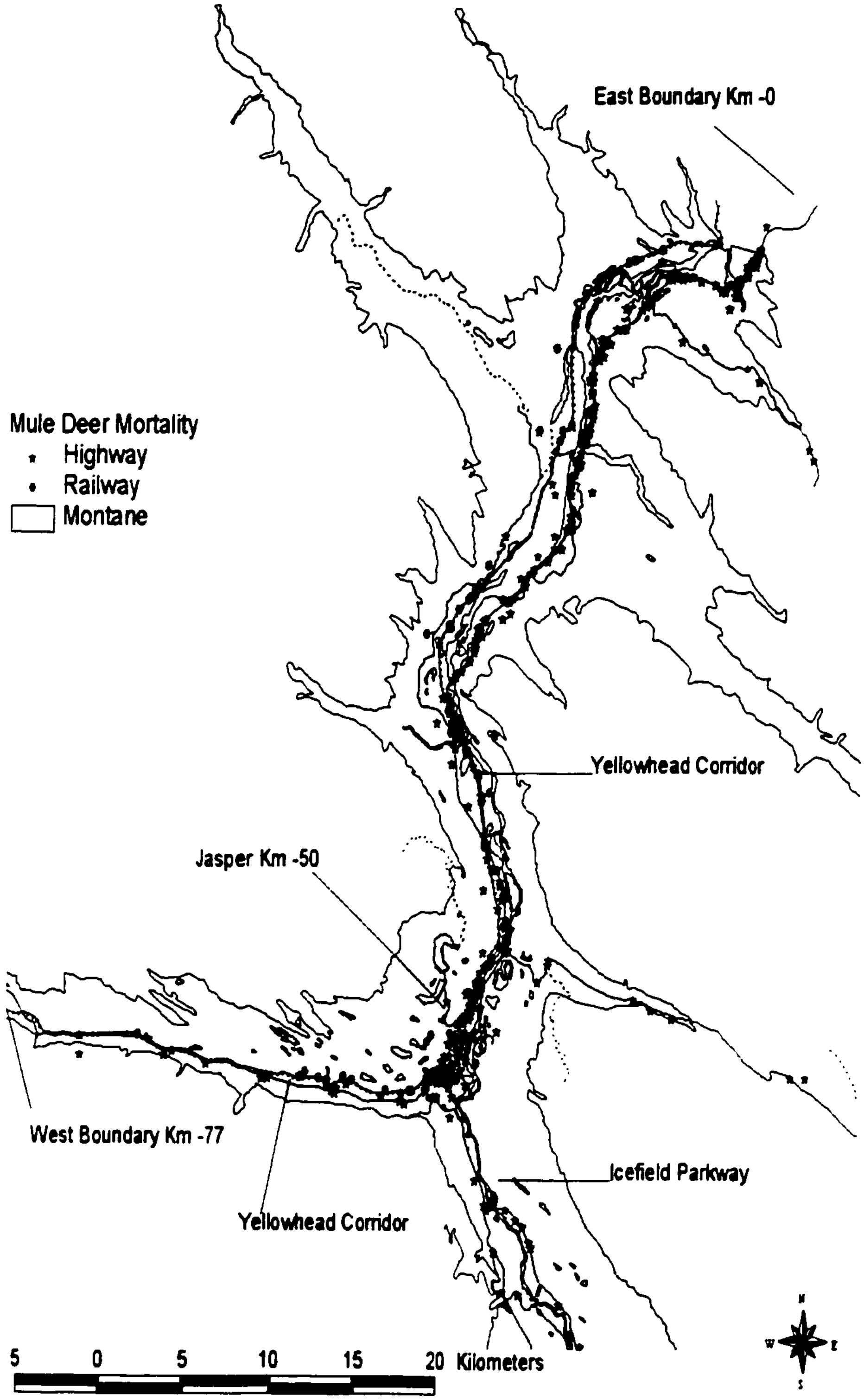

Figure 41. Mule deer collision locations on the Yellowhead Highway and the Canadian National Railway, 1956-1999

Table 10. Number of mule deer collisions by kilometre on the Yellowhead Highway (YH) and the Canadian National Railway (CNR), 1956-1999

Km	YH	CNR	Km	YH	CNR	Km	YH	CNR
1	10	1	*27*	10	1	*53*	16	2
2	7	0	*28*	6	2	*54*	3	3
3	9	0	*29*	3	0	*55*	0	1
4	3	1	*30*	5	5	*56*	3	0
5	2	0	*31*	3	0	*57*	1	1
6	9	2	*32*	6	2	*58*	0	1
7	1	0	*33*	8	2	*59*	1	2
8	5	1	*34*	3	3	*60*	3	2
9	1	0	*35*	4	0	*61*	0	0
10	7	0	*36*	2	0	*62*	0	0
11	3	0	*37*	2	1	*63*	0	0
12	5	0	*38*	0	0	*64*	3	0
13	4	0	*39*	2	3	*65*	0	0
14	2	0	*40*	2	0	*66*	0	0
15	6	1	*41*	3	0	*67*	0	0
16	8	2	*42*	5	0	*68*	1	0
17	4	1	*43*	2	0	*69*	0	0
18	9	0	*44*	3	0	*70*	2	0
19	4	0	*45*	5	0	*71*	0	1
20	2	0	*46*	6	1	*72*	0	0
21	6	0	*47*	9	5	*73*	0	0
22	6	0	*48*	8	4	*74*	0	0
23	5	0	*49*	11	8	*75*	1	0
24	3	1	*50*	8	9	*76*	0	0
25	5	1	*51*	7	8	*77*	0	0
26	3	4	*52*	10	8	*Total*	296	90

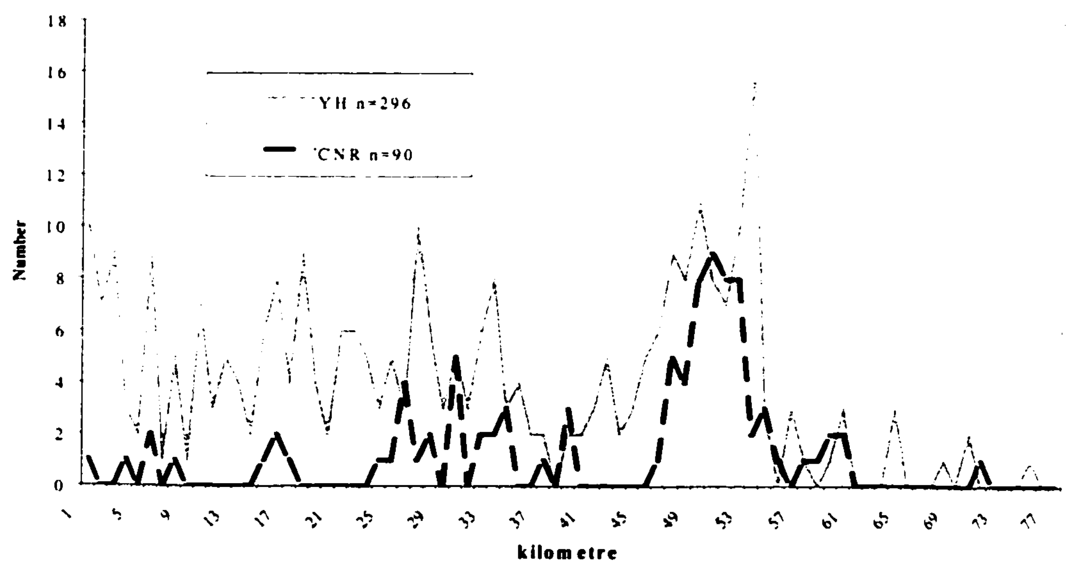

Figure 42. Number of mule deer collisions by kilometre on the Yellowhead Highway (YH) and the Canadian National Railway (CNR), 1956-1999

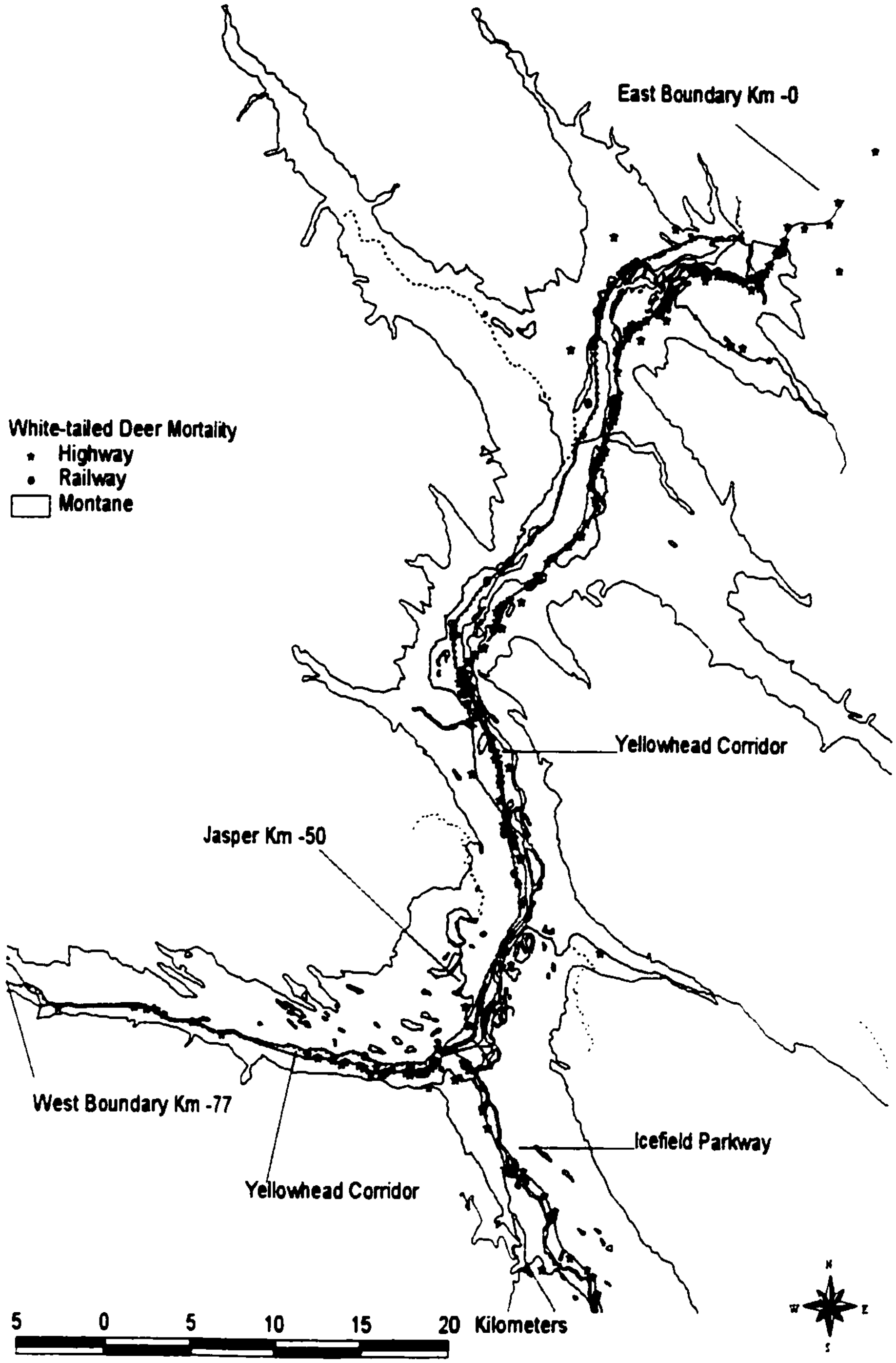

Figure 43. Whitetail deer collision locations on the Yellowhead Highway and the Canadian National Railway, 1970-1999

Table 11. Number of whitetail deer collisions by kilometre on the Yellowhead Highway (YH) and the Canadian National Railway (CNR), 1970-1999

Km	YH	CNR	Km	YH	CNR	Km	YH	CNR
1	12	0	*27*	1	0	*53*	0	0
2	11	0	*28*	6	0	*54*	6	0
3	10	0	*29*	3	2	*55*	8	0
4	10	0	*30*	0	1	*56*	6	0
5	9	0	*31*	2	2	*57*	2	0
6	13	0	*32*	5	0	*58*	4	1
7	3	0	*33*	7	0	*59*	2	0
8	10	0	*34*	4	0	*60*	2	0
9	20	0	*35*	0	0	*61*	3	0
10	1	1	*36*	2	2	*62*	1	0
11	9	0	*37*	3	0	*63*	0	0
12	4	1	*38*	2	0	*64*	0	0
13	0	0	*39*	2	0	*65*	0	0
14	1	0	*40*	3	1	*66*	0	0
15	6	1	*41*	4	0	*67*	1	0
16	4	0	*42*	2	2	*68*	0	0
17	2	1	*43*	0	0	*69*	1	0
18	8	0	*44*	1	0	*70*	0	0
19	4	0	*45*	0	0	*71*	1	0
20	2	0	*46*	1	1	*72*	1	0
21	1	0	*47*	1	0	*73*	1	0
22	3	0	*48*	1	0	*74*	0	0
23	1	0	*49*	0	0	*75*	0	0
24	2	0	*50*	0	0	*76*	0	0
25	3	0	*51*	0	0	*77*	1	0
26	2	2	*52*	0	1	*Total*	241	19

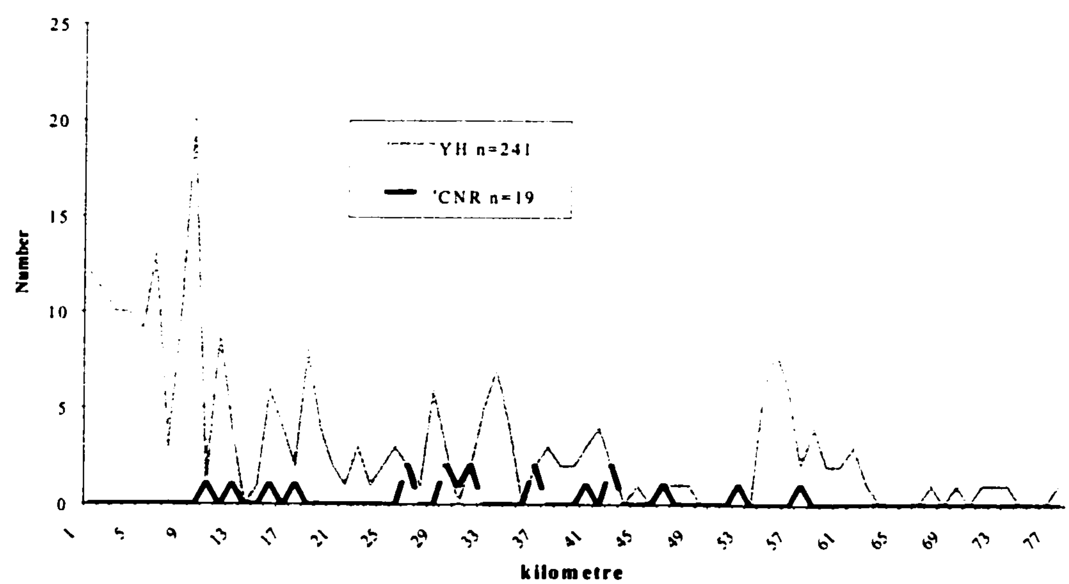

Figure 44. Number of whitetail deer collisions by kilometre on the Yellowhead Highway (YH) and the Canadian National Railway (CNR), 1970-1999

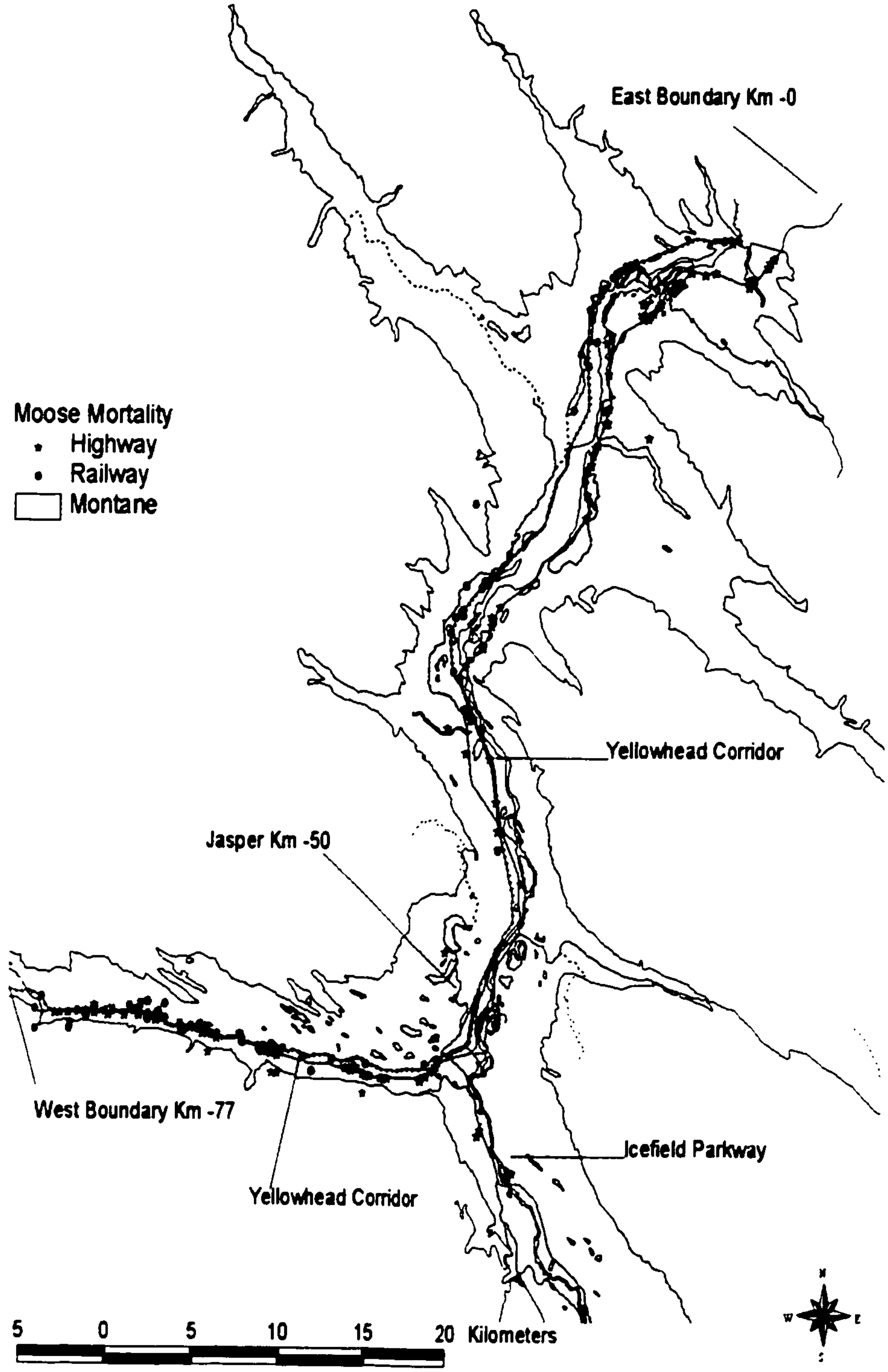

Figure 45. Moose collision locations on the Yellowhead Highway and the Canadian National Railway, 1960-1999

Table 12. Number of moose collisions by kilometre on the Yellowhead Highway (YH) and the Canadian National Railway (CNR), 1960-1999

Km	YH	CNR	Km	YH	CNR	Km	YH	CNR
1	2	1	*27*	0	0	*53*	0	1
2	1	0	*28*	3	4	*54*	4	0
3	4	0	*29*	1	0	*55*	6	0
4	0	0	*30*	0	2	*56*	0	0
5	2	0	*31*	0	1	*57*	1	1
6	1	0	*32*	1	0	*58*	2	1
7	5	2	*33*	1	0	*59*	4	1
8	3	1	*34*	2	0	*60*	5	0
9	4	1	*35*	1	0	*61*	0	1
10	3	1	*36*	1	0	*62*	0	1
11	0	0	*37*	0	0	*63*	0	2
12	1	1	*38*	0	0	*64*	1	1
13	1	1	*39*	2	0	*65*	8	3
14	0	0	*40*	1	1	*66*	0	1
15	2	0	*41*	0	0	*67*	0	5
16	2	0	*42*	0	0	*68*	1	2
17	2	0	*43*	1	0	*69*	2	2
18	5	0	*44*	0	0	*70*	4	6
19	0	0	*45*	0	0	*71*	1	5
20	1	0	*46*	0	0	*72*	7	3
21	1	0	*47*	0	0	*73*	1	4
22	0	0	*48*	0	0	*74*	2	0
23	0	0	*49*	0	0	*75*	6	1
24	0	2	*50*	0	0	*76*	1	0
25	0	1	*51*	0	0	*77*	3	1
26	0	4	*52*	0	0	*Total*	113	65

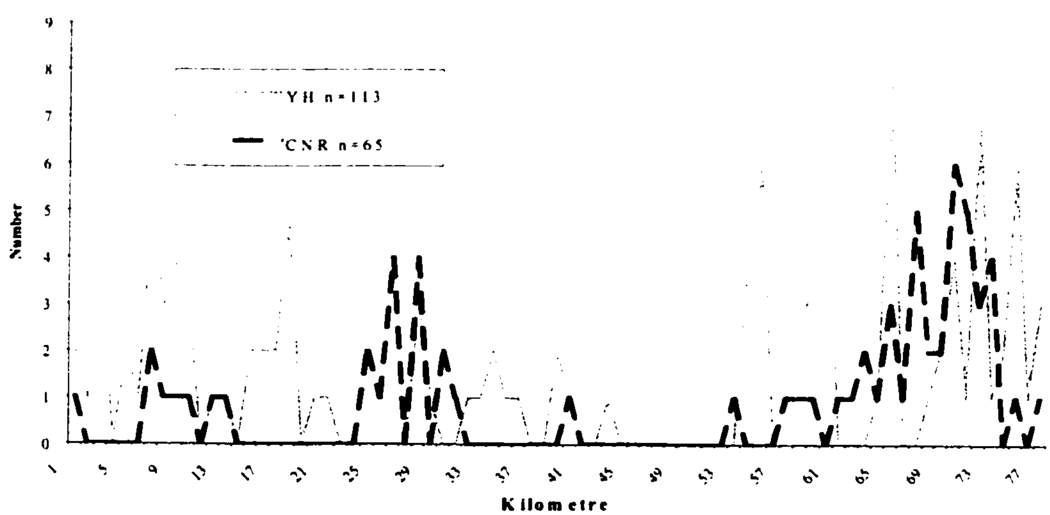

Figure 46. Number of moose collisions by kilometre on the Yellowhead Highway (YH) and the Canadian National Railway (CNR), 1960-1999

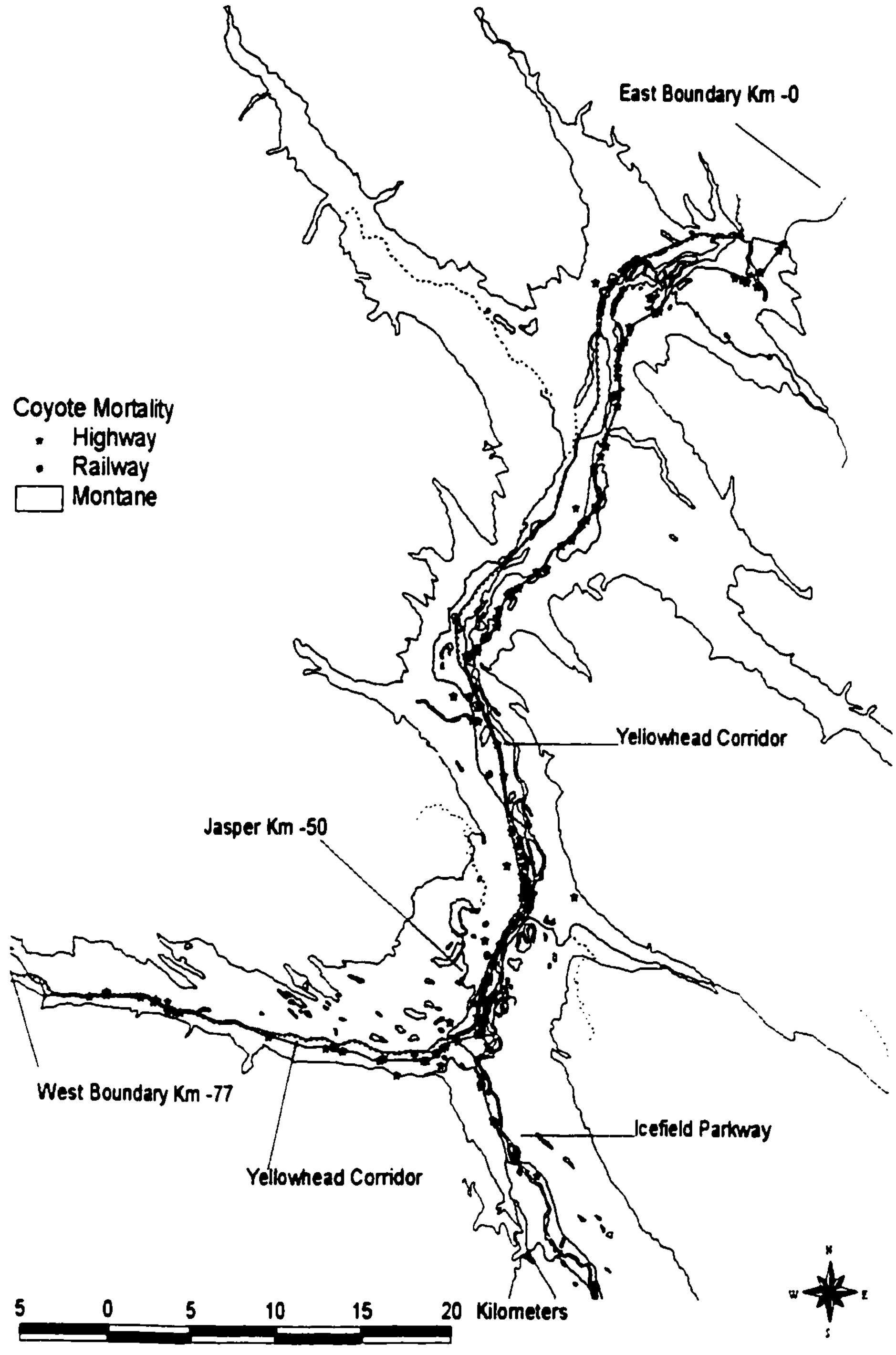

Figure 47. Coyote collision locations on the Yellowhead Highway and the Canadian National Railway, 1962-1999

Table 13. Number of coyote collisions by kilometre on the Yellowhead Highway (YH) and the Canadian National Railway (CNR), 1962-1999

Km	YH	CNR	Km	YH	CNR	Km	YH	CNR
1	1	0	*27*	3	0	*53*	1	0
2	1	0	*28*	3	0	*54*	3	1
3	2	0	*29*	2	0	*55*	3	0
4	1	0	*30*	1	0	*56*	0	0
5	0	0	*31*	5	0	*57*	0	0
6	0	0	*32*	0	0	*58*	2	0
7	0	0	*33*	2	0	*59*	0	0
8	0	0	*34*	1	0	*60*	1	0
9	1	0	*35*	1	0	*61*	2	0
10	1	0	*36*	1	0	*62*	0	0
11	1	0	*37*	0	0	*63*	0	0
12	2	0	*38*	1	0	*64*	1	0
13	1	0	*39*	0	0	*65*	0	0
14	1	0	*40*	0	0	*66*	0	0
15	2	0	*41*	2	0	*67*	0	0
16	0	0	*42*	3	0	*68*	0	0
17	0	0	*43*	4	0	*69*	0	0
18	2	0	*44*	6	0	*70*	5	0
19	1	0	*45*	4	0	*71*	2	0
20	1	0	*46*	1	0	*72*	2	0
21	2	0	*47*	2	1	*73*	0	0
22	2	0	*48*	1	0	*74*	2	0
23	1	0	*49*	4	0	*75*	1	0
24	1	0	*50*	1	0	*76*	0	0
25	1	0	*51*	4	0	*77*	0	0
26	1	0	*52*	3	0	*Total*	106	2

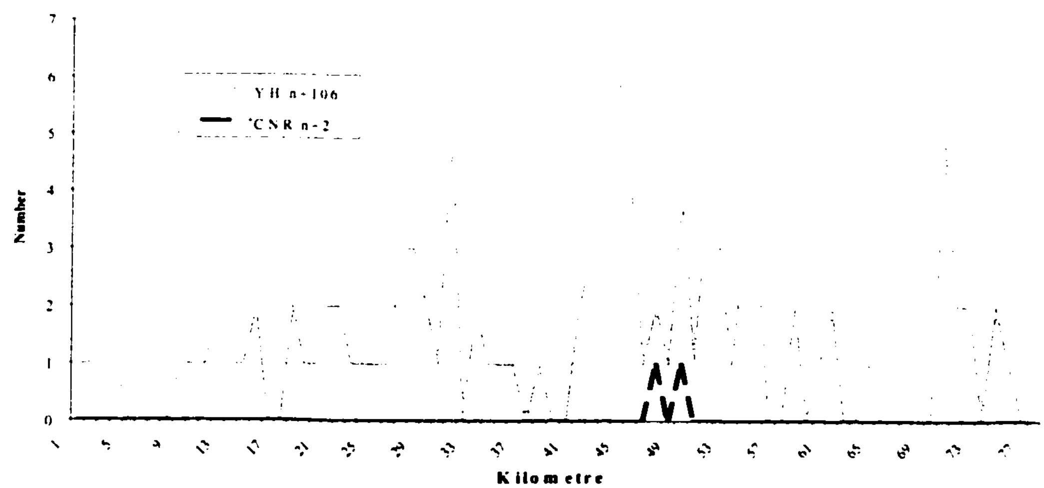

Figure 48. Number of coyote collisions by kilometre on the Yellowhead Highway (YH) and the Canadian National Railway (CNR), 1962-1999

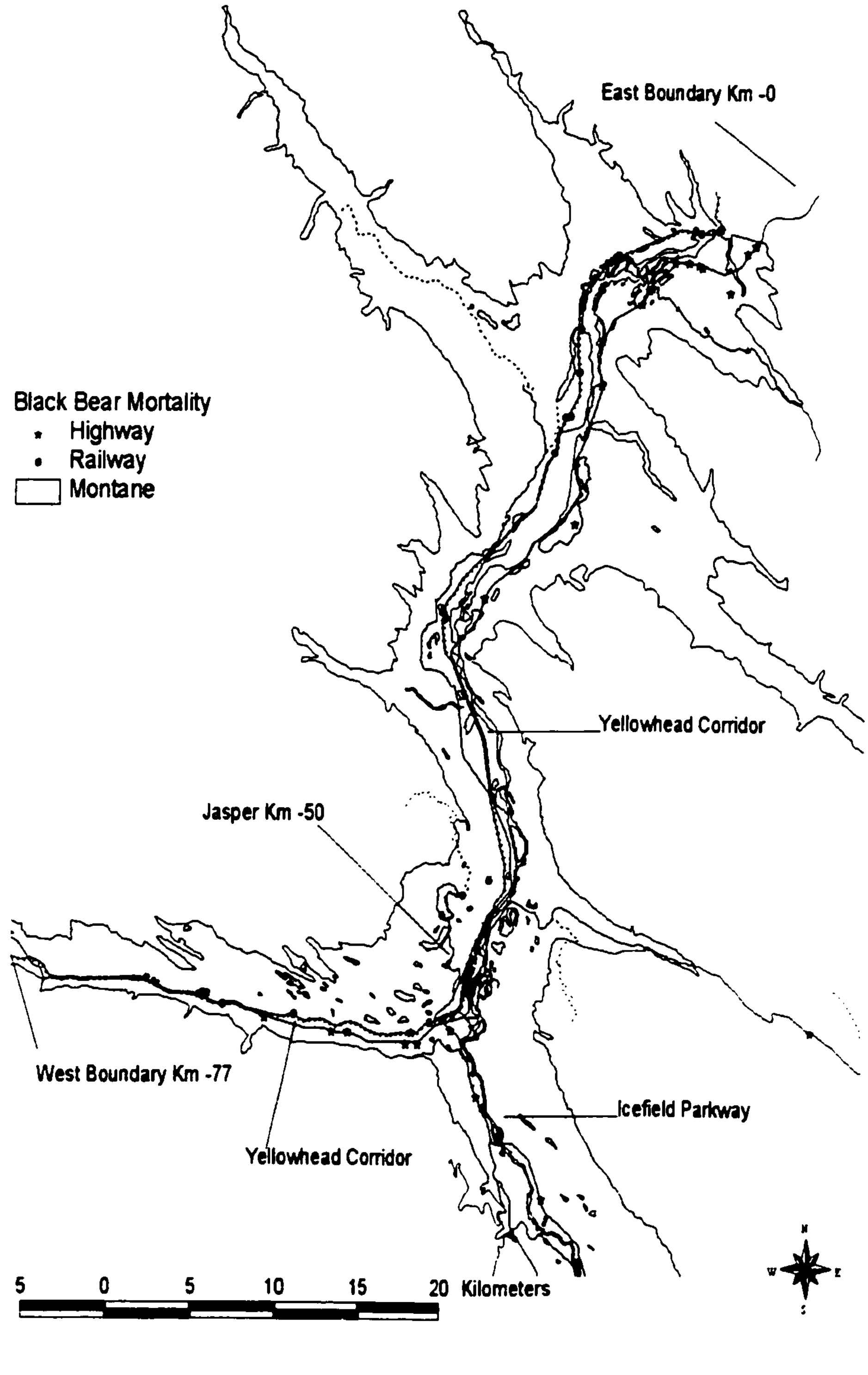

Figure 49. Black bear collision locations on the Yellowhead Highway and the Canadian National Railway, 1969-1999

Table 14. Number of black bear collisions by kilometre on the Yellowhead Highway (YH) and the Canadian National Railway (CNR), 1969-1999

Km	YH	CNR	Km	YH	CNR	Km	YH	CNR
1	1	1	*27*	0	0	*53*	2	1
2	0	2	*28*	1	0	*54*	0	0
3	0	0	*29*	0	1	*55*	1	0
4	0	0	*30*	0	0	*56*	1	0
5	1	0	*31*	0	0	*57*	0	0
6	2	0	*32*	0	0	*58*	0	0
7	2	0	*33*	0	0	*59*	0	0
8	1	1	*34*	0	0	*60*	1	0
9	1	0	*35*	0	0	*61*	1	1
10	0	0	*36*	0	0	*62*	0	0
11	0	0	*37*	0	0	*63*	0	0
12	1	1	*38*	0	0	*64*	0	0
13	0	0	*39*	0	0	*65*	1	0
14	0	1	*40*	1	0	*66*	0	1
15	1	0	*41*	0	0	*67*	0	1
16	0	2	*42*	0	0	*68*	0	0
17	0	0	*43*	0	0	*69*	0	0
18	0	1	*44*	0	0	*70*	0	0
19	0	0	*45*	0	0	*71*	0	1
20	0	0	*46*	0	0	*72*	0	0
21	0	0	*47*	1	0	*73*	0	0
22	0	0	*48*	1	0	*74*	0	0
23	0	0	*49*	3	0	*75*	0	0
24	0	0	*50*	3	0	*76*	0	0
25	0	0	*51*	1	0	*77*	0	0
26	0	0	*52*	0	2	*Total*	28	18

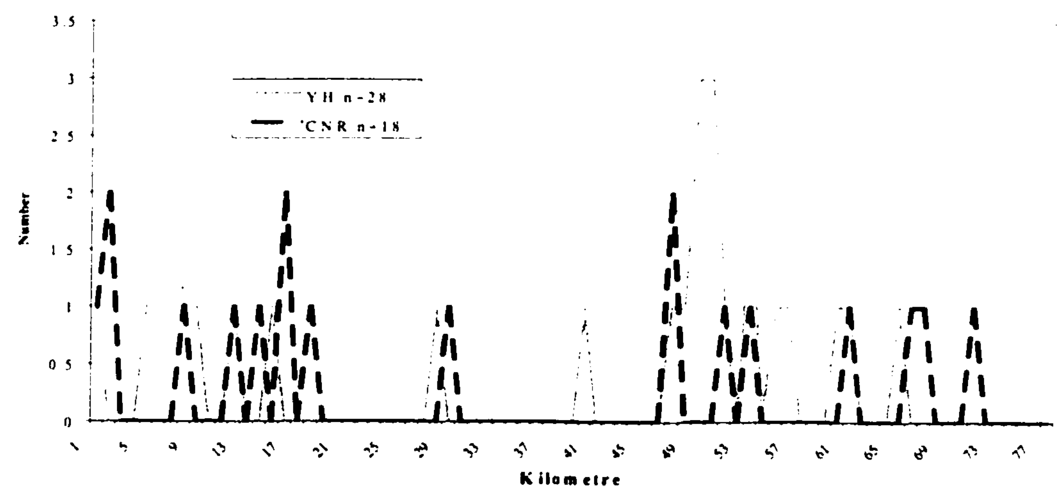

Figure 50. Number of black bear collisions by kilometre on the Yellowhead Highway (YH) and the Canadian National Railway (CNR), 1969-1999

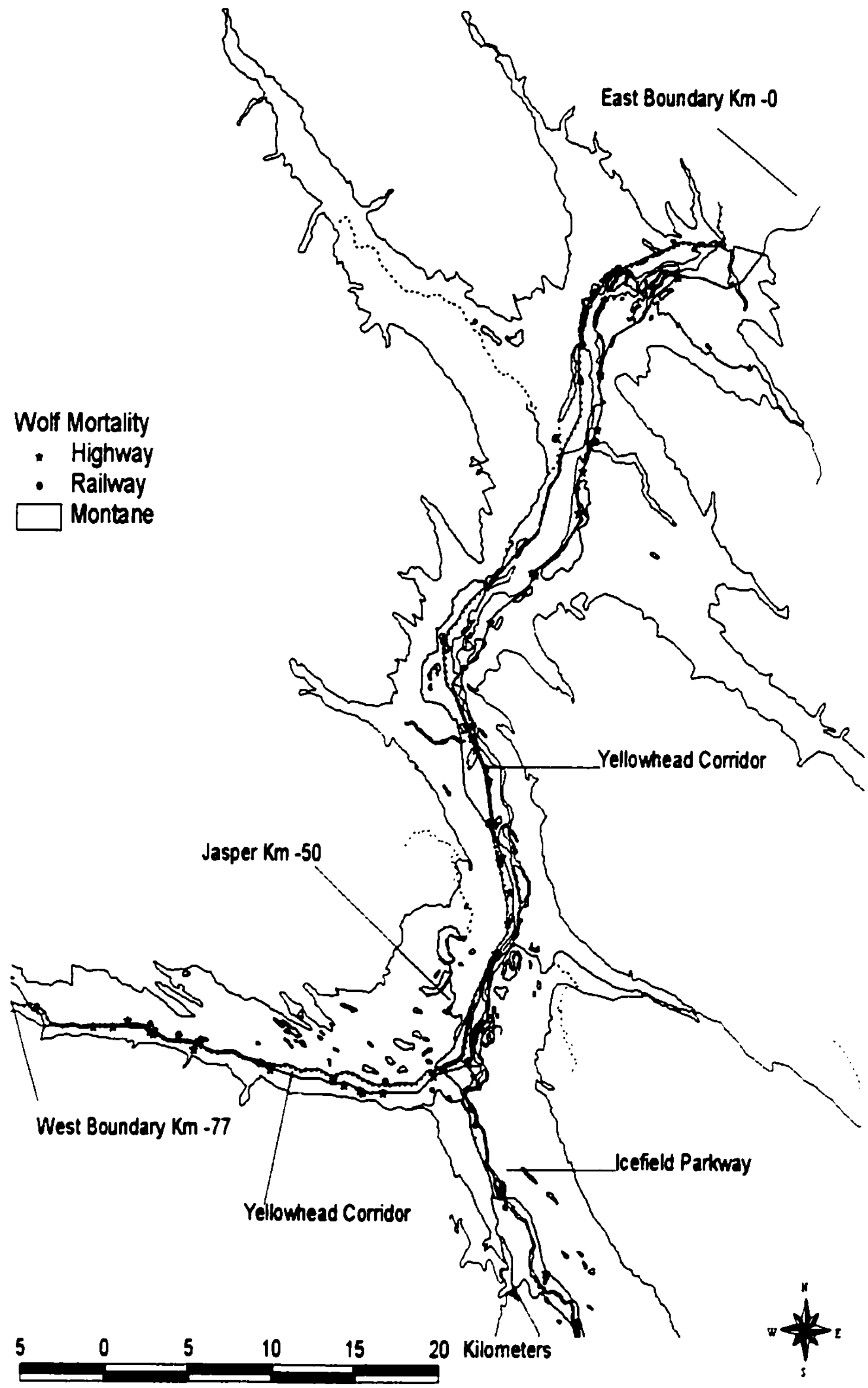

Figure 51. Wolf collision locations on the Yellowhead Highway and the Canadian National Railway, 1968-1999

Table 15. Number of wolf collisions by kilometre on the Yellowhead Highway (YH) and the Canadian National Railway (CNR), 1968-1999

Km	YH	CNR	Km	YH	CNR	Km	YH	CNR
1	0	0	*27*	0	0	*53*	0	0
2	0	0	*28*	1	0	*54*	1	0
3	0	0	*29*	0	0	*55*	0	1
4	0	0	*30*	0	0	*56*	0	0
5	0	0	*31*	0	0	*57*	2	0
6	1	0	*32*	0	0	*58*	1	0
7	0	1	*33*	0	0	*59*	1	0
8	0	0	*34*	0	2	*60*	2	0
9	0	0	*35*	2	0	*61*	0	0
10	0	0	*36*	1	0	*62*	0	0
11	0	1	*37*	1	0	*63*	0	0
12	0	1	*38*	0	0	*64*	1	0
13	1	1	*39*	0	2	*65*	1	0
14	0	0	*40*	0	0	*66*	0	0
15	0	0	*41*	2	0	*67*	0	1
16	2	0	*42*	0	0	*68*	0	1
17	1	0	*43*	1	0	*69*	1	0
18	1	0	*44*	1	0	*70*	0	0
19	0	0	*45*	0	0	*71*	1	1
20	0	0	*46*	2	0	*72*	1	0
21	0	0	*47*	0	0	*73*	1	0
22	0	0	*48*	0	0	*74*	1	0
23	2	0	*49*	1	0	*75*	1	0
24	2	0	*50*	0	0	*76*	0	0
25	0	1	*51*	0	0	*77*	0	1
26	0	0	*52*	1	0	*Total*	37	14

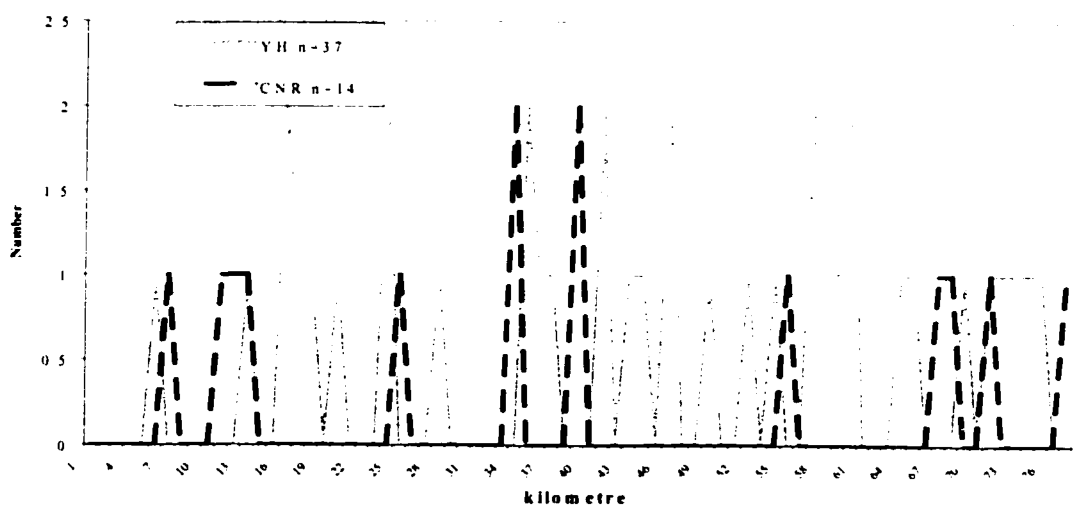

Figure 52. Number of wolf collisions by kilometre on the Yellowhead Highway (YH) and the Canadian National Railway (CNR), 1968-1999

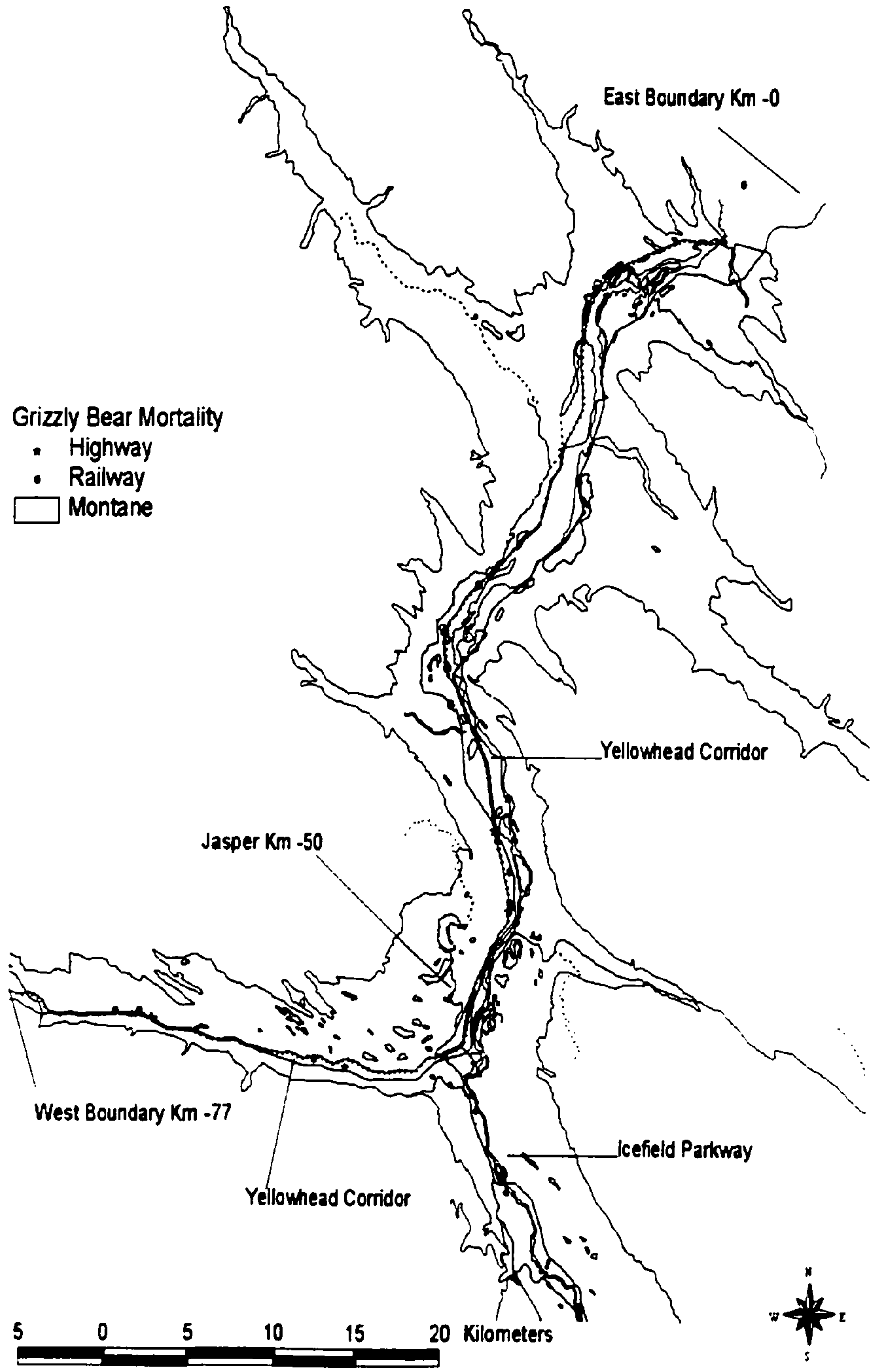

Figure 53. Grizzly bear collision locations on the Yellowhead Highway and the Canadian National Railway, 1968-1999

Table 16. Number of grizzly bear collisions by kilometre on the Yellowhead Highway (YH) and the Canadian National Railway (CNR), 1968-1999

Km	YH	CNR	Km	YH	CNR	Km	YH	CNR
1	0	0	*27*	0	0	*53*	0	0
2	0	0	*28*	0	0	*54*	0	0
3	0	0	*29*	0	0	*55*	0	0
4	0	0	*30*	2	0	*56*	0	0
5	0	0	*31*	0	1	*57*	0	0
6	0	0	*32*	0	0	*58*	0	0
7	0	0	*33*	0	0	*59*	0	0
8	0	0	*34*	0	0	*60*	1	0
9	0	0	*35*	0	1	*61*	0	1
10	0	0	*36*	0	0	*62*	0	0
11	0	0	*37*	0	0	*63*	0	0
12	0	1	*38*	0	0	*64*	0	0
13	0	0	*39*	0	0	*65*	0	0
14	0	0	*40*	1	1	*66*	0	0
15	0	0	*41*	0	0	*67*	0	0
16	0	0	*42*	0	2	*68*	0	0
17	0	0	*43*	3	1	*69*	0	0
18	0	0	*44*	0	0	*70*	0	0
19	0	0	*45*	0	0	*71*	0	1
20	0	0	*46*	0	0	*72*	0	1
21	0	0	*47*	0	0	*73*	0	0
22	0	0	*48*	0	0	*74*	0	0
23	0	0	*49*	0	0	*75*	0	0
24	0	0	*50*	0	0	*76*	0	0
25	0	0	*51*	0	0	*77*	0	0
26	0	1	*52*	0	0	*Total*	7	11

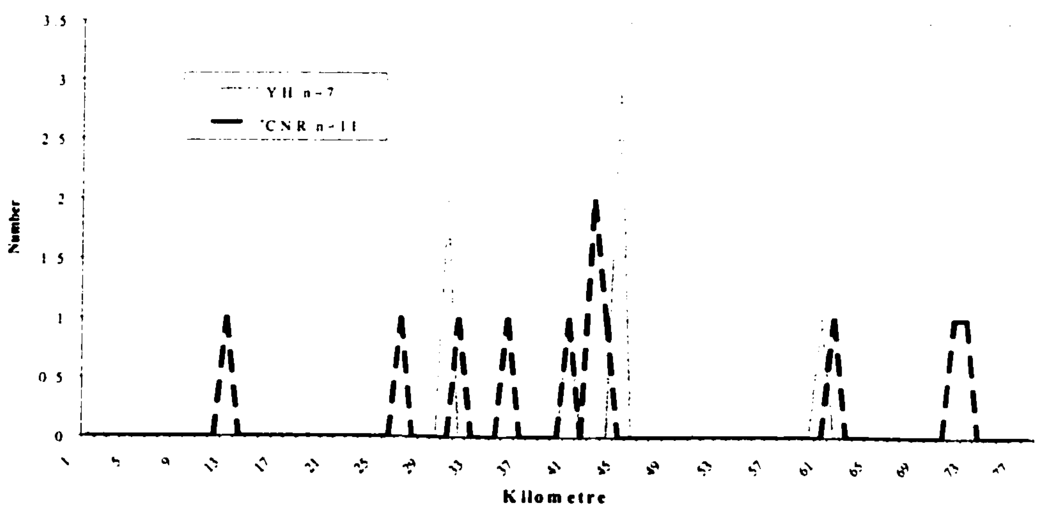

Figure 54. Number of grizzly bear collisions by kilometre on the Yellowhead Highway (YH) and the Canadian National Railway (CNR), 1968-1999

3.7 Study Question 7. Have collisions with elk significantly affected the number of elk counted adjacent to the Yellowhead Highway and the Canadian National Railway?

Elk collisions make up 53% of all wildlife collisions. From 1951 to 1999, 1 353 elk have been recorded as killed in collisions on highways and the railway (Fig.55).

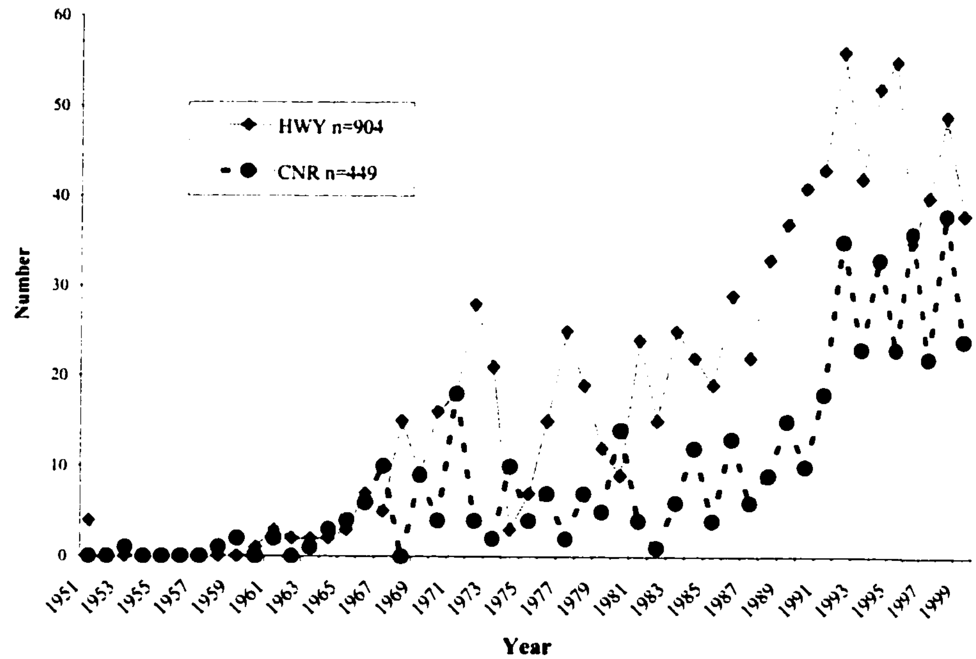

Figure 55. Yearly elk collisions (n=1353) on Highways and the Canadian National Railway, 1951-1999

Sixty-seven percent of elk collisions occurred on highways and 33% have occurred on the Canadian National Railway. Aerial and roadside surveys carried out by park staff from 1983 to 1998 determined that the number of elk adjacent to the Yellowhead Highway and Canadian National Railway increased from 400 to 928 elk (Bradford 1999). During this period yearly collisions with elk averaged 10.2 % of the elk population adjacent to the Yellowhead Highway and the railway. To determine if yearly collision rates were statistically significant a chi-squared goodness of fit test was carried out on elk collisions and survey data from 1983 to 1998. A chi-squared test showed there was no significant association between collision rates and elk survey data ($\chi 2$ 1.07, d.f. =6, P=0.99). This test suggests collision rates did not significantly effect the number of elk counted from 1983 to 1998.

3.7.1 Discussion

Elk collisions have increased during the study period probably in response to an increased elk population and increased traffic volumes. During this period, YOY mortality was 21% of annual productivity. Damas and Smith (1982) used a removal factor of less than 25% of annual productivity as having a minor effect on wildlife populations. Survey information and YOY mortality data supports this conclusion.

3.8 Study Question 8. Have reduced speed zones been effective in reducing wildlife collisions?

Damas and Smith (1982) concluded that the problem of wildlife vehicle collisions in National Parks was concentrated on the major corridors of higher speed traffic but they did not address the actual role that speed plays. A number of experimental mitigation studies began with the assumption that lower speeds mean fewer collisions (Pojar *et al* 1971). Damas and Smith (1982) also suggested reduced speed zones in high collision locations as a mitigation measure to reduce wildlife vehicle collisions.

In 1991, three Slow-Down-for-Wildlife-Zones were established on the Yellowhead Highway reducing the maximum speed from 90 kilometres per hour to 70 kilometres per hour. The criteria for selecting the reduced speed zone locations were high wildlife collision and traffic congestion. The combined length of these speed zones is 15.5 kilometres. Reduced speed zones are located in the following areas: Location 1- Disaster

Point, 4.0 kilometres in length; Location 2- Mile12, 2.5 kilometres in length; and Location 3- Townsite Bypass, 9 kilometres in length (Fig.56).

To answer study question 8 a new study period was created out of the full study period. The new study period was from 1983 to 1998 (16 years) and is divided into two additional periods. Additional periods are: period 1, 8 years from 1983-1990 (pre- 70 kilometre/hour zones) and period 2, 8 years from 1991-1998 (70-kilometre/hour zones).

Wildlife survey information adjacent to the Yellowhead Corridor is not available for all species with the exception of elk. Elk numbers have been determined by both aerial and roadside survey. During the study period the number of elk counted adjacent to the Yellowhead Highway increased from 400 to 928 elk. During period 1 (pre 70 kilometre/hour zones) the number of elk counted adjacent to the Yellowhead Corridor increased 40% from 400 to 560 elk and during period 2 (70 kilometre/hour zones) the number of elk counted increased 66% from 560 to 928 elk (Fig. 57). The greatest increase (178%) in the number of elk counted occurred adjacent to location 3. Location 3 is located between the town of Jasper and the Jasper Park Lodge (a large resort complex). Elk are attracted to these areas because of foraging opportunities (lawns and gardens) and a high level of human use, which provides elk with security from predators.

Bighorn sheep populations are believed to be stable or increasing slightly (Bradford 1999). Bighorn sheep inhabit rock outcrops adjacent to the highway. Outcrops provide access to escape terrain for bighorn sheep. There are five locations where rock outcrops exist adjacent to the highway and these are the only locations where bighorn sheep collisions occur on the highway. Three of these locations are within 70 kilometre per hour zones.

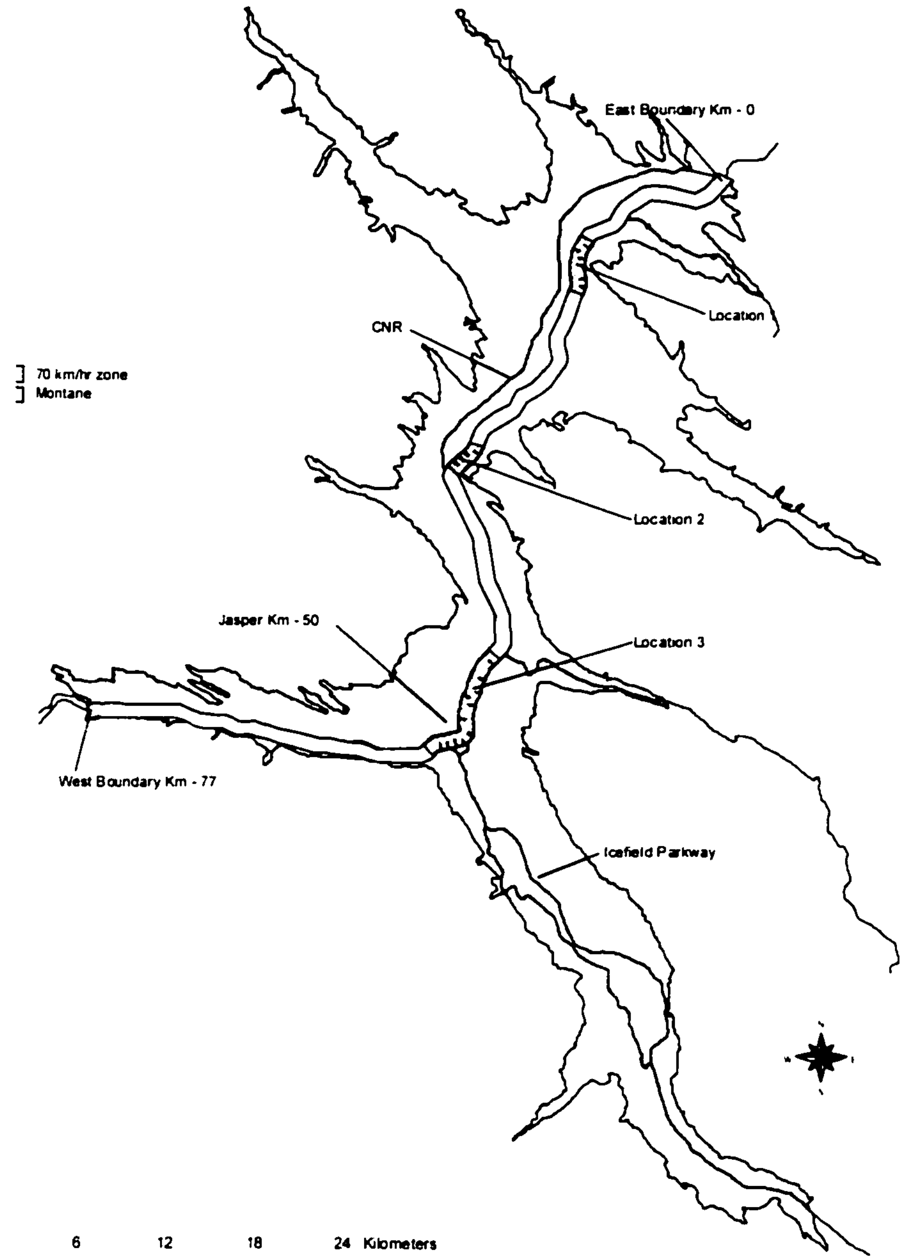

Figure 56. Location of three 70 kilometre per hour zones on the Yellowhead Highway

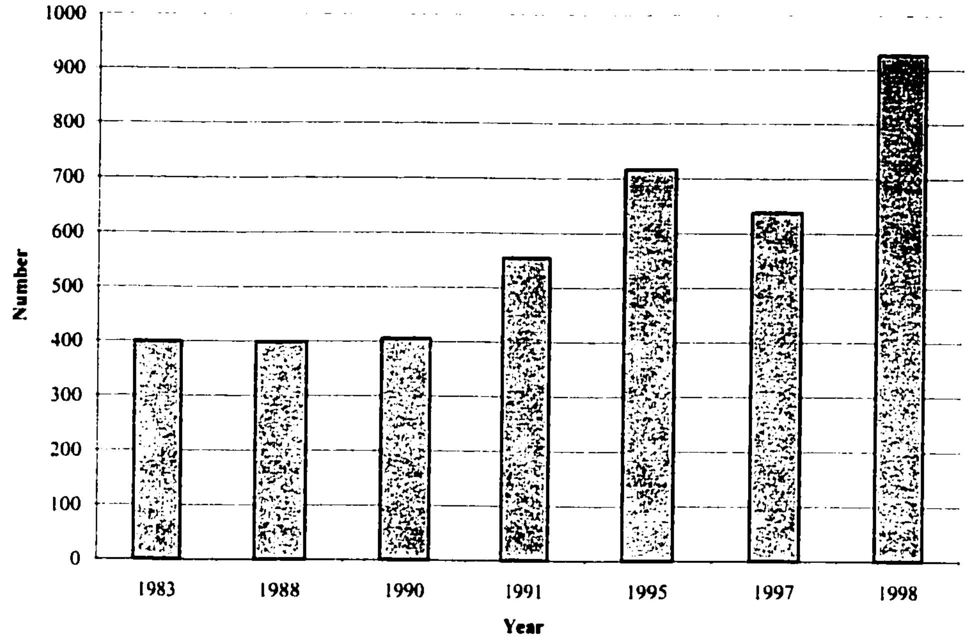

Figure 57. Elk survey information, Yellowhead Corridor, 1983-1998

The majority of elk collisions occur on a 30-kilometre section of the Yellowhead Highway. This section begins at the West End of Location 2 and ends 6 kilometres west of Location 3. During the study period, 315 or 79% of elk/vehicle collisions occurred in this section and 81 occurred outside this section. This section contains one 70 kilometre per hour zone (location 3) and a 21-kilometre 90 kilometre per hour area. Seventy-kilometre zones are marked on each side of the highway by 1.92m.x 3.67m signs and smaller traditional speed indicator signs (Fig. 58). Other locations on the highway are posted with wildlife warning signs in the form of large white elk silhouettes (Fig.59).

Figure 58. Reduced speed zone signs

Figure 59. Wildlife warning signs

Total park elk collisions equalled 557 collisions during the study period however only 396 collisions contained confirmed collision locations on the Yellowhead Highway or occurred on roads other than the Yellowhead Highway. All references to elk collisions in 90 kilometre per hour areas and 70 kilometre per hour areas are taken from a 30-kilometre section of the Yellowhead Highway. This section begins at the West End of Location 2 and ends 6 kilometres west of Location 3. Elk are seasonally concentrated within the 30-kilometre highway section with the exception of a herd (1998 count =276 elk) that occupies year round range adjacent to Location 3.

The local police detachment (RCMP) and the Warden Service issued a yearly average of 5,200 and 275 speeding violations respectively. Seventy-five percent of traffic enforcement occurs during daylight periods (Kuntz 2000). From 1983 to 1998 traffic, volumes increased 50% from 802 401 to 1 20 3312 vehicles per year.

The average speed of transport trucks and passenger vehicles in two 70 kilometre per hour zones and one 90 kilometre per hour zone was determined using traffic classifiers during 1995. This was done to determine if drivers reduced their speed when entering a 70 kilometre per hour zone (Fig. 60). The majority of drivers reduced their vehicle speed when entering a 70 kilometre per hour zone.

Location 3 recorded fewer passenger vehicles which is a result of passenger vehicles bypassing the traffic classifier by travelling through the town of Jasper. This does not occur to the same extent with transport trucks where the totals in each location are similar (111 717 vs. 109 979 vehicles). There is nothing to indicate that this trend did not occur during periods 1 and 2. Therefore, it is believed relative traffic volumes remained similar between periods 1 and 2 in each 70 kilometre per hour zone. The speed of vehicles involved in a wildlife collision is not known.

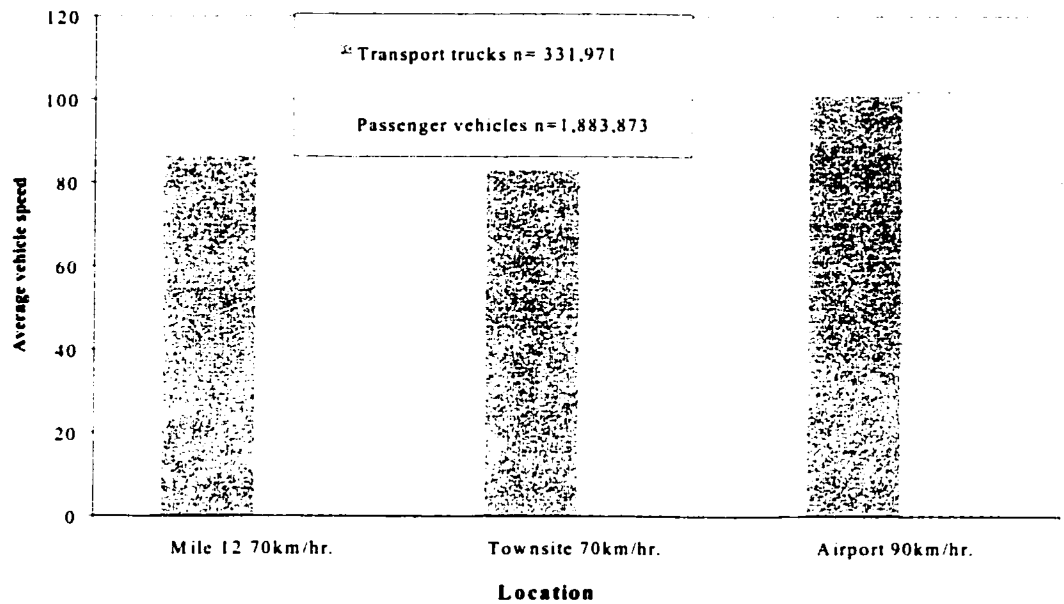

Figure 60. Average speed of passenger vehicles and transport trucks on the Yellowhead Highway, 1995

3.8.1 Method

Collision comparisons have been made between periods 1 and 2 using collision data collected from the Yellowhead Highway and the Canadian National Railway. A more detail analysis of elk and bighorn sheep collisions is provided because these two species provided the largest sample size. Other species are not represented in sufficient numbers to allow specific species analysis. Therefore, collisions other than elk and bighorn sheep were grouped as "other wildlife". Location 1 and 2 contain insufficient sample sizes (collisions) with the exception of bighorn sheep. The analysis of elk is limited to Location 3 because of insufficient sample sizes in Location 1 and 2. The number of collision events is used in this analysis rather than the number of animals killed. Occasionally more than one animal is struck per collision.

Bighorn sheep collisions occur on short (2-3 kilometre) sections of the highway. The majority of collisions occur within 70 kilometre per hour zones in Locations 1 and 2. Collision comparisons between periods 1 and 2 are made and are expressed as a percentage increase or decrease. Because data collected from bighorn sheep collisions is not replicated in other areas, to the extent replication occurs for elk, a statistical significance test was not carried out on bighorn sheep data.

Elk collision data taken from a 30-kilometre section of the highway is used in the analysis. This area contains one 70 kilometre per hour zone (9 kilometres in length) and the remainder is a 90 kilometre per hour zone (21 kilometres in length). The majority (80%) of elk collisions occur in this 30-kilometre section of the Yellowhead Highway (315 compared to 81). Collision comparisons between periods 1 and 2 are made and are expressed as a proportional increase or decrease. A Fishers exact test is used to determine statistical significance.

3.8.2 Results

Collision data taken from Locations 1, 2 and 3 and 90 kilometre per hour areas is listed in Table 17. During periods 1 and 2- 165 collisions with bighorn sheep occurred in 70 kilometre per hour zones and 50 occurred in 90 kilometre per hour areas. In 90 kilometre per hour areas bighorn sheep collisions decreased between periods 1 and 2 by 33% from 30 to 20 collisions. In 70 kilometre per hour zones bighorn sheep collisions increased by .01 % from 82 to 83 collisions. Bighorn sheep collisions increased by 36% on the Canadian National Railway from 72 to 98 collisions (Table 17).

Table 17. Number of bighorn sheep and elk collisions during pre (period 1) and post 70/km/hr. zones (period 2) periods on the Yellowhead Highway and the Canadian National Railway, 1983-1998

70 kilometre per hour area	**Period 1 No 70km/hr zone**	**Increase/decrease**	**Period 2 70km/hr. zone**
Bighorn sheep	82	>.01%	83
Elk	62	>24%	77
90 kilometre per hour area			
Bighorn sheep	30	<33%	20
Elk	62	>83%	114
Canadian National Railway			
Bighorn sheep	72	>36%	98
Elk	65	>190%	189

During period 1, elk collisions in Location 3 equalled collisions in 90 kilometre per hour areas, 62 collisions in each area. During period 2, 77 elk collisions were recorded in location 3 (70 kilometre per hour zone) and 114 collisions were recorded in 90 kilometre per hour areas. Between periods 1 and 2, elk collisions increased by 84% in 90 kilometre per hour areas from 62 to114 collisions. During this same period elk collisions increased by 24% from 62 to 77 collisions in the 70 kilometre zone (Location 3) (Fig. 61).

Collisions increased from period 1 to period 2 in 90 kilometre per hour areas from 2.94 collisions/kilometre to 5.42 collisions/kilometre or 84%. Collisions increased from period 1 to period 2 inside the 70 kilometre per hour zone from 6.88 collisions/kilometre to 8.55 collisions/kilometre or 24%. In Location 3, the number of elk collisions per 100 elk in period 1 was 7.8 collisions/100 elk. During period 2, the number of elk collisions in Location 3 was 2.8 collisions/100 elk, a 5% reduction in elk collisions.

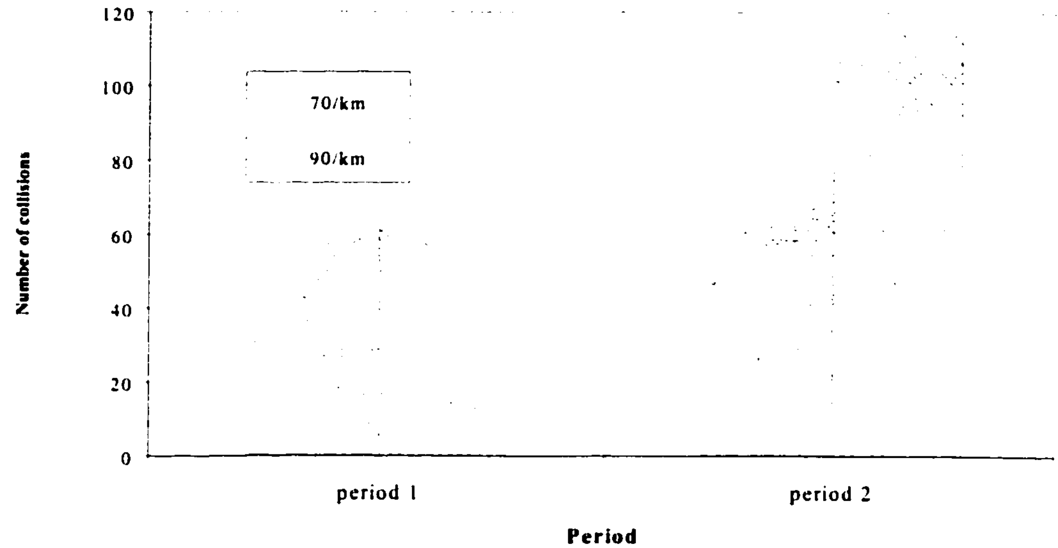

Figure 61. Elk collisions in 70 kilometre per hour and 90 kilometre per hour zones during periods 1 and 2, 1983-1998

To determine if differences in elk collisions were statistically significant between periods 1 and 2 a Fisher's exact test was carried out. A Fishers exact test (right tail) showed a weak association between periods 1 and 2 ($\chi 2$ 13.68, d.f. =7, P=.057).

3.8.3 Other Wildlife

Spatial information used in the analysis of other wildlife is taken from kilometre 0 to kilometre 60 on the Yellowhead Highway. This area contains a combined length of 15.5 kilometres of three 70 kilometre per hour zones. Seventy kilometre zones are spaced at kilometre 11.5 to 15, 29 to 31 and 45.5 to 54. Other wildlife is mule deer, whitetail deer, moose, black bear, coyotes and wolves. During period 1, there were 215 collisions with other wildlife on the Yellowhead Highway, 61 of these collisions occurred in future 70 kilometre per hour zones. During period 2 this same area had 264 collisions, 65 of these collisions were within 70 kilometre per hour zones. Collisions with other wildlife outside

70 kilometre per hour zones increased from 215 to 264 collisions or 23%. Collisions with other wildlife inside 70 kilometre per hour zones increased from 61 to 65 collisions or 6% (Table 18).

Table 18. Other wildlife collisions in 70 kilometre per hour and 90 kilometre per hour areas during periods 1 and 2, 1983-1998

70 kilometre per hour	**Period 1 No 70km/hr zone**	**Increase/decrease**	**Period 2 70km/hr. zone**
Other wildlife	61	>6%	65
90 kilometre per hour			
Other wildlife	215	>23%	264

3.8.4 Discussion

There are spatial and temporal differences between bighorn sheep and elk collisions. Elk are more widespread over the study area compared to bighorn sheep, which are restricted to rocky outcrops adjacent to the Yellowhead Highway. Comparisons of elk collisions inside and outside 70 kilometre zones are more reliable because elk are distributed throughout the study area.

Collision times throughout the day are notably different for elk and bighorn sheep (Fig.62). Over a 24-hour period elk collisions peak during the early morning and late evening periods compared to bighorn sheep collisions which peak during mid afternoon. Although bighorn sheep are considerably smaller than elk, an assumption can be made that sheep are easier for drivers to see during daylight periods compared to elk during low light periods. In addition, bighorn sheep congregate in small groups on the highway to lick road salt and loaf, increasing their visibility. Drivers are more likely to act to avoid a collision with bighorn sheep when they are more visible during daylight periods. Additionally, the majority of traffic enforcement occurs during daylight periods.

The application of winter mix, (sand mixed with 5% salt), to roads and foraging opportunities attract bighorn sheep to the highway. Bighorn sheep are not disturbed by traffic volumes. They remain in the traffic lanes despite traffic volumes and are less likely than other wildlife to move off the highway when it is occupied by vehicles. When this happens traffic congestion usually occurs and vehicle speeds are reduced because of the congestion. The resulting traffic congestion may have a greater affect on bighorn sheep collisions than vehicle speed. Elk do not exhibit similar behaviour patterns as bighorn sheep, specifically the tendency to remain in the traffic lanes despite traffic volumes.

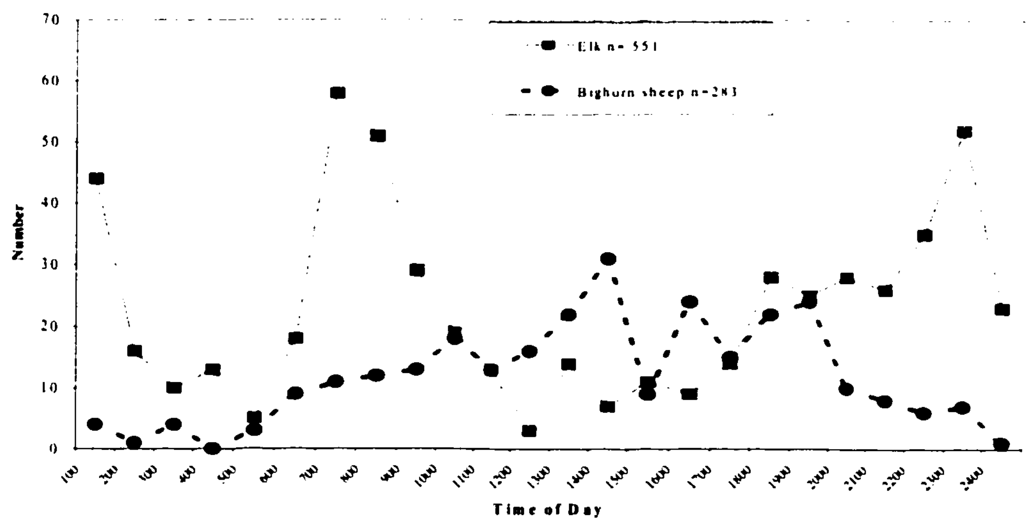

Figure 62. Hourly elk and bighorn sheep collisions on the Yellowhead Highway, 1951-1999

Comparisons between bighorn sheep highway collisions and Canadian National Railway collisions are not as rigorous for bighorn sheep as are comparisons for elk. This is because bighorn sheep occupy short sections of habitat and the Athabasca River creates an obstacle to sheep movement in Locations 1 and 2. Comparisons between elk collisions on the highway and the Canadian National Railway are more rigorous because the Canadian National Railway is within 100-200 meters of the 30-kilometre area used in this analysis and there are no obstacles to elk movement between the Yellowhead Highway and Canadian National Railway.

3.8.5 Conclusion

The majority of elk collisions occur on a 30-kilometre section of the Yellowhead Highway. The number of elk counted in this area during the study period increased from 400 to 928 elk. The greatest increase in the elk counts (178%) 99 to 276 occurred adjacent to Location 3 (70 kilometre per hour zone). Elk collisions in the 9 kilometre 70km/hr zone (location 3) increased by 24% compared to an 84% increase in the 21 kilometre 90km/hr area. Despite the dramatic increase in the number of elk counted during period 2, adjacent to the 70km/hr zone, collisions with elk did not increase at the same rate as collisions in 90 kilometre per hour zones or on the Canadian National Railway.

Although 70 kilometre zones were established in high elk and bighorn sheep collision areas other wildlife are also involved in collisions in these areas. Other wildlife collisions increased by 23% in 90 kilometre areas and by 6% in 70 kilometre zones. Other wildlife population fluctuations during the study period are not known. However, the spacing of 70 kilometre zones is evenly distributed within kilometre 0 to 60 (Fig.56). It is reasonable to conclude that any changes in other wildlife populations would occur equally inside and outside 70 and 90 kilometre per hour areas. Other wildlife collisions increased by 23% in 90 kilometre areas and 6% in 70 kilometre zones.

A 20 kilometre per hour reduction in the posted highway speed from 90 kilometres per hour to 70 kilometres per hour reduced the rate of elk vehicle collisions and the rate of vehicle collisions with other wildlife. Reduced speed zones had a negligible affect on reducing the rate of vehicle collisions with bighorn sheep; this is likely a result of bighorn sheep behaviour compared to other wildlife behaviour. Traffic congestion may be a more significant contributor to bighorn sheep collisions than vehicle speed because of bighorn sheep behaviour.

Because reduced speed zones modify driver behaviour rather than wildlife behaviour, a net loss or negative ecological effect on other ecological components did not occur as a result of this mitigation. In addition, the social and economic costs to drivers are minimal. Reducing vehicle speeds by 20 kilometres per hour from 90 kilometres per hour to 70 kilometres per hour increases the time it takes to travel 15.5 kilometres by 2.9 minutes.

3.9 MITAGTION THAT HAS BEEN USED IN JASPER NATIONAL PARK OR IS PROPOSED

The majority of collisions occur on the Yellowhead Highway and Canadian National Railway. Removal or relocation of either of these corridors is unlikely. The alternative is reducing the effect of transportation corridors on wildlife by implementing mitigation to reduce wildlife collisions. Mitigation that has been used or is proposed for use in Jasper National Park is listed in Table 19.

The first year that mitigation measures were implemented to reduce wildlife collisions was in 1991. However, the fencing of the Jasper landfill and the installation of bear proof garbage containers in and around the Jasper townsite occurred in 1982. The Jasper landfill (current waste transfer facility) is located within 100 metres of both the Yellowhead Highway and the Canadian National Railway at kilometre 45. The reason for fencing the landfill was not to reduce collisions. However, collisions with grizzly bears declined since this facility was bear proofed (Fig. 63). A reduction in black bear collisions did not occur and is probably a result of black bears moving into areas vacated by grizzlies.

The Brule tunnel is located at kilometre 1 (Fig. 2) on the railway. Bighorn sheep use the tunnel as a refuge area during inclement weather. This 500-metre section of track has the highest collision rate (63 collisions) on the railway (Table 9). Short sections of fencing were installed during November 2000 barring bighorn sheep access to the tunnel without limiting sheep movement in the area. If this mitigation is successful, it will reduce sheep collisions on the railway by 33%.

Grain spills are caused by leaking grain cars on the railway. When these cars are parked for long periods, the grain accumulates between the tracks, on sidings and in the railyard. Black bears and ungulates are attracted to the leaked grain increasing their collision risk. Jasper National Park has suggested to the Canadian National Railway that they purchase a vacuum truck to collect spilled grain to reduce the collision risk to wildlife.

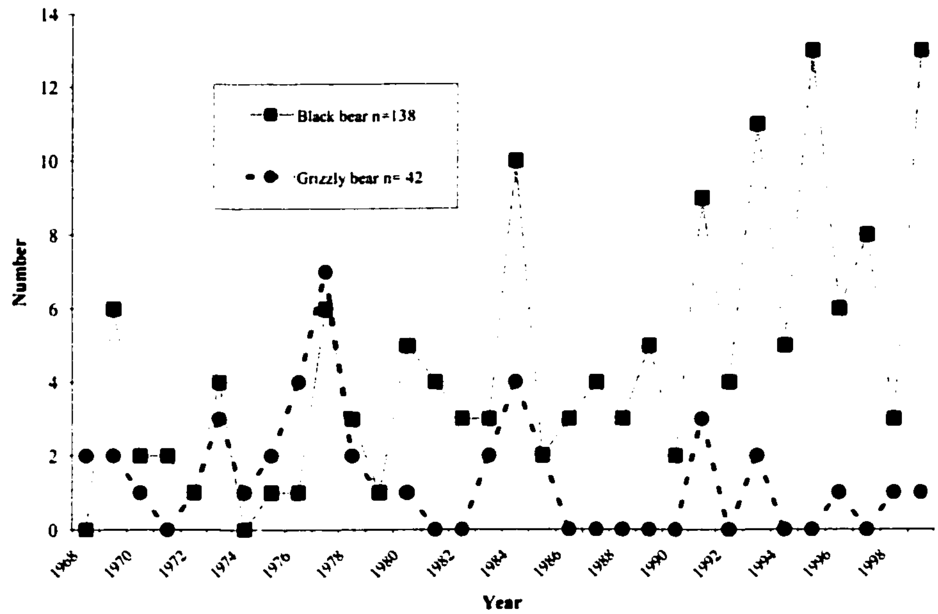

Figure 63. Yearly collisions with grizzly and black bears, 1968 to 1999

Table 19. Mitigation that has been used in Jasper National Park or is proposed, 1982-2000

Mitigation	Year(s)	Sponsor	Cost	Result
Fencing Brule Tunnel, CNR	2000	Canadian National Railway	$100,000.00	In progress
Grain spill removal, CNR	Proposed	Canadian National Railway	$250,000.00	Proposed
Mineral supplement, Hwy	1991/92	Parks Canada	$800.00	Not effective
Wildlife warning signs, Hwy	1991	Parks Canada	$26,000.00	Unknown
Reduced speed zones, Hwy	1991	Parks Canada	$2,000.00	Positive
Roadside mortality flags Hwy	1990's	Parks Canada	Minimal	Unknown
Roadside reflectors, Hwy	1999	Parks Canada & Industry	$30,000.00	In progress
Taste aversion (LiCL), Hwy	2000/01	Parks Canada & Industry	$15,000.00	In progress
Taste aversion ($CaCl_2$), Hwy	1995	Parks Canada	$15,000.00	Not suitable
Fencing landfill & bear proofing garbage containers	1982	Parks Canada	$68,000.00 $170,000.00	Positive (indirect)

Another attractant for wildlife is salt. Salt is mixed at a 5% ratio to aggregate material (sand) and applied to highways for maintenance purposes. Wildlife, particularly bighorn sheep, are attracted to the highway to lick road salt. A sheep mineral supplement was placed in troughs adjacent to rock outcrops beside the Yellowhead Highway where bighorn sheep congregate. This was done to provide an alternative to highway salt. Alternative mineral supplements were not successful in stopping bighorn sheep from gathering on the highway (Bradford 1992).

Wildlife warning signs (Fig.59) were installed in 1991 on all roads in Jasper National Park where high wildlife collisions occur and at entrances to the park. There has been a reduction in highway collisions during the 1990's. It is possible that these signs have had an effect on collision rates during this period.

During the early part of the 1990's, small red flags were placed at all mortality locations on the Yellowhead Highway for a one-week period in August. Based on the number of inquires made to park staff by motorists it appears this program did capture the attention of motorists. It is not known why this program was stopped during the late 1990's. A lesser version of this program was re-implemented on a 10-kilometre section of Yellowhead Highway near the Jasper townsite during Environment week in 2000.

Reduced speed zones reduced the rate of elk vehicle collisions, but had a negligible effect on bighorn sheep collisions. Elk collisions were reduced from 7.8 collisions per 100 elk to 2.8 collisions per 100 elk in 70 kilometre zones. Collisions with other wildlife were also reduced in 70 kilometre zones.

Calcium Chloride ($CaCl_2$) was used during 1995 as a replacement for roadsalt and mixed with sand for road maintenance purposes. Bighorn sheep and other ungulates were not attracted to the highway to lick $CaCl_2$. However, $CaCl_2$ did not provide a safe driving surface because of ice build up at lower temperatures.

The evaluation of roadside reflectors and Lithium Chloride (LiCL), (taste aversion agent that is mixed with roadsalt), are ongoing and will be evaluated during 2002.

3.10 DEVELOPING MITAGTION TO REDUCE WILLDIFE COLLISIONS

Parks Canada's management goal for Jasper National Park states that "national transportation corridors will be managed in a way that supports Parks Canada's commitment to ecological integrity" (Parks Canada 2000). Based on the number of wildlife collisions this goal has not been met. Meeting this goal will become more difficult because of future development of the Yellowhead Highway. The number of vehicles on the Yellowhead Highway increases by 3% annually (Parks Canada 2000). As traffic volumes increase additional passing lanes will be required and possible twining of some sections as early as 2015 (Parks Canada 2000).

Ruediger (1996) identified important critical points in highway development and the effect on carnivores. Two of these critical points are the addition of passing lanes and highway twining. While these developments are necessary for safety purposes improved highways adversely effect carnivores and other wildlife species.

Achieving Parks Canada's ecological goals for transportation corridors will become more difficult to achieve as traffic volumes increase. Consequently, implementing mitigations that reduce wildlife collisions is required now to meet current and future management objectives.

There are two options when developing mitigations to reduce wildlife collisions, changing driver behaviour or changing wildlife behaviour. Two examples of this are reduced speed zones and wildlife fencing. Because a variety of variables influence the rate of collisions, each of these options should be used in developing mitigation. It is not within the scope of this thesis to comprehensively assess available mitigation. However, the data does point to obvious places to start. The following mitigation are presented to provide a starting point in the development of mitigation. Mitigation has been selected based on the following criteria:

- minimal disruption to wildlife movement;
- relatively low cost;
- minimal effect on park users;
- minimising the effect of mitigation on other ecological goals (no net loss);
- recognising the continued use of the Yellowhead Corridor as a national transportation corridor.

3.10.1 Implementing a commercial weight restriction on the Yellowhead Highway

The majority of wildlife collisions occur on the Yellowhead Highway. Based on data collected during 1995, transport trucks account for 12% of the traffic volume and 34% of collisions. When the vehicle type was determined (1980 to 1999) transport trucks accounted for 37% of collisions. The other major through road in Jasper National Park, The Icefeild Parkway, has a commercial vehicle weight restriction of 4.5 tonnes. Applying this weight restriction to the Yellowhead Highway would eliminate transport trucks from the Yellowhead Highway with the exception of local deliveries to the town of Jasper. This would also delay highway upgrades to the Yellowhead Highway because traffic volumes would decrease by around 12% and highway surface impacts caused by transport trucks would be reduced.

Applying a commercial weight restriction on the Yellowhead Highway would reduce wildlife collisions by a minimum of 37%. An option for transporting truck freight is the Canadian National Railway. This scenario would still allow the Yellowhead Corridor to be used as a National Transportation Corridor.

If this option was implemented and for some reason the railway was not used to transport truck freight the Trans-Canada Highway in Banff National Park would see an increase of around 110 000-transport trucks per year. Because the majority of the Trans-Canada Highway in Banff National Park is fenced the increase in transport truck traffic would have a minimal effect on collisions with large animals. On a regional scale this would localise wildlife mortality caused by transport trucks, to a corridor where mitigation is already in place.

Channelling transport trucks through the Banff Corridor would significantly reduce transport truck collisions with wildlife in Jasper National Park and would not increase collisions with large animals in Banff National Park.

3.10.2 Apply a temporal weight restriction on the Yellowhead Highway.

Collisions increase during specific periods based on changes in wildlife behaviour and traffic volumes examples are- establishment on winter range and the May to September high traffic volume period. Applying a weight restriction on the

Yellowhead Highway during peak collision periods will eliminate transport trucks during these periods, reducing collisions with wildlife.

3.10.3 Implementing a reduced speed limit for transport trucks.

Reducing the speed from 90 kilometres per hour to 70 kilometres per hour reduced the rate of elk collisions and collisions with other wildlife. Expanding this to transport trucks for the length of the Yellowhead Highway will increase the effectiveness of current mitigation. To ensure maximum effectiveness a reduced speed program must include speed enforcement. The most cost effective and efficient enforcement option is photo radar.

3.10.4 Communicate the problem of wildlife collisions to the trucking industry and other transportation associations.

Circulate an information package tailored for the trucking industry and other motorists asking their co-operation to reduce wildlife collisions. This could be accomplished by handouts at park gates, publications in trucking industry magazines, media advertisements and liaison with transportation industry organisations.

3.10.5 Relocating and expanding reduced speed zones.

Two of the three reduced speed zones (70 kilometres per hour) are located in high bighorn sheep collision areas. However, reduced speed zones had a negligible effect on reducing bighorn sheep collisions. Reduced speed zones were effective in reducing the rate of elk collisions and collisions with other wildlife. Fifty three percent of collisions on the Yellowhead Highway occur on a 30 kilometre section of highway from kilometre 30 to kilometre 60. Relocating and expanding these zones to high collision areas will reduce wildlife collisions. To ensure maximum effectiveness a reduced speed program must include speed enforcement. The most cost effective and efficient enforcement option is photo radar.

3.10.6 Crepuscular and nighttime closure for through-traffic on the Yellowhead Highway.

Daylight collision rates exceed crepuscular and night periods. However, recording methods indicate this may be biased towards daylight collisions. Because 75% of the traffic on the Yellowhead Highway is through-traffic, a crepuscular and nighttime highway closure would reduce night traffic by 75% on the Yellowhead Highway. This would significantly reduce collisions and have a minimal effect on park users.

3.10.7 Use of better wildlife warning systems on the Canadian National Railway and highways.

Three examples are: infrared detection, location collars on ungulates and mobile electronic signs. Kootenay National Park in conjunction with the Insurance Corporation of British Columbia is testing infrared detection monitors. Monitors cover a 5-kilometre section of Highway 93 in Kootenay National Park. When wildlife approach the highway and are detected by a heat sensitive camera, an electronic warning sign is activated alerting motorists.

Wildlife location collars are being used in the state of Washington, on a major freeway in the Sequim Valley, to alert motorists to the presence of wildlife. One in ten elk (lead cows) are fitted with a radio transmitter collar. When collared elk approach within 400 metres of the freeway an electronic warning sign is activated alerting motorists.

Jasper National Park has recently purchased an electronic mobile sign that can be programmed with both narrative and symbols alerting motorists to high collision locations and periods. This sign is also equipped with a radar unit that flashes the speed of approaching vehicles at drivers.

3.10.8 Removing roadside and railway attractants

Grain spills on the track, at sidings and in the Canadian National Railway yard attract ungulates and black bears, increasing the risk of collisions with these species. The purchase and use of a vacuum truck by Canadian National Railway would eliminate this attraction for wildlife.

Ungulates are attracted to roadside ditches to forage on non-native grass increasing their exposure to traffic. This has a significant affect on mule deer collision rates during spring green up. Replacing roadside vegetation with non-palatable native species will remove this attractant.

Roadsalt provides a readily available source of nutrients attracting ungulates to highways increasing the risk of collisions. Reducing the amount of roadsalt and or eliminating roadsalt will reduce and or eliminate this attractant for wildlife.

LiCL is currently being tested in Jasper National Park to determine its effectiveness for discouraging bighorn sheep from licking roadsalt. LiCl is a taste aversion agent that is mixed with roadsalt. This research should continue.

3.10.9 Fence bighorn sheep collision locations

Collisions with bighorn sheep occur along short sections of highways and the railway. The main habitat feature attracting sheep to these areas is rock-outcrops that provide escape terrain for sheep. Generally, sheep are confined to these areas because of this habitat feature. Short sections of fencing, in some cases 200 to 300 metres, would limit sheep access to the highway and railway. Because of the limited length of fencing other wildlife movement will not be compromised.

3.10.10 Apply a toll charge for through-traffic on the Yellowhead Highway.

All visitors to Jasper National Park must purchase a park pass. However, through-traffic is not required to purchase a park pass. Through-traffic makes up 75% of traffic volumes and virtually 100% of transport truck volumes. Consequently, based on volume and traffic type through-traffic is responsible for the majority of collisions.

Passing lanes and twinning have been identified as a distinct possibility by the year 2015. Mitigating the effect of twining will require expensive mitigation. The cost of a variety of mitigations that have been implemented and/or suggested for the twinned sections of the Trans-Canada Highway in Banff National Park (Parks Canada 1999) are:

- Fencing- 2.5m x 1 kilometre with apron (both sides) $98 000;
- Culvert (concrete)- 2.4m x 3m x 70m $196 000;
- Culvert (steel)- 4m x 7m x 70m $295 400;
- Open span underpass -14 metres x 70 m $900 000;
- Overpass - 52 metres x 70m $1 750 000;
- Elevated road – 200 metres $12 500 000;
- Buried tunnel – 200 metres $23 070 000.

The cost of mitigation will be a significant factor in determining what type of mitigation will be used when the Yellowhead Highway is twinned. Mitigation such as elevated roads and buried tunnels will likely not be a viable option because of the high cost of these types of mitigation. To prepare for this likelihood Parks Canada should begin collecting a toll charge from through-traffic and applying these funds to future mitigation. A portion of these funds should also be used to implement mitigations to reduce current wildlife mortality.

CHAPTER 4

4.0 CONCLUSION

Passenger vehicles and transport trucks accounted for 99% of collisions during the study period. During 1995, wildlife collisions with transport trucks were disproportional greater than wildlife collisions with passenger vehicles. Passenger vehicles accounted for 80% of traffic volume and for 34% of collisions. Transport trucks accounted for 12% of traffic volume and for 34% of collisions. The reason for this difference is related to the general design of transport trucks compared to passenger vehicles. Design differences result in a greater stopping distance for transport trucks. From 1980 to 1999, when the vehicle type was determined passenger vehicles accounted for 63% and transport trucks for 37% of wildlife collisions.

Wildlife collisions have increased during the latter part of the study period (1980 to 1999) averaging 149 animals per year. Eight-two percent of collisions occurred from 1980 to 1999. Seventy-percent of collisions occurred on highways compared to the railway. Seventy-three percent of collisions occur on the Yellowhead Corridor. Ungulates make up 90% of species involved in collisions. After highway improvements (paving) and the addition of a second track on the Canadian National Railway wildlife collisions show a dramatic increase.

The Warden Service underestimates railway collisions for all species because of the difficulty in accessing all areas of the railway. Additionally, on both highways and the railway collisions with smaller species likely occur at a greater frequency than reported. This is largely due to the smaller size of these species.

Using collision data as an indicator of relative population changes shows that changes have occurred in the ungulate and carnivore composition adjacent to the Yellowhead Corridor during the study period. These changes are statistically significant for ungulates, black bear and grizzly bear. Statistically significant changes have not occurred in the wolf and coyote composition adjacent to the Yellowhead Corridor. Relative populations of elk and whitetail deer have increased and relative moose and mule deer populations have decreased. Relative bighorn sheep populations have remained stable. Based on this data, displacement of mule deer by whitetail deer may be occurring adjacent to the Yellowhead Corridor. From 1988 to 1999, collisions with elk did not significantly reduce the number of elk counted adjacent to the Yellowhead Corridor. The effect of collisions on other species is unknown.

A relationship between monthly highway traffic volumes and elk, bighorn sheep, moose and whitetail deer collisions was not shown. Other factors such as establishment on winter range adjacent to transportation corridors influence monthly collision rates of these species. A significant relationship between monthly highway traffic volumes and mule deer and carnivore collisions was shown, suggesting a relationship between monthly highway volumes and collision with these species.

Daily collisions show two peak periods on highways, 0600 hours to 1200 hours and 1800 hours to 2400 hours. Seventy three percent of highway collision occurs during this 12-hour period. Daily collisions on the railway show one-peak 12-hour period 0900 hours to 2000 hours. During this period 74% of railway collisions occur. Daily collision trends are similar for most species with the exception of bighorn sheep and bears. These species show a daily collision peak from 1100 hours to 1900 hours.

Because of the difficulty in accessing the railway by Park Wardens, the recording of some daily collision times on railways may be incorrectly recorded as the time the carcass was picked up versus the actual collision time. The extent of this recording error is not known. A similar recording error applies to a lesser degree on highways because of the difficulty of observing carcasses that are not reported during crepuscular and nighttime periods. The result of this recording error is a greater number of recorded daylight collisions than actually occur.

Collision rates vary on highways and the railway based on age class, sex and species of wildlife. Young of year elk, coyotes and wolves experienced relatively high collision rates ranging from 22% to 30%, indicating these age classes may be more susceptible to collisions than age classes of other species. The effect of YOY collisions on these species is greater for coyotes and wolves than elk because of lower carnivore reproductive rates, lower population densities and larger carnivore home ranges. In addition, YOY coyote and wolf collisions are likely greater than reported because of the smaller size of these species.

Information on wolf populations during the study period is lacking, However, based on YOY wolf collisions in 1996 and 1999 it is probably a majority of this age class was killed in collisions during these years. It is not known if these wolves were recent arrivals or if they had occupied areas adjacent to transportation corridors for a longer period of time. If they were recent arrivals the possibility of wolves establishing sustainable populations adjacent to transportation corridors is unlikely because of high YOY mortality. Based on the amount of time YOY wolves are exposed to traffic and trains compared to adults, collision data indicates YOY wolves may be more at risk of collisions than adults.

Grizzly bears are the only species were railway collisions exceed highway collisions. Transportation category (highway compared to railway) influences collision rates for elk but not for other species. Transportation category influences sex collision rates for elk and moose but not other species. Transportation category also influences age class collision rates for elk (greater on highways) and mule deer (greater on the railway) but not other species. Although a statistically significant association between transportation category and carnivore collision rates was not shown the effect on carnivores may be biologically significant.

Wildlife collision locations vary depending on the species. Fifty-three percent of collisions on the Yellowhead Highway occur on a 31-kilometre section of highway. Fifty percent of collisions on the Canadian National Railway occur on a 29-kilometre section of track. The majority of ungulate and bear collisions occur from kilometre 50 (Jasper townsite) to kilometre 0 (East Entrance to Jasper National Park). An exception are moose collisions that peak from kilometre 53 to kilometre 75. Wolf and coyote collisions occur along the length of each corridor. Collision locations for wolves are the most widespread.

From 1991 to 1998, reduced speed zones (90 kilometres per hour to 70 kilometres per hour) reduced the rate of elk collisions on a 9-kilometre section of the Yellowhead Highway. Collisions with other wildlife where also reduced during this period. Reduced speed zones had a negligible effect on reducing bighorn sheep collisions. This is likely a result of behavioural differences in bighorn sheep compared to other wildlife.

There are a variety of variables influencing wildlife collisions. Thirteen different variables have been identified in this thesis. These range from traffic volumes to individual species age classes. Each of these variables influence collision rates to varying degrees either increasing or decreasing collision rates depending on the magnitude of each variable (Fig.65). An example is traffic type because transport trucks account for a disproportional number of collisions compared to passenger vehicles an increase in transport truck volumes will increase collisions. Alternatively, a decrease in transport truck volumes will cause a decrease in collisions.

There are two options when developing mitigation to reduce wildlife collisions, one is change driver behaviour and the other is change wildlife behaviour. Changing driver behaviour through reduced speed zones and educational programs is significantly less expensive than implementing more expensive mitigation to change wildlife behaviour. In addition, changing driver behaviour does not negatively affect other ecological components.

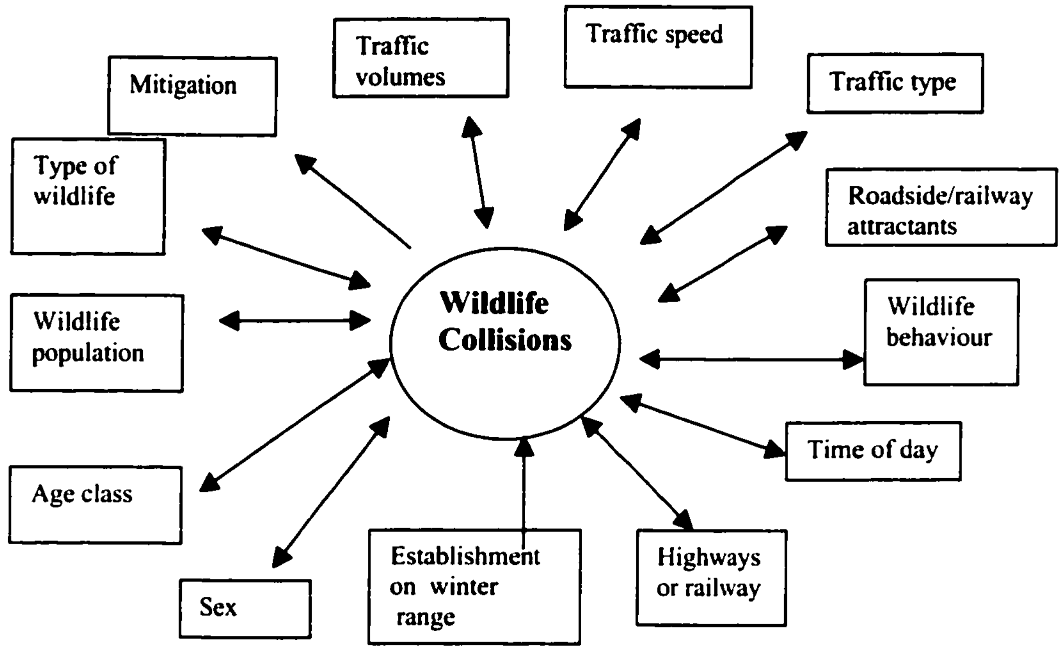

Figure 64. Model of variables influencing wildlife collisions

The effects of highways and the railway in Jasper National Park on wildlife are disproportionate to the area of land that they occupy. The effects on nine large animal species in Jasper National Park are;

- direct mortality of animals;
- habituation, highways attract ungulates to forage in ditches and access salt that is applied to road surfaces, carnivores may also be attracted to scavenge carcasses;
- disruption of regional populations; The National Parks Act and land use policy in Jasper National Park provides a level of protection that promotes the establishment of large ungulate populations. These populations are attracted to prime habitat in a confined space adjacent to high levels of human use on highways and the railway.

This in turn attracts carnivores that are more at risk from collisions than ungulates because of lower reproductive rates, lower population densities and larger home ranges. Regional populations may persist in the face of local extinctions because of the movement of individual animals and groups among populations (Ruediger 1996). The Yellowhead Corridor may undermine this process for carnivores;

- mortality on highways and the railway have different effects on collision rates based on age class, sex, type of wildlife, and transportation category;
- after highway and railway upgrades, collisions with wildlife increased;
- collisions with wildlife are not entirely influenced by traffic volumes, traffic type and wildlife behaviour also influence collisions rates.

Parks Canada has implemented a limited number of mitigation to reduce collisions, most of these, with the exception of reduced speed zones, have not been effective in reducing collisions. One of Parks Canada of objectives is to reduce wildlife mortality caused by collisions with vehicles and trains. Based on the increased collision rates during the study period Parks Canada has failed to meet this objective. Meeting this objective will become more difficult because of future development of the Yellowhead Highway.

Parks Canada's management goal for transportation corridors states "national transportation corridors will be managed in a way that supports Parks Canada's commitment to ecological integrity" (Parks Canada 2000). The number of vehicles on the Yellowhead Highway increases by 3% annually (Parks Canada 2000). As traffic volumes increase additional passing lanes will be required and possible twining of some sections as early as 2015 (Parks Canada 2000). In order to meet it's goal for transportation corridors Parks Canada should take action now to reduce existing collision rates and to plan for future development of the Yellowhead Highway.

4.1 RECOMMENDATIONS

The following recommendations are a summary of action that should be taken based on the information presented in this thesis and Parks Canada's management goals for transportation corridors.

4.2 Determine the effect of collisions on wildlife

The biological effect of collisions on wildlife and the ecosystem in Jasper National Park is largely unknown. In some species the effect of collisions may be significant including the effect on regional wildlife populations.

The Yellowhead Corridor cuts through prime wildlife habitat containing a large ungulate population. Predators are attracted to the Yellowhead Corridor to take advantage of this large prey base. An example is wolves. Because of the surrounding mountainous topography ungulates are restricted to areas adjacent to the corridor especially during the winter. To take advantage of this prey base, wolves are exposed to traffic to a greater extent than they would be in non-mountainous areas. Because of the lack of information on wolf populations, it is not known if collisions with wolves are with resident populations or with resent migrants. If collisions are with recent migrants the Yellowhead Corridor may be acting as a population sink drawing wolves from surrounding areas to an area where they are at a greater risk of collisions. If this is the case collisions on the Yellowhead Corridor are affecting local as well as regional populations. At some point highways become mortality sinks for carnivores, even where adjacent land uses allow their existence (Ruediger 1996)

Holoroyd and Van Tighem (1983) concluded whitetail deer populations in Jasper National Park were increasing and may be invading mule deer habitat. Displacement of mule deer by whitetail deer is well documented (Geist 1991). Relative collision data supports these conclusions. The current status of mule deer in Jasper National Park is unknown. Based on relative collision rates the mule deer population adjacent to the Yellowhead Corridor may be declining.

Collisions with smaller species are under represented in the database. In some cases collision data is totally absent two examples are reptiles and amphibians. It is unlikely based on collision data collected in other areas (Clevenger 2001) that collisions with these species does not occur.

These are three examples of areas were more comprehensive information is required to begin to better understand wildlife collisions and to develop specific mitigation.

4.3 Mitigation recommendations

With the exception of reduced speed zones, Parks Canada's attempts to mitigate collisions with wildlife have not been successful. The following short list of mitigation have been chosen based on the criteria in this thesis, and Parks Canada's goal for transportation corridors which is- "national transportation corridors will be managed in a way that supports Parks Canada's commitment to ecological integrity" (Parks Canada 2000).

All visitors to Jasper National Park must purchase a park pass. However, through-traffic is not required to purchase a park pass. Through-traffic makes up 75% of traffic volumes and virtually 100% of transport truck volumes. Consequently, based on volume and traffic type through-traffic is responsible for the majority of collisions. Because through-traffic is responsible for the majority of collisions it is reasonable that this component of traffic take responsibility for the costs associated with mitigation. Funds collected through a toll charge will allow Parks Canada greater flexibility when choosing mitigation now and in the future.

Collisions with bighorn sheep are restricted to short sections of highways and the railway adjacent to escape terrain. Wide-scale fencing reduced collisions with large animals in Banff National Park. With the exception of the recent fencing of the Brule tunnel on the railway, fencing has not been tried in Jasper National Park. The highest collision rates for bighorn sheep on the Yellowhead Highway occur along a short section of highway at Mile 12 (kilometre 31). Based on the high collision rates and surrounding topography this is the best location to experiment with short sections of fencing.

Relocation of reduced speed zones will significantly reduce collisions with wildlife. The benefits of this mitigation are, reduced speed zones are effective, there is a minimal ecological loss to other ecological components, and the social and economic costs are minimal.

A commercial weight restriction on the Yellowhead Highway would significantly reduce collisions, and delay highway upgrades. Options for transporting truck freight are the railway and the alternative route through Banff National Park. Relocating transport truck traffic to the Banff Corridor would localise the impacts to an area where mitigation is already in in-place. This approach is an example of managing Jasper and Banff National Parks on a regional or landscape scale to meet similar management goals.

There are strong temporal collision trends, both seasonal and hourly. A nighttime closure of the Yellowhead Highway for through traffic during low traffic volume and high collision periods (October to December) would significantly reduce collisions and not impact the majority of users of the Yellowhead Highway.

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Appendix I

Regression analysis traffic volumes and wildlife collision rates 1994 to 1996

All wildlife collisions (n=384) regression analysis 1994 to 1996

Regression Statistics	
Multiple R	0.375086
R Square	0.14069
Adjusted R Sq	0.054759
Standard Erroi	13.25952
Observations	12

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	287.851429	287.8514	1.6372418	0.229593779
Residual	10	1758.148571	175.8149		
Total	11	2046			

Elk collisions (n=130) regression analysis 1994 to 1996

Regression Statistics	
Multiple R	0.12472338
R Square	0.01555592
Adjusted R Square	-0.08288849
Standard Error	5.44953176
Observations	12

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	4.692703	4.692702628	0.158017	0.699341336
Residual	10	296.974	29.6973964		
Total	11	301.6667			

Whitetail deer collision (n=69) regression analysis 1994 to 1996

Regression Statistics	
Multiple R	0.012897
R Square	0.000166
Adjusted R Sq	-0.099817
Standard Erroi	3.663709
Observations	12

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	0.022329918	0.02233	0.0016636	0.968268494
Residual	10	134.2276701	13.42277		
Total	11	134.25			

Moose collisions (n=31) regression analysis 1994 to 1996

Regression Statistics	
Multiple R	0.411625
R Square	0.1694352
Adjusted R Square	0.0863787
Standard Error	1.3796296
Observations	12

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	3.882889	3.88289	2.039999	0.183688886
Residual	10	19.03378	1.90338		
Total	11	22.91667			

Mule deer collisions (n=53) regression analysis 1994 to 1996

Regression Statistics	
Multiple R	0.608878
R Square	0.370733
Adjusted R Square	0.307806
Standard Error	3.240913
Observations	12

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	61.88149	61.88149	5.891502	0.035617817
Residual	10	105.0352	10.50352		
Total	11	166.9167			

Bighorn sheep collisions (n=51) regression analysis 1994 to 1996

Regression Statistics	
Multiple R	0.227896
R Square	0.051936
Adjusted R Square	-0.04287
Standard Error	2.925111
Observations	12

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	4.687264	4.687264	0.547816	0.476229241
Residual	10	85.56274	8.556274		
Total	11	90.25			

Carnivore collisions (n=46) regression analysis 1994 to 1996

Regression Statistics	
Multiple R	0.687374
R Square	0.472483
Adjusted R Square	0.419731
Standard Error	2.383191
Observations	12

ANOVA

	df	*SS*	*MS*	*F*	*Significance F*
Regression	1	50.87066	50.87066	8.956733	0.013509313
Residual	10	56.796	5.6796		
Total	11	107.6667			