THE UNIVERSITY OF ALBERTA

ALTERNATIVES FOR BISON MANAGEMENT IN BANFF NATIONAL PARK

by

NORA R. KOPJAR

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

IN

WILDLAND RECREATION

DEPARTMENT OF FOREST SCIENCE

EDMONTON, ALBERTA

SPRING 1989

National Library of Canada
Bibliothèque nationale du Canada

Canadian Theses Service
Service des thèses canadiennes

Ottawa, Canada
K1A 0N4

ISBN 0-315-52795-1

Canada

THE UNIVERSITY OF ALBERTA

RELEASE FORM

NAME OF AUTHOR NORA R. KOPJAR

TITLE OF THESIS ALTERNATIVES FOR BISON MANAGEMENT IN BANFF NATIONAL PARK

DEGREE FOR WHICH THESIS WAS PRESENTED MASTER OF SCIENCE

YEAR THIS DEGREE GRANTED SPRING 1989

(SIGNED) ...Nora Kopjar...

PERMANENT ADDRESS:

RR #2

THREE HILLS, AB

T0M 2A0

DATED April 24 1989

THE UNIVERSITY OF ALBERTA

FACULTY OF GRADUATE STUDIES AND RESEARCH

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled ALTERNATIVES FOR BISON MANAGEMENT IN BANFF NATIONAL PARK submitted by NORA R. KOPJAR in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE in WILDLAND RECREATION.

....
Supervisor

....

....

....

....

Date 24 APRIL 1989

DEDICATION

To my parents

ANDY & MELBA KOPJAR

For laying such a solid foundation

for me to build upon.

ABSTRACT

Conflicts with wildlife have necessitated a reassessment of the present Buffalo Paddock facility in Banff National Park, Alberta. This study provides the framework and data required to analyze alternatives for bison management.

A historical review concluded that bison were indigenous to the Banff National Park area until *circa* 1860. Plains bison were reintroduced in 1897 as a captive herd. The herd was maintained until 1981, when the plains bison were replaced with the present wood bison herd.

The bison management factors pertinent to Banff National Park were reviewed. The habitat requirements of bison, effects of bison on their environment, herd management considerations, and the human dimensions of bison management in a national park setting are discussed.

Interpretation of the ecological land classification of the park identified nine Ecosites as potential bison forage habitat: six have suitable winter snow depths. The lower Howse/North Saskatchewan, Red Deer, and Bow River valleys are potential wintering areas for free-ranging bison. Four possible paddock relocation sites were identified.

A twelve week study of visitor use in the Buffalo Paddock revealed that the opportunity for viewing bison is limited due to vegetation screening and the timing of visitor use. The paddock receives significant use; approximately 26,000 vehicles or 120,000 visitors were recorded during the study period. About 6% of the vehicles using the Buffalo Paddock were buses, representing at least 50% of the visitors. Improved interpretation and facility design are required to address bison harassment and public safety concerns, and to improve the visitor experience.

The information obtained was applied to a review of five alternatives for bison management in Banff National Park. The recommended alternative is the introduction of a free-ranging bison herd. This would eliminate wildlife conflicts associated with the paddock, allow bison to reassume their role in the park ecosystem, and provide a unique opportunity for free-ranging bison management and interpretation. The next best alternative is

modification of the present Buffalo Paddock. Bison would be maintained in the park, and design changes would reduce wildlife conflicts, and improve the quality of the visitor experience

ACKNOWLEDGEMENTS

I sincerely thank my thesis supervisor, Dr. Peter J. Murphy, for his guidance and support. His continuing interest and encouragement are deeply appreciated. My committee members Dr. Peter Achuff, Dr. Thomas Burton, Dr. James Butler, and Hal Reynolds (Canadian Wildlife Service), provided valuable advice and discussion. I thank them for their efforts.

The Canadian Parks Service provided me with the opportunity to conduct my research in Banff National Park. Special thanks to Dr. Bruce Leeson, Western Region, who initiated and facilitated my study in many ways, and to the Banff Warden Service for their co-operation and hospitality during my field study.

I extend my thanks to the National Science and Engineering Research Council, the Canadian Parks Service, the Canadian Forestry Service (Human Resources Fund), and the University of Alberta (Central Research Fund) for financial support.

To my research assistant and friend, Tracy Thornton; thank you for your capable and cheerful assistance in the field and office, and for your companionship.

Several people who contributed to my thesis by providing information and guided tours, by sharing personal knowledge and insight about bison mangement, and through participation in the Buffalo Paddock study are gratefully acknowledged: A. Anderson (Public Works Canada), C. Anderson and the guides of Mountain Park Tours, D. Anions (Prince Albert National Park), J. Curry (Canadian Commercial Buffalo Limited), D. Gaudet (Rocky Mountain House National Historic Park), R. Kunelius and J. Nylund (Banff National Park), W. Olsen (Elk Island National Park), P. Tarleton (Riding Mountain National Park), D. Tilson (Waterton Lakes National Park), M. Meagher (Yellowstone National Park), J. Malcolm (National Bison Range), and B. Sanford and the bus drivers of Brewster Transportation and Tours. I also thank E. Gorman for arranging for my visit to Canadian Commercial Buffalo Limited.

To my fellow graduate students and friends, especially Lyn Konowalyk and Dan Graham; thank you for your encouragement, understanding, and friendship.

Finally, my deepest gratitude to my family for their loving support, emergency editing assistance, and patience throughout my graduate program. Your unfailing confidence gave me the determination to succeed.

Table of Contents

LIST OF TABLES

LIST OF FIGURES

1. INTRODUCTION AND STUDY OBJECTIVES

Wildlife has always played an important role in Canada's western national parks. Strategies for the management of park wildlife have evolved along with the national park system. Today, wildlife management in national parks is a complex task, the product of a century of changing wildlife populations, habitat succession and modification, facility development, the diversity of demands placed upon the park resources by visitor use, and changing national park objectives.

National park objectives in the early 1900s called for managers to provide visible wildlife as a constant attraction for park visitors and hence to promote the growing tourist industry (Foster 1978). Few administrative or natural restrictions hampered the efforts of early managers to increase the number and visibility of wildlife. This was especially true for ungulate populations. The operation of animal paddocks, the importation of wildlife from varied sources, the construction of a zoo, and wide-scale predator elimination programs were acceptable management practices. In addition, there was a great capacity for natural growth of wildlife populations resulting from a general wildlife scarcity in the mountain regions by 1915 and an increasing availability of habitat as the processes of succession occurred on the vast burns of the late 1800s and early 1900s (Holroyd & Van Tighem 1983). However, wildlife management was not to remain a simple matter of the protection of ungulates and the elimination of predators.

Events of the 1950s and 1960s led to a reassessment of wildlife management in the western national parks. The development of access and visitor facilities expanded as park use increased. This development was accompanied by a growing concern for the resource base. Wildlife managers, as well as increasing numbers of Canadians, became more aware that vital wildlife areas were being excessively altered (Holroyd & Van Tighem 1983). The loss of habitat, wildlife disturbance, and other possible impacts of development became concerns in the location and construction of campgrounds, roads, and other facility developments. In addition, the principles of ecology were being increasingly applied to the study and management of wildlife and habitat. In 1959, a seventy year period of predator control in the parks officially ended when the elimination of predator species was declared undesirable for wildlife management (Holroyd & Van Tighem 1983). The controlled elk (*Cervus elaphus*) slaughters which had been initiated in Banff and Jasper National Parks in the 1940s became a controversial wildlife management issue. The slaughter program was designed to control a perceived overpopulation of elk in order to reduce the impacts on vegetation and competing ungulate species. However, the necessity for and long term effects of the elk slaughter were questioned, and the criticism of concerned Canadians hastened the termination of the program in the late 1960s (Holroyd & Van Tighem 1983). This increased environmental awareness, expanded knowledge of ecological relationships and processes, and continuing concern about the impact of development and use on park environments and wildlife led to the adoption of the current Parks Canada Policy in 1979 (Parks Canada 1983).

The policy reflected changing times, placing greater emphasis on protection of natural and historic resources, interpretation and educational activities, and professional planning (Parks Canada 1983). It provided a renewed commitment to the dual program objective of the Canadian Parks Service which is:

> To protect for all time those places which are significant examples of Canada's natural and cultural heritage and also to encourage public understanding, appreciation and enjoyment of this heritage in ways which leave it unimpaired for future generations[1].

However, despite this dual mandate, the policy clearly identifies that the Canadian Parks Service will make protection of heritage resources its primary consideration, with ecological and historical integrity being regarded as prerequisites to use[2]. Information and interpretation are to be undertaken in order to encourage appropriate use of heritage resources as well as public understanding[3], and opportunities for outdoor recreation are to be provided only in ways consistent with protection of resources[4]. The policy statement specifically for national parks further echoes this dual mandate of resource protection and public use, and calls upon planners and managers to meet this objective. National park resource management policies

[1]Parks Canada Policy, Program Objective.
[2]Parks Canada Policy, Program Policy, 1.1.
[3]Parks Canada Policy, Program Policy, 2.1.
[4]Parks Canada Policy, Program Policy, 2.3.

present an additional challenge to managers by requiring that natural resources not only be "given the highest degree of protection"[5], but be "managed with minimal interference to natural processes to ensure the perpetuation of naturally evolving land and water environments and their associated species"[6]. For wildlife managers, the challenge is complicated by past management strategies and the continuing development and use of national parks which have affected and will continue to affect wildlife, habitat, and wildlife-habitat relationships. For any wildlife management decision, these challenges must be recognized and the impacts on the resource, on natural processes, and on park visitor use must be assessed.

One such management issue in Banff National Park concerns a small herd of wood bison (*Bison bison athabascae*) located in the Buffalo Paddock[7] near Banff Townsite. The wood bison, and before them, generations of plains bison (*Bison bison bison*) have been on display in the Buffalo Paddock since 1897. However, recent studies of wildlife in the Banff Townsite area have identified that the Buffalo Paddock, in addition to occupying range valuable to free-ranging ungulates, may present a serious barrier to wildlife migration (Parks Canada 1984, Achuff *et al.* 1986). This wildlife conflict has necessitated a reassessment of the Buffalo Paddock facility and of the future management of bison in Banff National Park.

The purpose of this study was to provide the framework required to analyze alternatives for bison management in Banff National Park. In order to address the varied concerns of wildlife management in a national park setting, a number of information needs had to be met. As national parks are to be managed in their natural state, it was necessary to establish whether or not bison were indigenous to the Banff National Park area. Pertinent information regarding the basic biology, ecology, physiology, and behavior of bison needed to be consolidated in a form that could be used to predict the feasibility of each bison

[5]Parks Canada Policy, National Parks Policy, 3.1.
[6]Parks Canada Policy, National Parks Policy, 3.2.1.
[7]The name buffalo is a misnomer for the North American *Bison bison* species which should be reserved for the Asian and African buffaloes, as they are distinct genera (Banfield 1974). Therefore this study will utilize the correct term, bison, except when referring to the Buffalo Paddock, as this is the historical and commonly used name of the facility.

management alternative and the expected impacts on park resources and ecosystems. Similarly, the practical aspects of herd management and the nature of bison human interaction associated with each alternative had to be outlined. Interpretation of the park biophysical inventory was necessary to allow the use of existing land classification maps to locate potentially suitable bison habitat. Finally, the aspect of visitor use had to be addressed. The quantity and quality of visitor use of the present Buffalo Paddock facility had to be determined, and management and design factors relating to the viewing and interpretation of bison had to be identified for each alternative.

The broad range of information required dictated that this study take an interdisciplinary approach. Four study objectives were developed to meet the information needs.

1. To establish and describe the prehistorical and historical presence and distribution of bison in Banff National Park.
2. To identify the bison management factors pertinent to Banff National Park including the habitat requirements of bison, the effects of bison on their environment, herd management considerations, and the human dimensions of bison management in a national park setting.
3. To analyze bison habitat in Banff National Park through interpretation of the Ecological (Biophysical) Land Classification of Banff and Jasper National Parks.
4. To examine present visitor use of the Buffalo Paddock facility and identify visitor related factors for consideration in future bison management.

The final study objective was to apply the information obtained to a review of the following alternatives for bison management in Banff National Park:

a. Paddock removal and elimination of bison from Banff National Park
b. Paddock removal and establishment of a free-ranging bison herd
c. Retention of the present Buffalo Paddock
d. Structural modification of the present Buffalo Paddock
e. Relocation of the Buffalo Paddock

2. STUDY AREA

2.1 Banff National Park

2.1.1 Location

Banff National Park is located in southwestern Alberta, in the Continental Ranges of the Southern Rocky Mountains (Figure 1) (Bostock 1976). The park includes 6640 square kilometers of mountainous terrain lying east of the Continental Divide.

2.1.2 Recreational context

Banff National Park is one of Canada's best known and most frequently visited national parks. It is recognized both nationally and internationally as Canada's first national park and as an area of exceptional scenic beauty. In 1985 it was declared a World Heritage Site, along with Jasper, Yoho, and Kootenay National Parks, because of its internationally significant resource values (Environment Canada - Parks 1986b).

Three major roadways provide access to the park from Alberta; the Trans-Canada Highway (Highway #1) from Calgary, the David Thompson Highway (Highway #11) from Red Deer, and the Yellowhead Highway (Highway #16) via the Icefields Parkway (Highway #93) through Jasper National Park, from Edmonton. Access from British Columbia is provided by the Trans-Canada Highway through Yoho National Park from Revelstoke and Vancouver, the Banff-Windermere Highway (Highway #93) through Kootenay National Park from Radium and Cranbrook, and the Yellowhead Highway via the Icefields Parkway through Jasper National Park, from Prince George. The Canadian Pacific Railway also passes through the park alongside the Trans-Canada Highway. There are nine park roads in addition to the major access routes already mentioned which provide opportunities for scenic viewing and access to various recreation, accommodation, and interpretation facilities (Environment Canada - Parks 1986a).

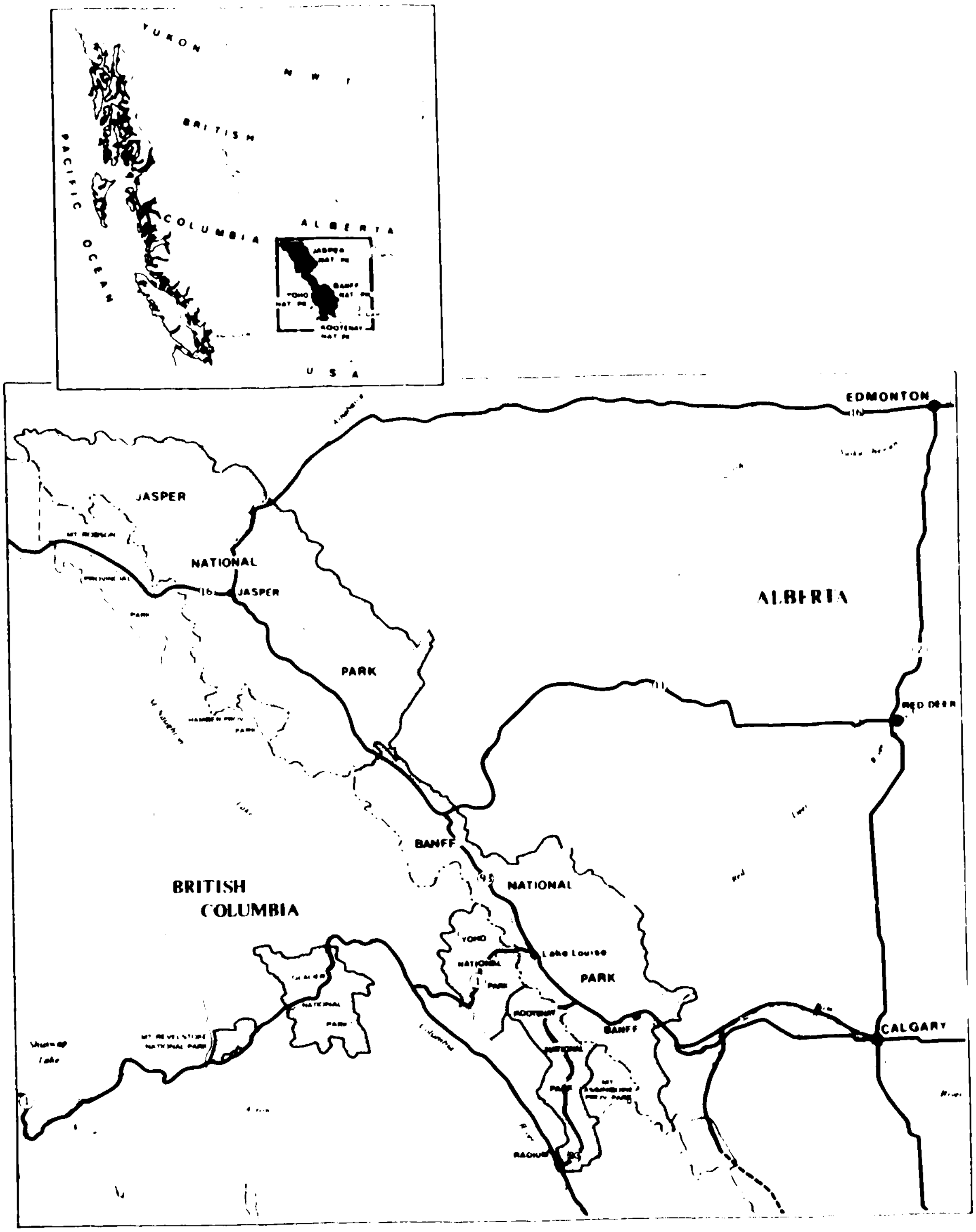


Figure 1. Regional setting of Banff National Park.

Over eight million people enter Banff National Park annually, with about half stopping to spend time in the park (Environment Canada - Parks 1986b). Approximately 80% of the park visitors are from Canada, 15% are from the United States and 5% are from overseas (Schulz 1985). Of the Canadian visitors, 80% are from Alberta and 7% from British Columbia, with the other provinces making up the remaining 13% (Schulz 1985).

Banff National Park provides a broad range of frontcountry and backcountry recreational opportunities to regional (primarily Calgary), national and international visitors. Major activities include driving for pleasure, sightseeing, camping, fishing, hiking, bicycling, horseback riding, cross-country and downhill skiing, canoeing, kayaking and rafting, lake boating, and mountaineering. The park is used year round, although the heaviest use periods occur in the summer and winter months (Environment Canada - Parks 1986b). Most of the use and facilities in the park are centered at Banff townsite, Lake Louise, and along the Trans-Canada Highway and the Icefields Parkway.

2.1.3 Physiography

The mountains of Banff National Park trend northwest to southeast, and are divided into two geologic subprovinces, the Front Ranges and the Main Ranges (Figure 2) (Price & Mountjoy 1970). The Front Ranges, which form the eastern portion of the park, consist of a series of fault blocks, thrust up and steeply tilted toward the southwest (Baird 1977). The resulting Front Range mountains are characterized by long smooth slopes on their southwest aspects, and steep cliffs and talus on their northeast faces. Between the mountains lie the asymmetrical valleys typical of the Front Ranges (Rutter 1972). The Main Ranges, west from Castle Mountain to the Continental Divide, are characterized by more gently inclined and less folded strata. The Main Range mountains are generally massive, castellate structures, separated by symmetrical, steep-walled valleys (Rutter 1972).

Elevation in the park varies from 1330 m at the point where the Bow River leaves the park, to the summits of the Continental Divide, with the highest mountain in Banff National Park being Mount Forbes at 3628 m. Many peaks in the Main Ranges exceed 3000 m and

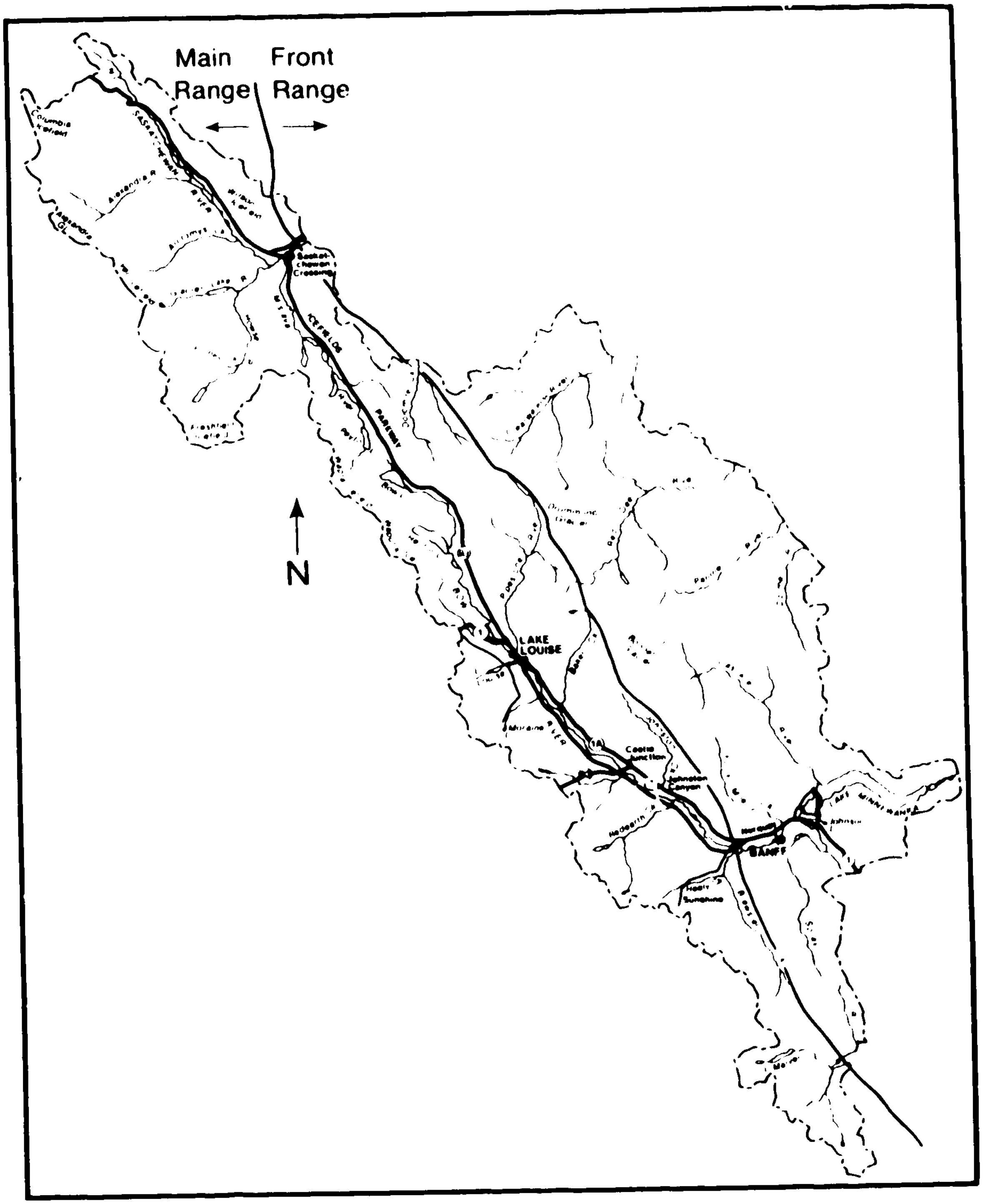


Figure 2. Major rivers and geologic subprovinces of Banff National Park.

icefields and glaciers are common. The summit elevations generally decrease from the Continental Divide eastward, with peaks in the Front Ranges averaging 2850 m (Robinson 1980). The elevation of park valleys is also high, with only the valleys of the major rivers, the North Saskatchewan and the Bow, having an elevation of below 1500 m.

The North Saskatchewan and Bow Rivers, along with the smaller Clearwater, Red Deer, and Panther Rivers cut across the northwest to southeast trending mountains to allow eastward drainage to the prairies. They are fed by many smaller rivers and creeks of the park and are, in turn, tributaries of the Saskatchewan River system which is the primary source of water for the Great Plains region of Alberta and Saskatchewan (Holland, Hillman & Allan 1982).

The physiography of Banff National Park is controlled largely by the mountain building processes, but the landscape has also been modified by glaciation, and post-glacial erosion and deposition. Extensive glaciation took place in the Pleistocene, when at least three major advances occurred (Rutter 1972). Since the last deglaciation of the major valleys about 10,000 years ago, only small neoglacial advances have occurred (Heusser 1956). However, retreating glaciers which still remain at high elevations continue to actively alter the landscape. Erosional and depositional processes carried on by water, wind, and gravity also continue to shape the landscape of Banff National Park.

2.1.4 Climate

In general, the climate of Banff National Park is continental, having long winters with occasional cold spells, and short cool summers with occasional hot spells (Janz & Storr 1977). Monthly temperature and precipitation means for Banff and Lake Louise are illustrated in Figures 3 & 4. July and August are the warmest months, with mean temperatures close to 15 °C, and December and January are the coldest months, averaging -10 °C (White 1985). Precipitation varies greatly throughout the park in both amount and timing. Banff receives a mean annual precipitation of 46 cm with the maximum precipitation occurring in late spring and early summer, whereas Lake Louise receives 77 cm of precipitation with the maximum

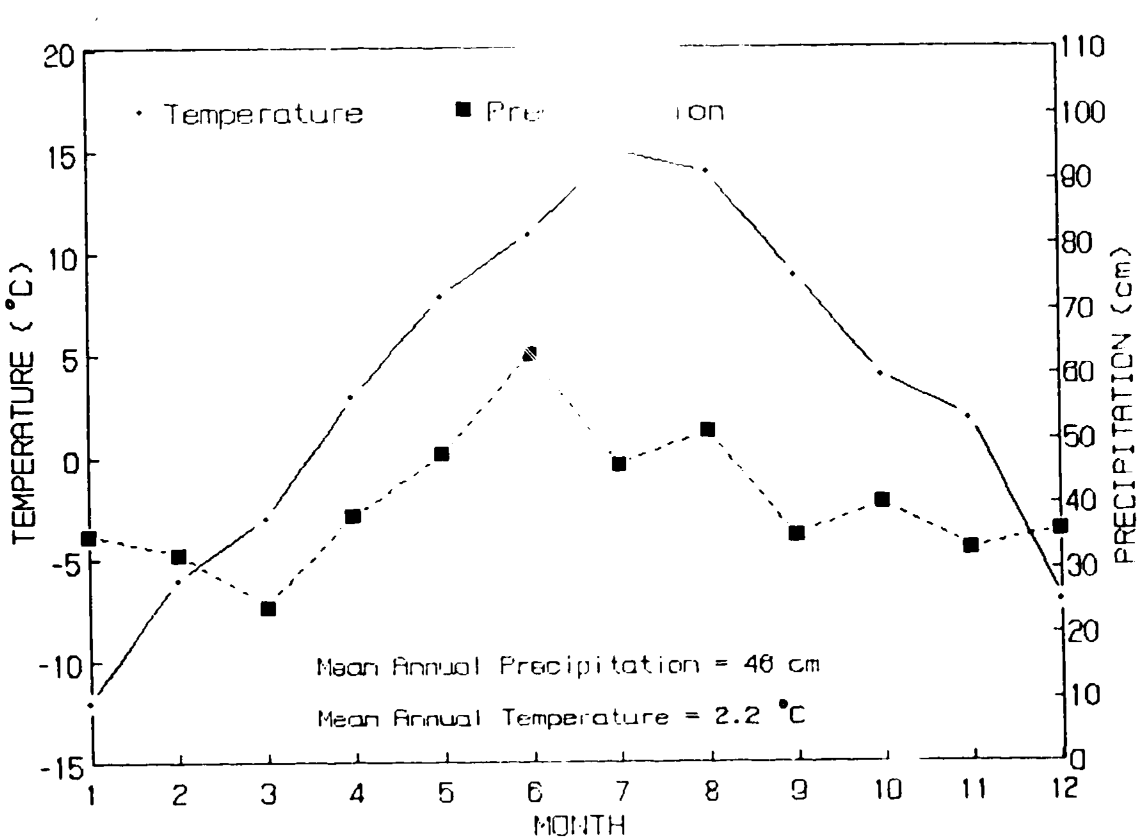


Figure 3. Monthly temperature and precipitation means for Banff, Alberta.

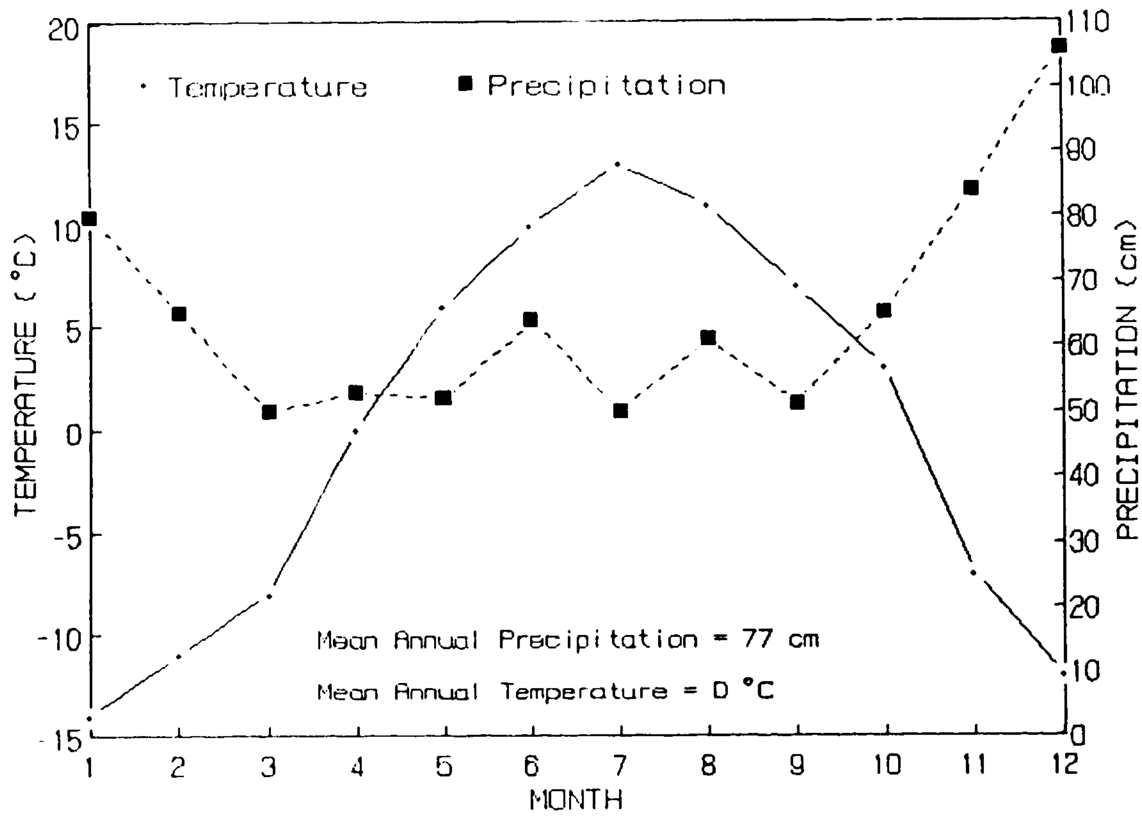


Figure 4. Monthly temperature and precipitation means for Lake Louise, Alberta.

occurring in the winter (White 1985). Much of Banff National Park is dry, with many of the main valleys receiving less than 50 cm mean annual precipitation (Janz & Storr 1977).

The continental climate, however, exhibits wide variations from these average conditions. In addition, this variation is magnified by the topographic and physiographic features of the park. Elevation, aspect, and valley orientation relative to prevailing winds and weather patterns greatly influence the meso-climatic and micro-climatic conditions at any given location (Janz & Storr 1977, Holland, Achuff, & Walker 1982).

2.1.5 Vegetation

This study utilizes the Ecological (Biophysical) Land Classification of Banff and Jasper National Parks (ELC) (Holland & Coen 1982, Holland & Coen 1983, Holroyd & Van Tighem 1983) which presents landform and soil, vegetation, and wildlife information in map and descriptive format. The ELC uses a three-level hierarchical system which classifies land according to landform, soil, and vegetation differences. The system defines three Ecoregions based on vegetation physiognomy and species composition that reflect microclimate, Ecosections based on broad landform, drainage class, and soil differences, and 124 Ecosites based on specific soil and vegetation differences (Holland & Coen 1983). Sites are mapped and wildlife information is presented at the Ecosite level. The following description of the three Ecoregions, the Montane, Subalpine, and Alpine, abstracted from Achuff (1982), outlines the vegetation of Banff National Park in general terms.

The Montane Ecoregion lies at elevations below 1600 m and is found in only two areas of the park, the Bow River valley east of Castle Mountain and the North Saskatchewan and Howse River valleys east of Glacier Lake. The Montane is dry (less than 50 cm precipitation/yr), with warm summers, and mild winters, often with intermittent snow cover. Forests dominated by Douglas-fir (*Pseudotsuga menziesii*), white spruce (*Picea glauca*), or aspen poplar (*Populus tremuloides*) and grasslands characterize the ecoregion. ELC vegetation types typical of the Montane include Douglas-fir/hairy wild rye (*Pseudotsuga menziesii/Elymus innovatus*)(C1), white spruce/fern moss (*Picea glauca/Thuidium* *abietinum*)(C2), lodgepole pine/juniper/bearberry (*Pinus contorta/Juniperus communis/Arctostaphylos uva-ursi*) (C3), aspen/hairy wild rye-peavine (*Populus tremuloides/Elymus innovatus - Lathyrus ochroleucus*)(C16), and junegrass-pasture sage-wild blue flax (*Koeleria cristata - Artemisia frigida - Linum lewisii*) (H6).

Above the Montane lies the Subalpine Ecoregion which is subdivided into the Lower Subalpine (1600 m to 2000 m) and the Upper Subalpine (2000 m to 2300 m). Precipitation (50 to 125 cm/yr) is greater and temperatures cooler than in the Montane. The Lower Subalpine is dominated by closed lodgepole pine and Engelmann spruce-subalpine fir (*Picea engelmannii - Abies lasiocarpa*) forests. ELC vegetation types which characterize the Lower Subalpine include lodgepole pine/buffaloberry/showy aster (*Pinus contorta/Shepherdia canadensis/Aster conspicuus*) (C6), lodgepole pine/buffaloberry/twinflower (*Pinus contorta/Shepherdia canadensis/Linnaea borealis*) (C19), Engelmann spruce-subalpine fir/feathermoss (*Picea engelmannii - Abies lasiocarpa/Hylocomium splendens*) (C13), and Engelmann spruce-subalpine fir/false azalea (*Picea engelmannii - Abies lasiocarpa/Menziesia glabella/Vaccinium scoparium*) (C14). The Upper Subalpine is cooler than the Lower Subalpine, with more precipitation and longer winters. Open Englemann spruce-subalpine fir forests and stunted tree growth are characteristic as a[illegible] subalpine larch-subalpine fir/grouseberry-everlasting (*Larix lyallii - Abies lasiocarpa/Vaccinium scoparium - Antennaria lanata*) (C23) forests which are found in the southern part of the park. Typical vegetation types of the Upper Subalpine include Engelmann spruce-subalpine fir/heather (*Picea engelmannii - Abies lasiocarpa/Phyllodoce glanduliflora - Cassiope mertensiana*) (O10), Engelmann spruce-subalpine fir/valerian-fleabane (*Picea engelmannii - Abies lasiocarpa/Valeriana sitchensis - Erigeron peregrinus*) (O9), Engelmann spruce-subalpine fir/grouseberry (*Picea engelmannii - Abies lasiocarpa/Vaccinium scoparium*) (C15), and Engelmann spruce-subalpine fir/rock willow/white mountain heather (*Picea engelmannii - Abies lasiocarpa/Salix vestita/Cassiope tetragona*) (C24).

The Alpine Ecoregion is an area characterized by a cold, harsh climate which occurs above the Upper Subalpine. The Alpine is treeless, vegetated by low shrub and herb communities such as heather-everlasting (*Phyllodoce glandulflora - Cassiope mertensiana - Antennaria lanata*) (L5), and mountain avens-snow willow-moss campion (*Dryas octopetala - Salix nivalis - Silene acaulis*) (H1) in wind exposed sites and white mountain heather-mountain avens-snow willow (*Cassiope tetragona - Dryas octopetala - Salix nivalis*) (L4) in sites with moderately deep snowbeds.

Overall, the vegetation of Banff National Park is largely subalpine forest with the Lower and Upper Subalpine each representing about 25% of the park area. The Montane Ecoregion comprises another two percent, and the Alpine about five percent. The remainder of the park is not vegetated.

2.2 The Buffalo Paddock

2.2.1 Location

The Buffalo Paddock[a] is a 40 hectare (ha) enclosure located northeast of Banff Townsite at the foot of Cascade Mountain (Figure 5). The paddock lies on the alluvial fan formed where Forty Mile Creek enters the Bow River valley. It is bordered on the north by Cascade Mountain, on the west and southwest by government and public horse corrals and access roads, on the south and southeast by the Trans-Canada Highway and on the east and northeast by an airfield and open grassland (Figure 6). At an elevation of approximately 1400 m, the Buffalo Paddock lies within the Montane Ecoregion of the park. Summers are warm with mean daily temperatures of 14.4°C in July and 13.3°C in August (Figure 3). Winters are mild, with mean temperatures for the coldest months, December and January, of -8.3°C and -10.6°C. Mean yearly precipitation is only 48 cm, with 42% falling as snow (Holland, Achuff & Walker 1982). Winter snow accumulation is low and, due to Chinook winds, the area is intermittently snow-free throughout the winter.

[a]The facility is described here as it existed during this study. In the spring of 1988, the size of the larger pasture was decreased by half and the smaller pasture was eliminated. However, unless otherwise indicated, reference to the Buffalo Paddock in the following sections refers to the pre-modification facility.

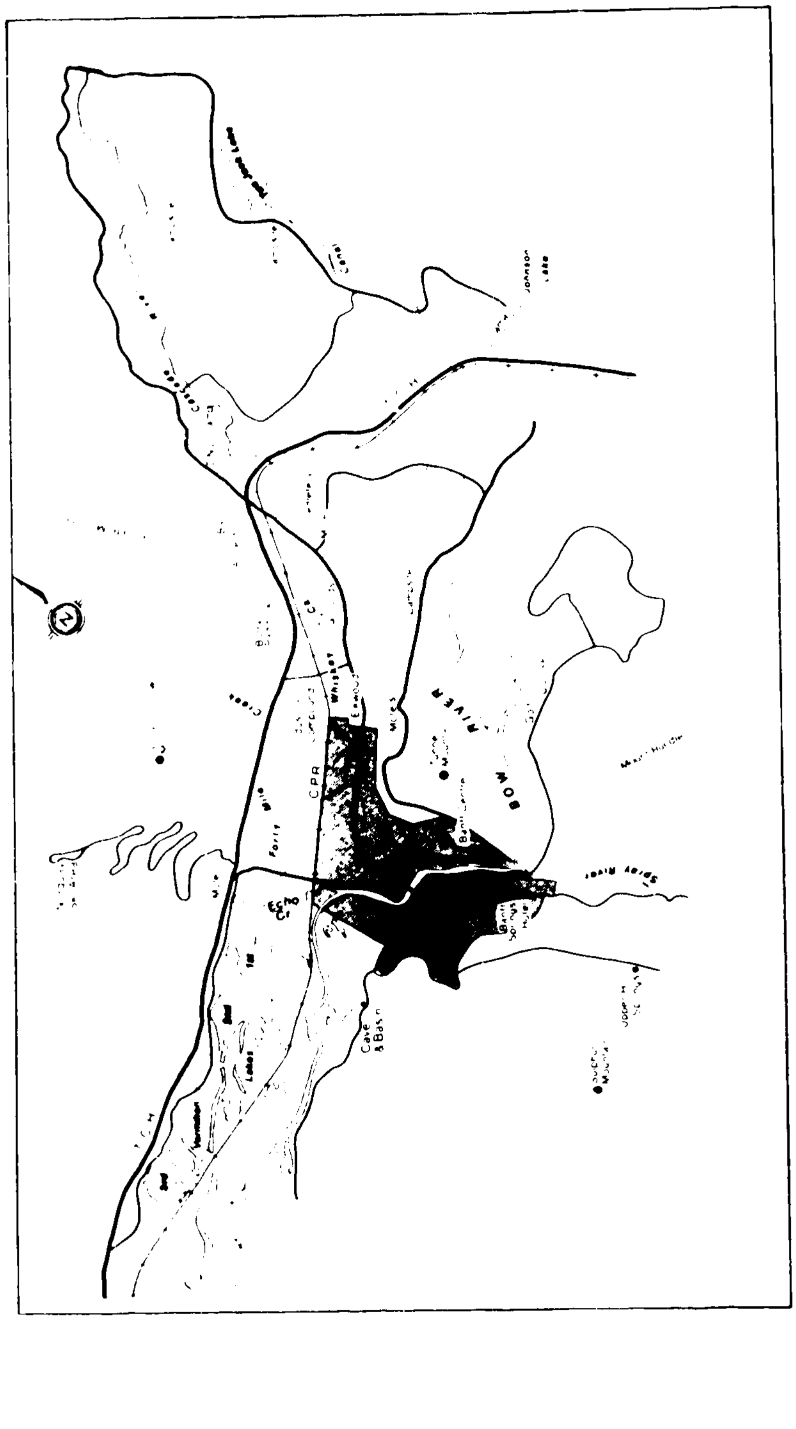


Figure 5. Location of Buffalo Paddock.

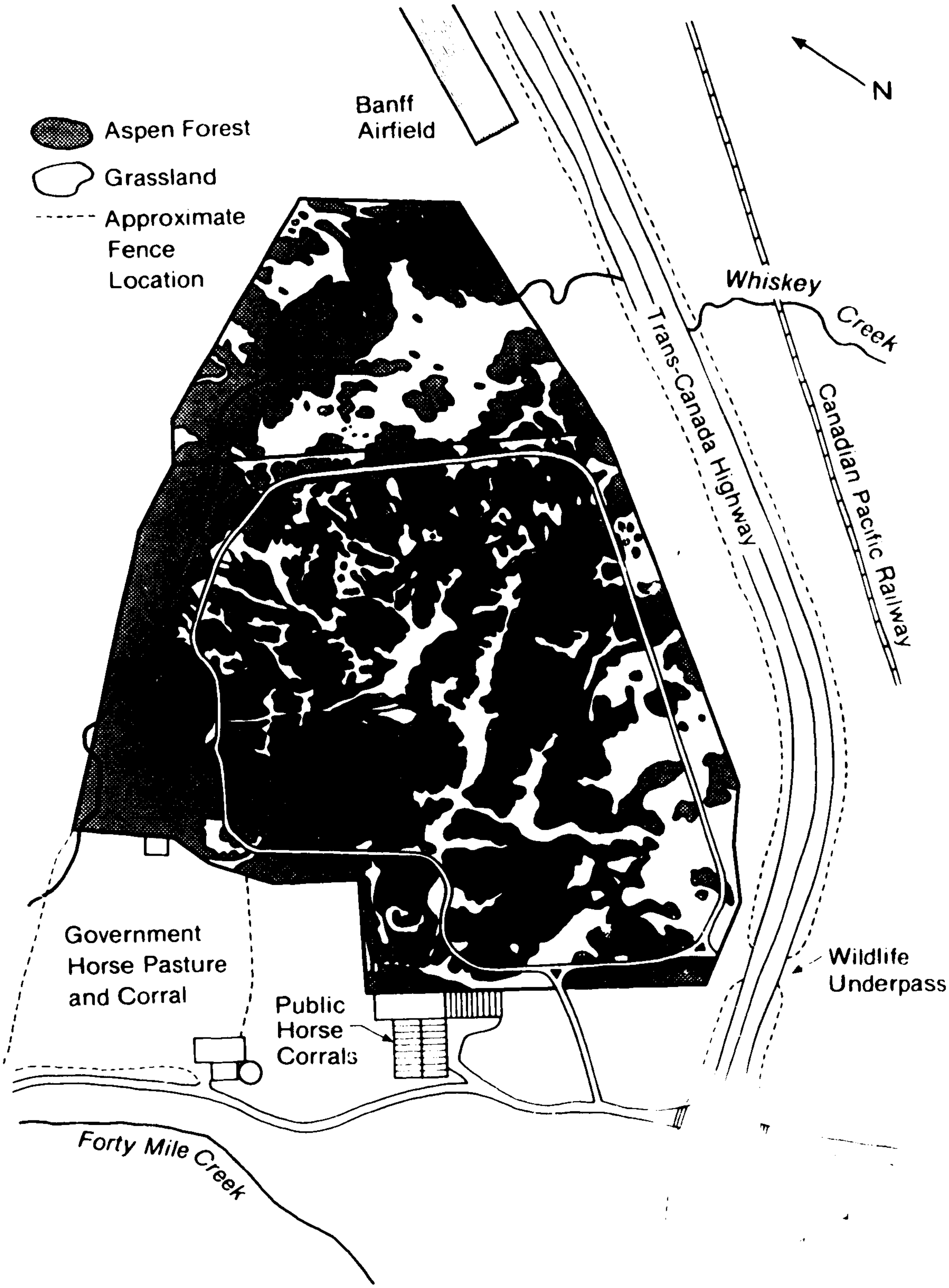


Figure 6. Buffalo Paddock facility and vicinity.

2.2.2 Vegetation

Two Ecosites, HD1, which is dominated by aspen forest, and HD4, a dry grassland, are found within the Buffalo Paddock. The paddock is divided into two pastures. The larger pasture is about 32 ha with 75% forest cover, and the smaller pasture is about 8 ha with 70% forest cover. The bison are confined to the larger pasture during the visitor season but in the fall, winter, and spring, they are periodically allowed access to the second pasture. A small stream flows through both pastures, along the base of Cascade Mountain and south across the Trans-Canada Highway to Whiskey Creek.

The two major vegetation types associated with HD1 and HD4 are aspen/hairy wild rye-peavine (C16) and June grass-pasture sage-wild blue flax (H6) respectively (Table 1). In general, the forested areas of the paddock are aspen dominated, with the occasional old Douglas-fir. However, along the stream banks, white spruce mixes with the aspen, and is dominant in some areas. Prickly rose (*Rosa acicularis*), buffaloberry, and common juniper (*Juniperus communis*) form a moderately dense shrub layer and the herb-dwarf layer is dominated by hairy wild rye and pine reedgrass (*Calamagrostis rubescens*), with some horsetail (*Equisetum* sp.) along the stream. The grassland areas are dominated by June grass and pasture sage, with a variety of forbs.

2.2.3 Facilities

A 2.4 m high paige wire fence surrounds the paddock and separates the two pastures. Vehicle access to the summer pasture is over a cattle guard gate on the southwest side, and a swing gate in the fence between the pastures provides access to the smaller paddock. There are no facilities specifically for bison handling. However, the Warden Service horse barns and corrals are located immediately west of the Buffalo Paddock and these facilities are used when necessary to load bison for shipping. There is also a shed located just outside the west corner of the Buffalo Paddock fence where hay for winter feeding is stored.

Table 1. Description of the major vegetation types found in the Buffalo Paddock.

C16: Aspen/hairy wild rye-peavine

Vegetation Layer	Species Composition	(%Cover)
Trees	aspen poplar	20-60
Shrubs	prickly rose	5-10
	buffaloberry	5-15
	common juniper	<1
Herbs-Dwarf Shrubs	hairy wild rye	15-40
	pine reedgrass	15-40
	peavine	1-3
	showy aster	<1
	wild strawberry	1-5
	northern bedstraw	<1
	wild vetch	<1
	common yarrow	<1

H6: June grass-pasture sage-wild blue flax

Vegetation Layer	Species Composition	(%Cover)
Herbs-Dwarf Shrubs	June grass	15-30
	pasture sage	1-20
	wild blue flax	1-10
	everlasting	1-10
	northern bedstraw	<5
	ragwort	1-5
	wild gaillardia	<5
Bryoids	(Tortula ruralis)	<3

2.2.4 Visitor access

The Buffalo Paddock lies directly northwest of the Trans-Canada Highway. Since the highway is now divided, there is access from the west-bound lane only. East-bound vehicles must travel two km past the Buffalo Paddock to an overpass which allows access to the west-bound lane. There is a 3.4 km loop road through the larger paddock which is open to visitors from snow melt to snow fall, generally early May to late September. Signage states that cycles, horses, and pedestrians are prohibited from entering the Buffalo Paddock and visitors are instructed to remain in their vehicles and enter the paddock at their own risk.

2.2.5 Wood bison herd

At present, a small herd of wood bison occupies the Buffalo Paddock. The base herd consists of one bull and [illegible] cows. However, total herd size ranges from four to thirteen animals because of varying calf numbers and, prior to 1988, due to the occasional absence of the adult male. After escaping once through an accidentally open gate, the original herd bull learned to leave the paddock at will, by walking over the cattle guard. He would leave the paddock in late fall or winter, spend up to six months ranging further up the Bow River valley, and then return to the paddock by the end of July for breeding season. In the spring of 1988, the free-ranging movements of this bull became unacceptable and he was replaced with a yearling bull from Elk Island National Park. Four calves have been born each year since 1982 but they are removed biannually.

3. BACKGROUND TO THE STUDY

3.1 The Buffalo Paddock as a Barrier to Wildlife Movement

The Banff Townsite Peripheral Land Use Initial Environmental Evaluation Interim Report (Parks Canada 1984) indicated that wildlife movement up and down the Bow River valley is severely limited in the vicinity of the townsite. The townsite lies within a natural constriction of the lower Bow River valley near the junction of several large valleys (Figure 7). The narrowest portion of the Bow River valley, from Stoney Squaw Mountain to Tunnel Mountain and to the base of Mount Rundle, provides a corridor for ungulate movement only 3.9 km wide. This corridor is further decreased to 1.9 km by the presence of the many facility, residential, commercial and transportation developments which exist in this area. Many ungulates, particularly elk, must travel through the remaining accessible area to reach seasonal ranges. They travel around Banff townsite area by four distinct travel routes (Olsen 1982,1984, Achuff *et al.* 1986) (Figure 7):

1. along the lower slopes of Mount Norquay and Stoney Squaw Mountain, and through the area south of the Trans-Canada Highway to Forty Mile Creek,
2. along the railroad right-of-way between the industrial compound and the townsite, through the Whiskey Creek area and onto the grasslands of the Indian Grounds area,
3. along the lower slopes of Sulphur Mountain, across the Banff Springs golf course, and along the Bow River between Mount Rundle and Tunnel Mountain,
4. and along the west slopes of Tunnel Mountain between the townsite and the cliffs on the north side.

The fence which surrounds the Buffalo Paddock has been identified as a significant barrier affecting the major northern travel route along the lower slopes of Mount Norquay and Stoney Squaw Mountain. The recent twinning and fencing of the Trans-Canada Highway past the Buffalo Paddock has further constricted this important travel route, and amplified the effect of the barrier created by the paddock fence. Ungulates in this vicinity moving from one side of the Trans-Canada Highway to the other must utilize a newly

Figure 7. Wildlife movement corridors in the Banff townsite area.

constructed underpass located at the bend in the highway at the south corner of the Buffalo Paddock. It is important that ungulates have access to this underpass. However, the location of the Buffalo Paddock interferes with ungulate movement from the airfield grasslands towards the underpass. Animals must travel either around the north side of the paddock along the lower slopes of Cascade Mountain, and around the government and public horse corrals on the west side of the paddock, or along the Trans-Canada Highway between the fences of the Buffalo Paddock and the highway through a corridor which is less than 100 m wide in the most constricted section.

In light of the critical state of wildlife movement corridors in this area of the Bow River valley, mitigative measures to facilitate movement, including the modification or relocation of the Buffalo Paddock, have been recommended (Parks Canada 1984, Achuff *et al.* (1986)).

3.2 Other Concerns Associated with the Buffalo Paddock

There are a number of further concerns associated with the presence of the Buffalo Paddock and bison in Banff National Park. The Buffalo Paddock excludes free-ranging ungulates from valuable grassland habitat and presents a method of wildlife management that appears to oppose national park philosophy. In contrast, the paddock provides for the protection of an isolated gene pool herd of the threatened wood bison and presents an opportunity for park visitors to view bison.

The Buffalo Paddock excludes free-ranging ungulates from 10 ha of Montane grassland. This Montane grassland, which is of primary importance to wintering elk, is of limited extent in the park, and there are less than 500 ha in the Bow River valley (Environment Canada - Parks 1986c). The grassland enclosed within the Buffalo Paddock would increase the highly important winter range formed by the Banff airfield and Indian Grounds grasslands by 10%. As the bison herd does not rely entirely on natural forage but is fed hay during the winter, it has been recommended that consideration be given to relocating the paddock to less valuable range or lowering the fence to allow access to free-ranging ungulates (Achuff *et al.* 1986).

The presence of captive wildlife appears to be in direct conflict with the national park concept and with policy that requires that park resources be protected and managed with minimal interference to natural processes. The issue of maintaining the enclosed bison herd in Banff National Park was explored briefly in an internal Warden Service report in 1982 (Ledwidge 1982). This report questioned the acceptability of captive bison management and emphasized the need to justify the presence of the Buffalo Paddock through an evaluation of its merit as a legitimate visitor attraction and as an isolated wood bison gene pool. Further policy directives of the Canadian Parks Service which address the reintroduction and management of wildlife are discussed in Section 4.0 of this thesis.

In January, 1981 the plains bison herd of the Buffalo Paddock was replaced by five wood bison. This replacement was part of the Wood Bison Rehabilitation Program designed to reestablish wood bison in Canada. The small herd consisting of one young bull, two mature cows, and two young cows was to provide an isolated gene pool for wood bison. The herd has reproduced successfully, with the addition of four calves annually. The calves have been shipped biannually to other wood bison rehabilitation projects. As these other projects begin to establish wood bison herds which will eventually be free-ranging, the importance of maintaining an isolated wood bison gene pool in Banff National Park will diminish. However, as it is government owned and controlled, it would still provide insurance should other herds become threatened by disease, predation, catastrophe, or hybridization.

The Buffalo Paddock has provided an opportunity for bison viewing in Banff National Park for the last ninety years. The facility is considered by some to be a traditional part of the Banff townsite area and it has become an established visitor attraction which receives a significant amount of use from bus tour agencies.

Thus, although the wildlife movement conflict is of primary concern, these other issues must also be considered in the evaluation of the Buffalo Paddock and alternatives for future bison management.

3.3 Alternatives for Bison Management

This study addresses five alternatives for bison management in Banff National Park[9]. The evaluation of these alternatives, which range from maintaining the present paddock through elimination of bison from the park must address a variety of concerns. Some of the pertinent ecological, management, and visitor use factors are presented here for perspective.

The first alternative is the elimination of bison from Banff National Park. This elimination would preclude further impact of bison on park resources. However consideration of this alternative would have to address issues such as the role of the Canadian Parks Service in preserving bison and providing education and interpretation related to the species, the merit of retaining bison in the park because they are an indigenous species, and the value of providing an opportunity for the park visitor to see bison.

The establishment of a free-ranging bison herd in the park is the second alternative. This would remove the migration barrier and could provide a unique bison management and viewing opportunity within Canada's mountain parks. However, a wide range of ecological, management, and visitor-related factors must be addressed. Some of the factors that should be considered are the location and extent of suitable habitat, the potential environmental impacts, a possible necessity to regulate the bison population, the control of herd migration inside and outside park boundaries, the opportunity for visitors to view the bison, and the nature of bison-visitor interaction.

The third alternative is to maintain the *status quo*. The Buffalo Paddock would be managed at its present size, and visitor use would continue, essentially unmodified. This requires evaluation of the acceptability of the barrier that the paddock presents to wildlife migration and an assessment of the quality of visitor experience. The possibility of changes within the paddock to increase bison visibility or improve habitat, and the environmental implications thereof, should also be considered with this alternative.

[9]These alternatives were identified by G. Fortin (Warden Service, Banff National Park) to J. E. Vollmershausen in a memorandum entitled 'Buffalo Paddock in Banff National Park'. November 24, 1983, and by Dr. B. Leeson (Natural History Research Division, Canadian Parks Service, Western Region, Calgary, Alberta. Pers. Comm., Dec. 1985).

The fourth alternative is to structurally modify the Buffalo Paddock in order to improve wildlife passage through the area by moving or altering the fence. A section of the fence could be moved to create a wider wildlife corridor, thereby decreasing the size of the paddock. This decrease in paddock size could be minimized by utilizing the smallest corridor that would still facilitate wildlife movement. This would maintain summer grazing capacity for a herd of reduced size and permit visitors to continue driving through the paddock to view bison. The possibility of replacing the area lost, by expanding the paddock in another direction, should also be examined. Conversely, the Buffalo Paddock could be reduced to a minimum size to serve solely as a display paddock, a step that would necessitate feeding year round and allow visitor viewing through the fence only. The second possible modification is the lowering and alteration of the fence to allow wildlife such as elk and deer (*Odocoileus hemionus* and *O. virginianus*) to pass through the paddock. A fence design which would both encourage ungulate passage and restrain the bison would have to be identified. In addition, the possibility of elk and deer competing with the bison for summer grazing and winter hay should be explored.

The fifth alternative, relocation of the Buffalo Paddock, would remove the paddock fence as a barrier to migration. However, consideration should be given to the environmental impacts that could occur on the new paddock site. The process of selecting a new site must address the habitat requirements of bison, and evaluate the suitability of the site for paddock construction and bison viewing.

3.4 The History of Bison in North America

3.4.1 Origin and evolution of bison in North America

Bison (genus *Bison*) have existed in North America since their immigration from northern Eurasia across the Bering land bridge during the early late Pleistocene (McDonald 1981, Reynolds *et al.* 1982, Meagher 1986). The earliest fossil records of the genus in North America appear in deposits of Illinoian age, 500,000 to 125,000 years B. P. (McDonald 1981).

The evolutionary line from these early bison to the present day ***Bison bison*** is complex and somewhat controversial (Guthrie 1980, McDonald 1981, Reynolds *et al.* 1982, Meagher 1986, van Zyll de Jong 1986). This taxonomic controversy extends to question the classification of the modern ***Bison bison*** to subspecies level. Presently, two subspecies of North American bison, ***Bison bison bison***, the plains bison of the prairie grasslands and ***Bison bison athabascae***, the wood bison of the parkland and boreal forest are generally recognized (Meagher 1986, van Zyll de Jong 1986).

3.4.2 Modern bison subspecies

The two subspecies of modern bison are similar in appearance. In general, the species is characterized by a massive head and forequarters and what appears to be disproportionately slender hindquarters (Banfield 1974, Reynolds *et al.* 1982, Meagher 1986). The head is low-slung on a short, thick neck that rises to a high shoulder hump. The pelage is brown, with long, dark, shaggy hair covering the forehead, neck hump, and frontquarters and shorter, lighter hair over the hindquarters. Both male and female bison have short black horns that rise laterally on the sides of the head, curve upward and inwards, and taper to a circular, relatively sharp tip. Bison have [illegible]ed tail of moderate length, and relatively short legs with rounded hooves. The sexes are dimorphic; however, the major difference is simply the smaller, slighter appearance of the females.

As well as being similar in appearance, studies of the karyotypes (Ying & Peden 1977) and selected blood characteristics (Peden & Kraay 1979) of wood and plains bison have found no significant differences between the subspecies.

However, other authors have documented differences in the morphology, pelage, and skeletal measurements of the wood and plains bison (Soper 1941, Skinner & Kaisen 1947, Soper 1964, Roe 1970, Banfield 1974, Geist & Karsten 1977, Ying & Peden 1977, Peden & Kraay 1979, McDonald 1981, Reynolds *et al.* 1982, Meagher 1986, van Zyll de Jong 1986). In general terms, the wood bison is darker in color than the plains, and is larger, with a taller, squarer shoulder hump. The wood bison have shorter and less dense hair on the head and frontquarters and lack the sharply demarcated, long-haired "cape" on the shoulders of the plains bison. Specific differences in cranial measurements, postcranial morphology, and external characters have been described by van Zyll de Jong (1986). In the most recent research on the systematics of the North American bison, van Zyll de Jong's craniometric analyses revealed a phenotypic discontinuity between boreal populations (wood bison) and plains populations (plains bison). Based on this discontinuity, further supported by evidence from analyses of postcranial morphology and external characters, van Zyll de Jong (1986), fully justifies the recognition of the two subspecies wood bison and plains bison. The Western Wildlife Directors Committee concurs with this designation for the purposes of bison management in Canada (The Wood Bison Recovery Team 1987).

3.4.3 Historical distribution of bison

The historical distribution of bison included most of central North America, from Mexico north to Great Slave Lake and from the Allegheny Mountains west to the Rocky Mountains as outlined in Figure 8. van Zyll de Jong (1986) found that the north-south division between wood and plains bison coincided approximately with the ecotone between grasslands and boreal forest in the northwestern part of the historical distributional range of bison. Although other authors (Skinner & Kaisen 1947, Banfield 1958, Roe 1970, Holroyd & Van Tighem 1983) have identified the bison of the Rocky Mountains as wood bison, the montane and intermontane specimens examined by van Zyll de Jong (1986) were identified as plains bison that likely penetrated the mountains through the predominantly east-west oriented river valleys and mountain passes.

3.4.4 Extermination of free-ranging bison

There were an estimated 30 (McHugh 1972) to 60 million plains bison (Roe 1970) and approximately 168,000 wood bison (Soper 1941) in North America when exploration and settlement of the west began. The bison already provided the Plains Indian tribes with much of their subsistence, and as the white man moved west the demand upon bison for food and

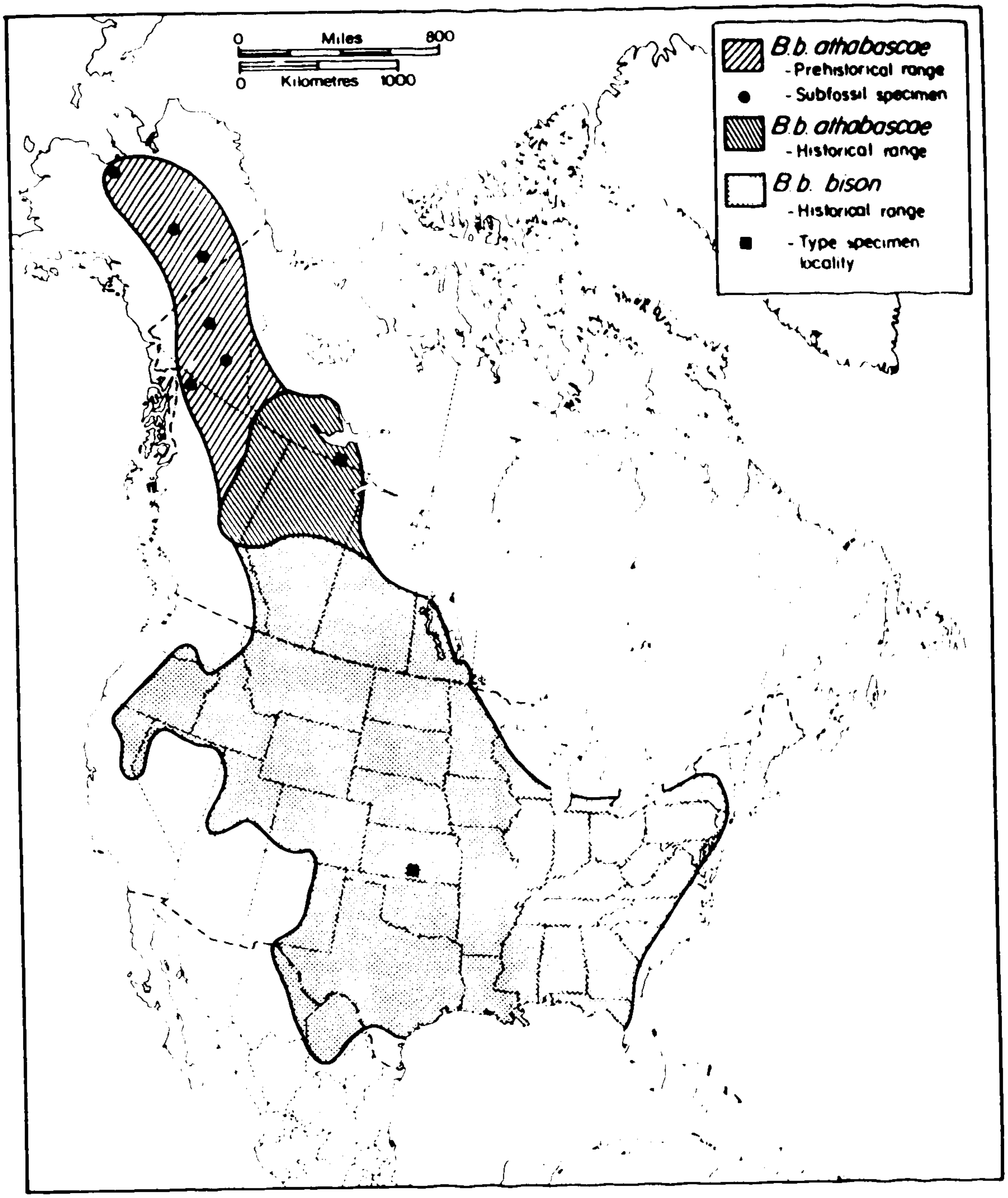


Figure 8. Historic and prehistoric distribution of bison in North America.

clothing increased (Roe 1970). However, it was not this subsistence hunting but rather the systematic slaughter of bison for the sake of robes, hides, and tongues, that eventually led to the near extermination of the species. The slaughter began as early as 1820 and continued with the concentrated destruction of the "southern" and "northern" herds occurring from 1870 to 1874 and 1876 to 1883, respectively (Hornaday 1889, Haines 1970, Roe 1970, Rorabacher 1970, McHugh 1972, Dary 1974, Ogilvie 1979, Lothian 1981). This virtually eliminated bison from the plains, except for a small free-ranging herd in Yellowstone National Park, and a few scattered animals in zoos and private herds. Hornaday (1889) estimated the total population of bison throughout the world as 1091. Likewise, the wood bison of the north were reduced to a small remnant wild herd in an area of the Mackenzie District in the vicinity of what is now known as Wood Buffalo National Park. Soper (1941) estimated that a low population for wood bison of 250 was reached during 1896 to 1900.

3.4.5 Protection and recovery of the Canadian bison herds

In the years following the disappearance of the last free-ranging herds, concern to preserve the bison mounted quickly (Coder 1975). The movement officially began in Canada. The Council of the North-West Territories passed an ordinance for the protection of buffalo at its first session in 1877 (North-West Territories 1877). In 1893 further legislation was passed by the Dominion Government to protect the last surviving wood bison herd located in the Mackenzie District of northern Canada (Soper 1941). However, enforcement of the law was difficult, and it was not until 1897 when the North West Mounted Police took over active administration of the legislation that the period of genuine protection for the wood bison began. This same year also marked the beginning of the preservation of plains bison in Canada. Three plains bison were donated to the Department of the Interior for display in Banff National Park (then Rocky Mountains Park)[10](Ogilvie

[10]Over time, the names of many of Canada's national parks have changed from Forest Reserves, to Parks, to Dominion Parks, and finally to National Parks. They will be referred to here by their eventual "National Park" titles for clarity of discussion.

1979, Lothian 1981). With the addition of 13 animals in 1898, the Banff National Park herd became the first bison herd in a long series to live and breed in Canada's national parks.

The northern herd of wood bison prospered under the protection of the North West Mounted Police, and the hiring of resident game guardians in 1911 ensured its continued well-being (Soper 1941). By 1914, the herd numbered 500 and appeared to have resettled a portion of its historic range bounded by the Slave, Peace, and Hay Rivers and the southern shore of Great Slave Lake (Soper 1941, Lothian 1981). Much of this range was designated as Wood Buffalo National Park in 1922, providing a permanent reserve for the 1500-2000 member herd which continued to increase throughout the 1920s (Soper 1941).

Meanwhile, the Canadian government was negotiating with Michel Pablo of Montana, to purchase his herd, the largest existing herd of plains bison, containing almost 30% of the world's bison (Coder 1975). The original stock for Pablo's herd was four calves captured by Walking Coyote near Milk River, Alberta in 1873 (Corner & Connell 1958). By 1884, Walking Coyote's herd, kept at the Flathead Indian Reservation in Montana, had increased to 13. The herd was then purchased by two Montana ranchers, Charles Allard and Michel Pablo. Twenty-six animals descended from bison captured in Texas and Manitoba were added to the herd in 1893. Following the death of Allard in 1896, his share of the herd, approximately 300 animals, was divided among his heirs. These animals became the foundation stock for most of the bison herds in the United States. In 1905, Canada began negotiations to purchase Pablo's share of the herd. Howard Douglas, the Superintendent of Banff National Park at the time, and his friend Norman K. Luxton, a prominent Banff businessman, are given credit for their perseverance in "strongly advocating" the purchase of the herd (Coder 1975, Lothian 1981).

In 1906 the purchase was approved and Canada became the owner of 716 plains bison. The transfer of the bison to Elk Island National Park and Buffalo National Park at Wainwright took place over five years, from 1907 to 1912. Attempts were made to move all bison to Buffalo National Park, but 48 animals were too elusive to capture and remained at Elk Island National Park (Corner & Connell 1958). Therefore, at the completion of the transfer, Canada had three public, protected herds of plains bison. A 1913 census showed 1188 bison at Buffalo National Park, 71 at Elk Island, and 28 at Banff (Lothian 1981).

These herds continued to grow. In fact, the herd at Buffalo National Park had grown to 6780 by 1923. The park became overstocked and slaughters were carried out in an attempt to alleviate the situation (Lothian 1981). However, the slaughters were heavily criticized by the public, the population continued to increase, and tuberculosis and brucellosis spread through the herd. The proposed solution was deemed to be the relocation of a portion of the herd. A controversial decision was made in 1924 to relocate plains bison to the recently established Wood Buffalo National Park (Lothian 1981). Despite warnings that the move would result in the spread of disease and the hybridization of the two bison subspecies, 6673 plains bison were shipped from Wainwright to Wood Buffalo National Park between 1925 and 1928. This measure however, did not completely ease the situation in Buffalo National Park. The continued growth of the herd, coupled with periodic drought conditions required that the slaughters continue and production of grain and hay for winter feeding be increased. By 1939 the continued operation of Buffalo National Park was being seriously questioned. Overgrazing, the cost of the maintenance program, and the high incidence of disease in the wildlife of the park led to the acceptance of an application by the Department of National Defence to use the entire area of Buffalo National Park as a military training area. A huge slaughter program was carried out in late 1939 and the park was abolished to enable military takeover in 1940 (Lothian 1981). However, there remained relatively disease-free herds of plains bison in both Banff National Park and Elk Island National Park.

When the 6673 plains bison were introduced to Wood Buffalo National Park in the 1920s, they outnumbered the resident wood bison population by approximately four to one. Their arrival had far-reaching effects on the future of wood bison in Canada. As predicted, disease spread quickly through the population and the two subspecies hybridized freely. The herd size increased and by 1934 the population of the Park was estimated at 12,000 (Soper 1941). This was largely a hybrid population, and by 1940 it was generally believed that wood bison had become extinct (Skinner & Kaisen 1947, Reynolds 1980).

However, some felt it possible that small isolated herds of wood bison did exist in the remote northwestern region of the Park (Soper 1941, Fuller 1962, Reynolds 1980). This speculation proved to be true and such a herd was found during an aerial survey of the park in 1957 (Reynolds *et al.* 1982). An isolated herd of two hundred bison, later confirmed to be morphologically representative of wood bison, was located in the Nyarling River area. This small herd was to become the source of breeding stock from which to build the world's remaining herds of wood bison. However, their future was soon threatened by an anthrax epidemic that broke out in the Hook Lake area, along the Slave River, in 1962 (Novakowski *et al.* 1963). To protect these remaining wood bison, 18 animals from the Nyarling River herd being held near Fort Smith, were transferred the following year to a location northeast of Fort Providence, Northwest Territories. Sixteen animals survived to establish the Mackenzie Bison Sanctuary herd. Two years later, in 1965, 24 more animals were transferred from the Nyarling River herd to an isolation area in Elk Island National Park. Twenty one animals survived to establish an 'litional breeding herd for wood bison and to further protect the gene pool from hybridization (Wood Bison Recovery Team 1987).

3.4.6 Present status of bison in Canada

3.4.6.1 Plains bison

Plains bison in Canada are raised on private ranches, displayed in zoos and game farms, and protected in four western Canadian national parks and one national historic park. The management of plains bison varies greatly among agencies, in keeping with their widely diverse goals.

Plains bison are classified as domestic animals in Alberta, Saskatchewan, and Manitoba. They are raised on nearly 100 ranches, farms, and Indian Reserves in Alberta alone (Bunnage 1985). Some herds are managed as 'hobby herds', but more are managed for bison production to meet the growing national and international demand for bison meat and by-products (Jennings & Hebbring 1983). Bison ranching operations, however,) ,ot serve to protect the plains bison gene pool. Ranchers will obviously breed bison to meet their needs, selecting for preferred form, maximum productivity, and relatively domesticated temperament. A greater degree of gene pool protection is provided by a number of national park, small zoo, and game farm herds. However, as most of these are small, captive herds, genetic manipulation occurs again as animals showing wild characteristics often must be culled to prevent management problems.

The largest captive plains bison herd is that of Elk Island National Park. The animals range freely through most of the northern portion of the fully fenced park. However, the herd is intensively managed to maintain the population between 400 and 450 animals. The herd is culled biannually, and surplus animals are tested for dise... sold or shipped to other areas. The Elk Island herd has been classified as disease ... since 1971 and acts as a source herd for private herds, zoo herds, and the herds of other parks. As the bison of Elk Island National Park roam freely throughout most of the park, they can easily be seen by visitors. In addition, during the summer, about 20 animals are kept in a 55 ha drive-through display paddock to ensure good viewing (Olsen pers. comm. 1986[11]).

Small captive herds of plains bison were established in Riding Mountain (1931)(Tarleton pers. comm. 1987[12]), Prince Albert (1933)(Anions pers. comm. 1987[13]), and Waterton Lakes National Parks (1952)(Tilson pers. comm. 1986[14]), and Rocky Mountain House National Historic Park (1982)(Gaudet pers. comm. 1987[15]) for plains bison preservation, visitor viewing, historical significance, and interpretation. Because of their limited range, these herds are fed when necessary during the winter months and culled through shipment of surplus animals. In addition to the display herd in Prince Albert National Park, a small free-ranging herd, remnants of a herd of fifty plains bison that were released on provincial land by the Saskatchewan government in 1969, has

[11]W. Olsen, Park Warden, Elk Island National Park.
[12]P. M. Tarleton, Park Warden, Riding Mountain National Park.
[13]D. Anions, Park Warden, Prince Albert National Park.
[14]D. Tilson, Park Warden, Waterton Lakes National Park.
[15]D. Gaudet, Rocky Mountain House National Historic Park.

become established in the southwest corner of the park (Minton & Schmidt 1984).

The largest free-ranging bison herd in the world is the hybrid herd of Wood Buffalo National Park, with a population of approximately 4200 (Wood Bison Recovery Team 1987). Although the herd has been managed intensively in the past in an attempt to control disease, current practices do not include roundup or active management. Hunting is prohibited and natural population regulation is allowed to operate.

The Slave River Lowlands herd is another hybrid bison herd which migrated to that area from Wood Buffalo National Park in the 1940s. This herd of about 200 animals (Bison Disease Task Force 1988) is also free-ranging, although it is has been managed as a game species, and is at present hunted by holders of General Hunting Licences (Reynolds & Hawley 1987).

3.4.6.2 Wood bison

Following the transfers from Wood Buffalo National Park in the 1960s, wood bison herds existed in only two locations, Elk Island National Park and the Mackenzie Bison Sanctuary. In 1975, the Wood Bison Rehabilitation Program was initiated to begin the work of reestablishing wood bison in Canada (Reynolds *et al.* 1982). The objectives of the program were to establish a minimum of three free-ranging, self-perpetuating populations of wood bison in areas of former range, and to ensure the protection and preservation of the wood bison gene pool through the dispersal of small breeding herds to zoological gardens and parks (Reynolds *et al.* 1982). The declaration of wood bison as an endangered species in 1978 (Novakowski 1978), led to the ultimate goal of the program, that is, to reestablish sufficient numbers of wood bison in the wild to warrant removal of the species from the endangered list.

To date, the program has successfully transferred wood bison to seven parks and zoos as part of the captive breeding program for preservation of the gene pool (Wood Bison Recovery Team 1987). The present bison herd in Banff National Park is one such breeding herd which began with the transfer of five wood bison from Elk Island National Park to Banff in 1981.

The establishment of free-ranging herds has proven to be somewhat more difficult, but progress is being made. The Mackenzie Bison Sanctuary herd had experienced fluctuations in population level but had increased to over 2000 animals by 1989 (Reynolds pers. comm. 1989[16]). The second attempt to establish free-ranging wood bison was not successful. The transfer of 28 wood bison from Elk Island National Park to Jasper National Park in 1978 resulted in failure when the relocated bison did not remain in the park. The bison moved out of the park onto provincial agricultural land and had to be returned to Elk Island National Park (Davidson & Norcross 1978). A herd transferred to the South Nahanni-Liard River valley, Northwest Territories in 1980, numbered 49 animals in 1989 (Reynolds pers. comm. 1989). In addition, three further release projects are underway. These projects utilize large, on-site holding corrals in which relocated animals are maintained for several years in anticipation that their progeny will locate nearby when released. These projects are located in the northern Interlake district near Waterhen, Manitoba (34 transferred in 1984, pre-calving population 185 in 1989), an area in northwestern Alberta in the vicinity of Hay-Zama Lakes (29 transferred in 1984, population 29 in 1989 due to poor productivity and culling for management purposes, first release postponed until disease issues resolved), and an area in the Nisling River valley in southwestern Yukon (34 transferred in 1986, population 27 captive and 34 free-ranging in March 1989) (Reynolds pers. comm. 1989).

[16]H. Reynolds, Canadian Wildlife Service, Edmonton, Alberta

4. SUMMARY OF RELEVANT CANADIAN PARKS SERVICE POLICY AND WILDLIFE MANAGEMENT GUIDELINES

Any decision regarding the future management of bison in Banff National Park must consider the policies and guidelines of the Canadian Parks Service. In addition to the overall Canadian Parks Service objective of resource protection and use, wildlife management is directed by a number of other policies and guidelines defined by the National Parks Act and Regulations, Parks Canada Policy, Parks Canada Directives and Technical Manuals, and Western Region Directives. Eastcott (1984) summarized the portions of these documents which relate to wildlife in Directions for Wildlife Management, A Summary. These directions touch on many aspects of wildlife management: preservation and protection, resource use, public information, intra-agency and inter-agency cooperation, resource monitoring, and research. Strategies for wildlife management in Banff National Park must consider all of these elements. The following discussion reviews those directions which are particularly relevant to the analysis of the future management of bison in Banff National Park.

As previously stated, the National Parks Policy for resource management calls for the application of management strategies that protect natural resources in a manner that interferes minimally with natural processes[17]. However, the Canadian Parks Service is also to assume responsibility for protecting representative natural areas of Canadian and international significance[18]. This protection must include preserving the wildlife species which are an integral part of those natural systems. In the interest of maintaining such representative natural ecosystems, the reintroduction of wildlife species which were formerly indigenous to a park, is permitted and encouraged[19]. The National Parks Policy places some restrictions on possible reintroduction by stating that the impacts on other plants and animals must be acceptable, the reintroduction must be compatible with park objectives, and possible conflicts

[17]Parks Canada Policy, National Parks Policy, 3.2.1.
[18]Parks Canada Policy, Program Policy, 3.1 and 3.4.
[19]National Parks Wildlife Regulations 15(1)(c); Parks Canada Policy, National Parks Policy, 3.2.7; and Parks Canada Directives, Vol. 4., National Parks and Landmarks Directive 4.4.13.

with neighboring land uses must be considered[20].

The most detailed direction for the reintroduction of native animal species is found in the National Parks and Landmarks Directive 4.4.13[21]. The Directive states that:

> Native animal species once present but now absent are to be reintroduced into a National Park.

It also presents guidelines for the reintroduction process. Documentation must be compiled by experts to provide proof that the species and sub-species were indigenous to the park, to outline the availability of the exact subspecies for reintroduction, to evaluate the occurrence and carrying capacity of suitable year-round habitat, and to describe the potential effects of the reintroduction on the species itself, the flora and fauna of the park, and the human element. The Directive also stipulates that only anima[illegible] certified as disease free and healthy are to be released into a park.

While these directions would allow the reintroduction [illegible] son to Banff National Park, they do not specifically address the issue of a captive reintroduction. Directive 4.4.13 above does appear to recognize captive herds as valid method of reintroduction, as it cites the establishment of bison in "several western parks" as precedent for species reintroduction[22]. Of the bison in western parks, only those of Wood Buffalo National Park are truly free-ranging. The bison of Elk Island National Park are free-ranging within park boundary fences, but the populations in Banff, Waterton Lakes, Prince Albert[23], and Riding Mountain National Parks are confined within enclosures. It would seem that a policy which requires resource management to emulate natural processes, would preclude such captive wildlife management. However, there are certain exceptions in which interference is allowed, which may apply to captive bison management. The manipulation of naturally occurring processes is allowed if a desired animal species cannot be maintained by natural forces[24], and the manipulation of

[20]Parks Canada Policy, National Parks Policy, 3.2.7 (i),(ii),(iii).
[21]Parks Canada Directives, Vol. 4., National Parks and Landmarks Directive 4.4.13.
[22]National Parks and Landmarks Directive 4.4.13.2.3.
[23]In 1969 an additional, free-ranging bison herd was introduced to the Prince Albert National Park ecosystem.
[24]Parks Canada Policy, National Parks Policy, 3.2.3.vii.

habitat is allowed to provide habitat critical to the survival of an animal species[25]. These policies allow such manipulation when it is necessary to prevent the loss of a *desired* animal species. Therefore, in order to determine if these policies apply to the management of captive bison in Banff National Park it is necessary to evaluate two major factors: the desirability of preserving bison in Banff National Park, and the acceptability of the manipulation required to preserve them as a captive herd.

In addition to the specific policy requirements for wildlife management, any proposed action concerning bison management in Banff National Park would be subject to the Environmental Assessment and Review Process of the Canadian Parks Service[26]. This process is designed to ensure that decision-making fully considers all environmental implications of proposed management actions within the parks. The Environmental Assessment and Review Process would evaluate the effect of the proposed bison management action on a broad range of environmental parameters including atmosphere, land, water, species and populations (vegetation and wildlife), and cultural features (social, historical, and archaeological) (Parks Canada 1981).

The future management of bison in Banff National Park is therefore governed by a number of policies and guidelines. The application of these policies and guidelines, however, requires that a number of factors be evaluated: the role and responsibility of Banff National Park in the preservation of bison, and in the interpretation of bison as part of Canada's heritage; the desirability of managing bison as part of the natural system of Banff National Park; and the acceptable level of environmental manipulation and ecological impact associated with the management of bison in the park.

---

[25]Parks Canada Policy, National Parks Policy, 3.2.6.
[26]Parks Canada Policy, National Parks Policy, 3.3.1.

5. METHODOLOGY

5.1 Review of Historical Distribution and Bison Management Factors

A review of literature was conducted and supplemented by personal interviews. Archaeological studies, historical reviews, and records of skull recovery and wallow observation were reviewed to establish and describe the prehistorical and historical presence and distribution of bison in Banff National Park. The ecology, biology, physiology, and behavior of bison were reviewed in order to identify the factors associated with the management of bison. The major factors of concern were the habitat requirements of bison, the effects of bison on their environment, herd management considerations, and the human dimensions of bison management in a national park setting. Although two bison subspecies are recognized, the management factor review was conducted on the species level, assuming that little or no difference exists between basic ecology, biology, physiology, and behavior of the two subspecies. As research specific to wood bison is limited, the review relied heavily on information available for plains bison.

5.1.1 Literature review

The literature review included published research papers and books, and unpublished theses, management plans, reports, park files and other documents. Materials were reviewed at the University of Alberta, University of Calgary, University of Montana, Montana State University, Canadian Wildlife Service (Edmonton, Alberta), Archives of the Canadian Rockies (Banff, Alberta), Canadian Parks Service, (Western Region (Calgary, Alberta), Banff, Elk Island, and Waterton Lakes National Parks), Yellowstone National Park, and the National Bison Range (Moiese, Montana). Additional literature was obtained through interlibrary loan and correspondence with a number of agencies.

5.1.2 Personal interviews

In order to supplement the information gained in the literature review and obtain information not available in written form, persons knowledgeable about research, planning, and management concerning bison and park visitors were interviewed at Banff, Elk Island, Waterton Lakes, and Yellowstone National Parks, the Canadian Wildlife Service in Edmonton, and the National Bison Range in Montana.

5.2 Analysis of Bison Habitat

The analysis of bison habitat in Banff National Park involved two major components; the identification of suitable forage habitat for a free-ranging bison herd and the identification and description of possible paddock relocation sites. The Ecological (Biophysical) Land Classification of Banff and Jasper National Parks (Holland & Coen 1982, Holland & Coen 1983, Holroyd & Van Tighem 1983) (ELC) was the primary source of habitat information and was used to identify and locate Ecosites (map units) potentially suitable for bison forage.

5.2.1 Ecosite and winter range identification

The ELC and accompanying biophysical maps were reviewed to identify bison habitat in Banff National Park. The descriptions of the 85 vegetation types defined by the classification system (Holland & Coen 1982) were examined to determine the occurrence of known bison forages as identified by the review of literature. First, a broad selection of vegetation types and Ecosites was conducted. Those vegetation types with typical cover values of 20% or greater for all grass, sedge, and horsetail species combined were identified. The use of such a low cover limit allowed for the identification of all vegetation types that could contribute even marginally to bison habitat. While these vegetation types would not on their own provide adequate forage for bison, they could complement areas identified below as *primary* habitat or could potentially be improved through site modification. The included vegetation types which had cover values of 50% or greater, were also identified simply to indicate their relatively higher forage values. The Ecosites for which these vegetation types were dominant or codominant were then selected, with the exclusion of those vegetation types and Ecosites mapped only in Jasper National Park.

A second, more vigorous selection was then conducted to identify *primary* bison habitat. Studies have shown that bison select for open range which is dominated by grasses and sedges. Therefore, *primary* bison forage habitat was identified by selecting from the previously identified vegetation types only those low shrub-herb and herb-dwarf shrub vegetation types for which grasses or sedges were dominant or co-dominant. The related Ecosites were then identified as *primary* bison habitat.

The third step was to identify bison winter range. Maximum Ecosite snow depth as recorded during the Wildlife Inventory of the ELC was used to identify suitable *primary* forage habitat Ecosites. Based on the review of literature, limiting snow depths for bison range from 50 cm for calves to 122 cm for adults, depending on snow conditions. An intermediate snow depth of less than 100 cm was used for the purpose of Ecosite selection. Possible bison wintering areas were then determined by examining the occurrence of suitable wintering Ecosites throughout the park and considering the degree of present winter use by elk.

5.2.2 Paddock relocation site selection and on-site reconnaissance

Possible sites for paddock relocation were identified and an on-site reconnaissance was conducted for each area. Site selection was confined to the Bow River valley east of Lake Louise and the Cascade River valley below Lake Minnewanka. This was done to allow for visitor and management access to the sites via existing roadways and to avoid undeveloped areas and areas of deep winter snow. Possible paddock sites were selected through consultation with persons familiar with the area[2] and by using the biophysical inventory maps and aerial photographs to locate available areas with appropriate Ecosites and disturbed areas

[2] Dr. B. Leeson, Natural History Research Division, Canadian Parks Service, Western Region, Calgary, Alberta; R. Kunelius, Park Warden, Banff National Park; and A. Anderson, Environmental Coordinator, Public Works Canada, Banff, Alberta.

that could be reclaimed to create suitable habitat. All the Ecosites selected in step one of the Ecosite identification were considered, as site manipulation and supplemental feeding would be possible in a relocated paddock.

An initial on-site reconnaissance was carried out at each of the relocation sites identified. The reconnaissance consisted of a site walk-over to evaluate the vegetation communities, cover habitat, availability of water, present wildlife and human use, suitability of the terrain for paddock construction, and the predicted visibility of bison and overall quality of visitor experience. The primary advantages to be gained or maintained by relocating the paddock would be to remove the Buffalo Paddock from critical elk range and travel corridors and to provide an opportunity for visitors to view bison in a natural setting. Therefore, any sites which did not meet these criteria were eliminated. An additional, second-round reconnaissance was then carried out on the remaining sites and summary sheets were prepared which briefly described each site based on the following variables:

1. Bison Requirements
    a. Forage (quality, quantity, and accessibility)
    b. Cover (adequacy)
    c. Water (availability)
2. Environmental Compatibility
    a. Wildlife (habitat, movement, and increased human use)
    b. Vegetation and soil (construction, habitat manipulation, bison impacts)
    c. Visual/aesthetic (intrusion on environment)
3. Visitor Use
    a. Compatibility with present/planned use
    b. Predicted visibility of bison
    c. Aesthetic quality of setting
    d. Access
4. Cost Effectiveness
    a. Construction

b. Maintenance

Relative merit values of low, medium, and high were assigned to each variable for each site, and illustrated in matrix form.

5.3 Study of the Present Buffalo Paddock

A twelve week study of the present Buffalo Paddock was carried out from May 14 to August 5, 1986. The objectives of the Buffalo Paddock study were to describe the attributes of the bison viewing opportunity in the Buffalo Paddock, to quantify visitor use of the facility, and to examine the interaction of bison and visitors in the paddock. As it was not possible to interview park visitors, two indirect study components, scheduled observation of the bison and visitors in the Buffalo Paddock, and collection of information from agencies which conducted tours through the paddock, were designed to answer the following questions relating to the three objectives.

Attributes of [illegible] Bison Viewing Opportunity:

1. How often are bison visible in the Buffalo Paddock and does bison visibility vary acco[illegible]ng to the time of day, the observable weather, or as the study period progresses?
2. If bison are seen, how often will they remain visible for a period of at least ten minutes?
3. How many bison are seen in a sighting?
4. How close are the bison seen and does the distance vary according to the time of day, the observable weather, or as the study period progresses?
5. How obstructed are views of bison sighted and does this vary according to the time of day, the observable weather, or as the study period progresses? Also, if bison are not 100% visible, what is the screening medium?
6. What bison activities [illegible] most often observed?

Visitor Use of the Buffal[illegible] P[illegible]dock:

1. How many vehicles [illegible] [illegible]uffalo Paddock daily, and does this vary according to the day of week or as the [illegible] [illegible]d progresses?
2. What type of vehicles en[illegible] [illegible]uffalo Paddock?

3. What is the licencing state, province, or territory of vehicles entering the Buffalo Paddock?
4. How long do vehicles spend in the Buffalo Paddock?
5. How often do vehicles travel the loop road more than once?
6. How many vehicles, and what types of vehicles stop during a bison sighting being conducted by the observer?
7. How many vehicles enter the Buffalo Paddock per minute and does this rate vary according to the time of day, the observable weather, or as the study period progresses?
8. How many vehicles are seen per minute when the observer is driving through the Buffalo Paddock and when the observer is conducting a bison sighting, and how do these rates vary with the time of day, the observable weather, and as the study period progresses?
9. According to the cooperating tour agencies, what time of day are their tours conducted, how many visitors do they have per tour, how often are they successful in sighting bison, and what is the general reaction of their passengers?

Interaction of Visitors and Bison:

1. Do visitors comply with signage prohibiting the entrance of pedestrians, cyclists, and horses to the Buffalo Paddock and telling visitors to remain in their vehicles?
2. What is the observable reaction of bison to vehicles and visitors when visitors remain in their vehicles, to visitors who leave their vehicles, and to visitors who approach them?

5.3.1 Observation of bison and visitors

5.3.1.1 Sampling design

The sampling design for bison and visitor observation was based on 69 days of available manpower during the 84 day study period. In order to concentrate sampling on the days which would be likely to receive highest visitor use, (Friday, Saturday, Sunday and Monday), the fifteen non-sampling days were chosen in mid-week. All twelve Wednesdays were chosen as non-sampling days to provide some regularity in the work schedule. Three Tuesdays and Thursdays, namely Thursday June 5, Tuesday June 24, and Thursday July 17 were selected randomly to make up the additional three non-sampling days.

The basic sampling unit was defined as a *loop* driven around the circular road of the Buffalo Paddock. Loops were conducted on the hour from 0600 to 2000, effectively sampling fifteen daylight hours. With 69 sampling days, this gave a population size of 1035 (69 *x* 15) loops. The required sample size to estimate population proportions at a 95% confidence level with ± 5% error was calculated at 280 loops (Cochran 1963, Yamane 1967, Agresti & Agresti 1979).

There were a number of elements to be considered in designing the schedule of observation loops:

1. Eight hour or split shift days were required for operational reasons.
2. As the observer had other duties to perform daily, the time spent at the Buffalo Paddock and in travel to and from it could not exceed six hours per day.
3. Equal division of the 280 sampling loops among the 69 sampling days was desired.
4. Each of the fifteen possible loop start times (from 0600 to 2000 hours) was to be represented equally.
5. Each loop start time was to be distributed evenly across the study period and across the days of the week.

To accommodate these requirements the schedule of observation loops was designed as follows:

1. The 280 loops were divided among the 69 sampling days resulting in 65 days having four loops and four days having five loops.
2. The sampling loops were scheduled as pairs at the beginning and end of each day, or as a triplet at one end of the day and a single loop or loop pair at the other end of the day. This design did not allow for independence of the paired loops. However, as the presence of the observer was no different than that of another visitor, it was assumed that the validity of the observations of the second loop were not affected.
3. The fifteen possible loop start times were spread evenly across the 280 loops,

resulting in ten start times being represented by nineteen loops each, and the remaining five start times being represented by eighteen loops each. Times when the Buffalo Paddock would be likely to receive lower visitor use, (0600, 0700, 1800, 1900, and 2000 hours) were chosen for the lesser representation.

4. A systematic approach was taken in order to spread the fifteen possible loop start times as evenly as possible across the six days of the week sampled and across the study period. The resulting observation loop schedule is given in the Appendix.

5.3.1.2 Sampling procedures

Visitor vehicle traffic through the Buffalo Paddock was recorded using a trail counter installed on the loop road approximately 150 m into the paddock. The counter was read every morning at 0800 hours to determine daily visitor use and total visitation for the study period. Counter readings were taken before and after observation loops to enable calculation of a traffic rate (vehicles/minute) for each loop. The accuracy of the counter was checked during each traffic observation period (see below) by comparing the visual count of the traffic observation period with the counter reading obtained for the period. The daily traffic count was adjusted to account for passage of the research vehicle and other known non-visitor vehicles.

The field instructions and forms for conducting observation loops, bison sightings, and traffic observation periods are to be found in the Appendix. However, the general information gathered through each of these three procedures is discussed here.

Observation Loops

During the twelve week study, 280 observation loops were conducted at the times designated by the schedule. Each loop required approximately thirty minutes to complete, plus the time required for carrying out bison sightings. The information for each loop was recorded on a *Paddock Observation Loop Form* which indicated the date, and the time and number of the loop. The observable weather, as specified by sky condition and precipitation codes (Table 2) was recorded for each loop and changes were noted throughout the loop. During the loop, all vehicles observed were recorded by vehicle type (Table 3) and the names of commercial tour agencies represented were specified. Additional observations recorded information such as the presence of other wildlife in the Buffalo Paddock, unusual visitor behavior, or abnormal loop procedures (*e.g.* research vehicle blocked by traffic).

Bison Sightings

A *bison sighting* procedure was carried out whenever bison were observed during a loop, with up to a maximum of three sightings per loop. The information for each sighting was recorded on a *Bison Sighting Form* which indicated the date, the loop, the time and the number of the sighting. Sky condition and precipitation codes were recorded to describe observable weather during the sighting. As each bison became visible during the sighting, it was identified on the *Bison Sighting Form*. For each bison, for every minute of the sighting, codes specifying the distance of the bison from the research vehicle, the percent of the bison visible, the medium which was screening the bison from view, and the activity of the bison was recorded (Table 4). The research vehicle was moved as necessary during the sightings to maintain the best possible view of the bison. Vehicles observed during the sighting were recorded by vehicle type on the *Paddock Observation Loop Form*, specifying to which sighting number they referred, and whether or not the individual vehicles stopped. Additional observations such as those made for the observation loop above were also recorded. The sightings were limited to a maximum of ten minutes in length. Shorter sightings occurred when all of the bison moved out of sight and could not be relocated by the end of the next minute, even by moving the research vehicle.

Traffic Observation Periods

Traffic observation periods of varying lengths were carried out as time permitted. They were generally conducted from the time the loop ended until the

Table 2. Sky condition and precipitation codes.

Sky Condition Codes	Precipitation Codes
1 = Sunny (scattered clouds) 0-5/10 cloud cover	1 = No precipitation
2 = Intermittent rain 6/10 - 9/10 cloud cover	2 = Cloudy (broken cover)
3 = Overcast, high clouds	3 = Light, steady rain
4 = Overcast, low clouds	4 = Heavy, steady rain

Table 3. Vehicle type categories.

Private	= includes all vehicles except buses, rented or privately owned which are operated by non-commercial drivers (cars, trucks, vans, campers, motorhomes).
*Private rental	= includes private vehicles which can be positively identified as being rented (i.e. rental sticker in window or on bumper).
Bus Tour	= includes all commercial bus tours and school buses.
Other Tour	= includes all commercial tour vehicles other than buses (taxi cabs, vans).
Non-Visitor	= includes all non-visitor vehicles such as Warden Service, construction, and maintenance vehicles.

*Private rentals were only identified during the Traffic Observation Periods

Table 4. Bison observation codes.

	View Codes		Activity Codes
Distance	Percent Visible	Screening	
1= 0-10m	1= 100%	B=Bison	F=Feeding
2= 11-50m	2= 75-99%	V=Vegetation	W=Walking
3= 51-100m	3= 50-74%	T=Topography	S=Standing
4= 100+m	4= 25-49%	X=Other(specify)	L=Lying down
	5 = 0-24%		R=Running
			X=Other(specify)

end of the hour. However, because of time constraints, some loops were not followed by traffic observation periods and some traffic observat periods did not follow a loop. The information for each traffic observation period was recorded on *Paddock Traffic Observation Forms I and II* which indicated the date, the time, and the number of the traffic observation period. The observable weather was recorded throughout the period using the sky condition and precipitation codes. The paddock traffic counter was read at the start and end of each traffic observation and compared with the visual count for the period to detect any counter malfunctions. For each vehicle observed, the vehicle type (Table 3) (including specification of tour agencies), the state, province, or territory of the licence plate, and the vehicle description for subsequent recognition were recorded. The times that vehicles entered, left, or began a second loop of the Buffalo Paddock were recorded so that the total and average number of minutes spent in the Buffalo Paddock could be calculated. Additional visitor or vehicle observations were also recorded as appropriate.

5.3.1.3 Data analysis

Data were coded and entered for analysis using the University of Alberta computer system and the Statistical Package for the Social Sciences (SPSSX) statistical program. Descriptive statistics, namely frequencies, percentages, means, and standard deviations were generated for all variables. These statistics were used to check for data entry errors, and to summarize variables as required. The relationships between variables of interest were explored using the Chi-square test of independence, with Lambda, or Kendall's tau-b rank correlation as appropriate. The level of significance was set at $p<.05$, the commonly used level for studies of this nature.

5.3.2 Tour agency participation

5.3.2.1 Data collection

Several agencies known to conduct tours through the Buffalo Paddock were asked to participate in the B·f·   ddock study. Co-operation was received from two tour agencies, Brewster Tra   ation and Tours, and Mountain Park Tours. Bus drivers from Brewster Transportation and Tours, and guides from Mountain Park Tours completed forms (Appendix) outlining the tours that the   ded through the Buffalo Paddock during the study period. They recorded the date and time of their tours, the num   of passengers, the weather, the number and activity of bison observed, and the reactions of passengers. The tour agencies were also asked to record for the study period the times of their Buffalo Paddock tours and the total number of visitors that they served.

5.3.2.2 Data analysis

The information obtained from the tour agencies was summarized by hand. Frequencies, percentages, means, and standard deviations were calculated as required. Weather conditions and the number and activity of bison were inconsistently reported and so were not evaluated. Visitor reactions were only briefly summarized, as available.

6. RESULTS I. PREHISTORY AND HISTORY OF BISON IN BANFF NATIONAL PARK

6.1 Archaeological Evidence

Free-ranging bison were present in Banff National Park from prehistoric times through to the mid-nineteenth century. Archaeological investigations of a prehistoric campsite near Vermilion Lakes in the Lower Bow River valley have revealed bison bone fragments dated from 11,000 to [illegible] years BP (before present) (Fedje & White 1984). A cranial fragment from Banff townsite identified as *Bison bison occidentalis* yielded a radiocarbon date of 3240 ± 90 years BP (Harington 1984). Bison bone fragments have also been found at a number of other archaeological sites in Banff National Park dating from early prehistoric (ca. 13,000 BC to 5500 BC) to historic times (post AD 1750), indicating the continued presence and human utilization of bison (Christensen 1971). These sites include the Lower and Middle Bow, Cascade, Panther, Red Deer, North Saskatchewan, and Howse River valleys (Table 5, Figure 9).

6.2 Accounts of Early Travellers 1808 - 1859

The journals of early travellers in the Banff National Park area record sightings of bison and bison sign from 1808 - 1859 (Table 6). These sightings extend the observed bison distribution to include the valleys of the North Saskatchewan, Siffleur, Bow, and Pipestone Rivers, the Howse River to Howse Pass, and Simpson Pass up Healy Creek from the Bow River (Figure 9). The killing of a bison cow, one of a group of seven, on the Pipestone River in 1857 was the last record of free-ranging bison seen in the park, although Dr. Hector made note of a bison track in the Siffleur River valley in 1859 (Roe 1957, 1970, Banfield 1958, Spry 1963).

Table 5. Archaeological evidence of bison in Banff National Park.

Site Number	Borden Number	General Location	*Period of Origin	+Source
26R	EhPw-5	Muleshoe	E - L	2
27R	EhPw-6	Muleshoe	E - L	1
35R	EiQb-1	Lake Louise Townsite	L	2
45R	EgPu-2	Carrot Ck	L	2
68R	EhPv-24	Whiskey Ck	L	4,8
69R	EhPv-26	Cave and Basin	L	8
105R	EhPv-45	Vermilion Lakes	L	13
148R	EhPv-3	Vermilion Lakes	U	1
149R	EhPv-4	Mt. Norquay	U	2
152R	EhPv-7	Vermilion Lakes	U	2
153R	EhPv-8	Fireside	E	5,10
156R	EhPv-15	Mt. Norquay Road	E	1,7
162R	EhPv-93	Vermilion Lakes	M - L	13
162R	EhPv-58	Vermilion Lakes	M - L	13
163R	EhPv-10	Banff Airport	U	13
349R	EhPu-1	Stewart Canyon	E - L	1,14
351R	EhPu-8	Johnson Lake	UP	2
353R	EhPu-10	Johnson Lake	UP	1,13
355R	EhPv-11	Bankhead	M	1
357R	EhPv-16	Cascade R	UP	1,13
360R	EhPw-1	Backswamp	E - M	6
361R	EhPw-2	Backswamp	E - L	3
379R	EjPw-11	Windy Cabin	UP	1
380R	EjPw-12	Windy Cabin	UP	1
418R	EkPx-4	Scotch Camp	M - L	15
501R	EhPv-71	Vermilion Lakes	L	6
515R	EhPv-18	Fenland Trail	M - L	6
562R	EhPv-97	Recreation Grounds	UP	6
1076R	ElQe-1	Saskatchewan Crossing	M	2
1077R	ElQe-2	Howse R	U	1
1192R	EhPv-108	Cascade R	E - L	12
1207R	EgPv-14	Banff Golf Course	L	9
1210R	EhPv-126	Banff Golf Course	M	9
1237R	EhPu-18	Banff Townsite	U	12
1326R	EhPt-2	Devil's Gap	L	8
		Banff Townsite	M	11

*Period of Origin:
E=Early Prehistoric (ca. 13,000 B.C. to 5,500 B.C.)
M=Middle Prehistoric (ca. 5,500 B.C. to A.D. 750)
L=Late Prehistoric (ca. A.D. 200 to 1,750)
H=Historic (Post 1,750 A.D.)
U=Unknown
UP=Unknown Prehistoric

Table 5. (Continued)

+Source:
1=Christensen (1971:197-199)
2=Christensen (1971) after Wilson (1971:32)
3=Damp etal. (1980)
4=Fedje (1982)
5=Fedje (1986a)
6=Fedje (1986b)
7=Fedje (1987a)
8=Fedje (1987b)
9=Fedje & Landals (1987)
10=Fedje & White (1984)
11=Harington (1984)
12=Head & Van Dyke (1986)
13=I.R. Wilson Consultants, Ltd. (1985)
14=McIntyre & Reeves (1985)
15=Van Dyke (1987)

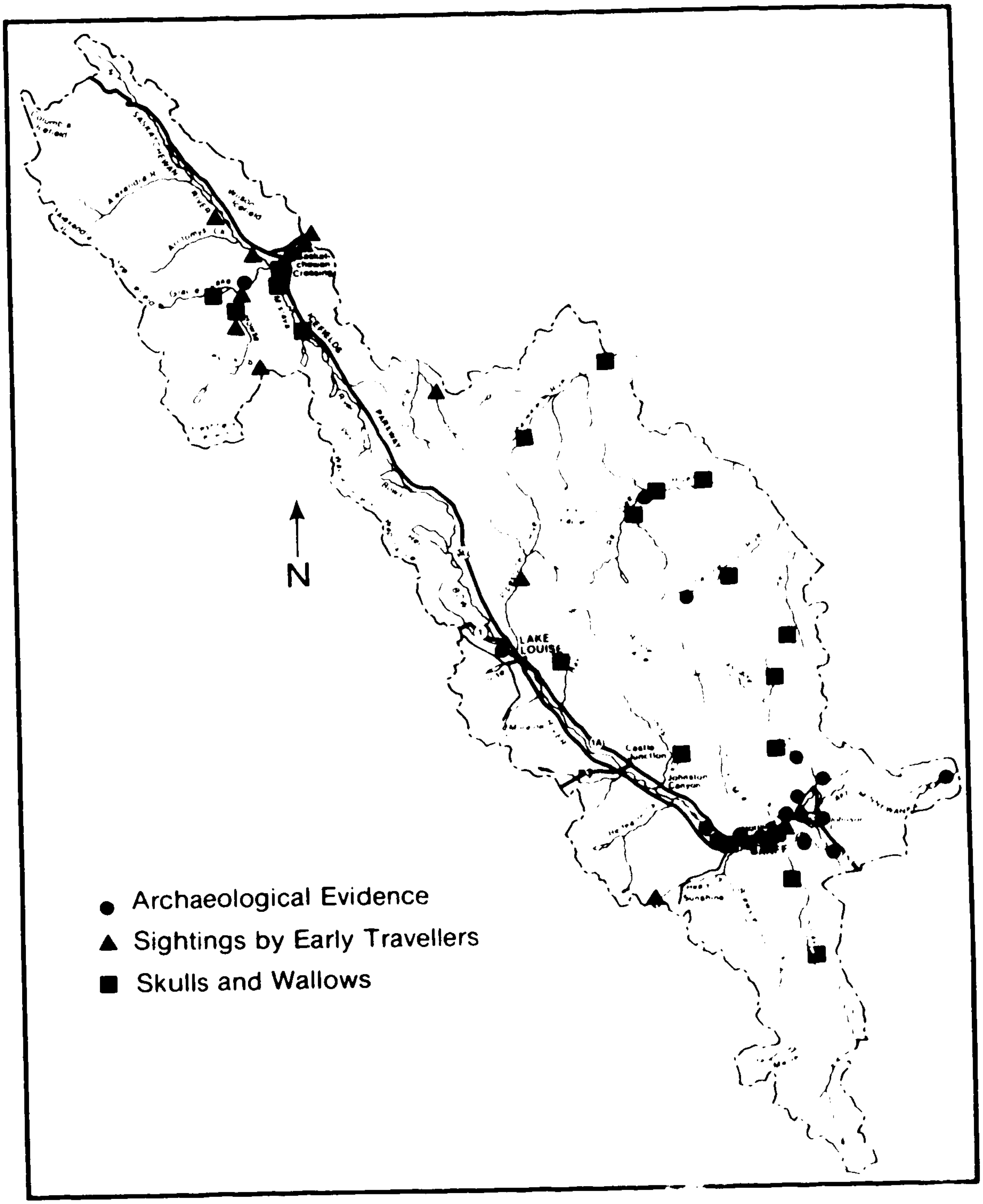


Figure 9. Historic and prehistoric distribution of bison in Banff National Park, Alberta.

Table 6. Accounts of bison and bison sign recorded by early travellers to Banff National Park (1808-1859).

Time and General Location of Sighting	Sighting Description	Traveller & (*Source)
1808 N. Sask. R.	bison	David Thompson (2)
1808 Upper N. Sask. near headwaters (Howse Pass)	bison	David Thompson (5)
Oct 1808 N. Sask. Valley	2 cows killed	David Thompson (1)
Aug 1809 Upper N. Sask. near headwaters (Howse Pass)	bison	David Thompson (5)
Aug 1809 Howse Pass	bull & 2 calves killed	David Thompson (1)
1810 Howse Pass	bison	David Thompson (2)
1810 Sask. R. Valley	bison	David Thompson (2)
June 1810 Sask. R.	carcass in river	David Thompson (1)
June 1810 Sask. R.	bull killed	David Thompson (1)
Aug 1810 Upper Sask. Valley	bull killed	David Thompson (1)
Late 1810 near Kootenay Plain, well above Rocky Mtn. House	buffalo numerous	Alexander Henry (5)

(Cont.)

Table 6. (Continued)

Time and General Location of Sighting	Sighting Description	Traveller & (*Source)
Feb 1811 Sask. between Rocky Mtn. House and Kootenay Plains	bison crossing ice	Alexander Henry (5)
7 Feb 1811 Kootenay Plains	large herds of "wood" bison	Alexander Henry (1)
8 Feb 1811 Kootenay Park+	W. limit of bison wintering range	Alexander Henry (5)
1841 Simpson Pass	bison tracks	George Simpson (2,5)
14 Apr 1841 Near Banff	bison numerous	Rev. R. T. Rundle (4)
1857 Pipestone Valley	cow killed, one of 7	William -Guide (1,4,5,6)
Sept 1858 N. Sask. R. near headwaters and Howse River	bison dung	Dr. Hector (1,3,5)
1859 Kootenay Plains	bison dung and wallows	Earl of Southesk (1,3)
Aug 1859 Siffleur Valley	fresh bison track	Dr. Hector (4,5,6)

+Kootenay Park: likely refers to an area at the junction of Glacier Creek and the Howse River (Christensen 1971).

*Sources:
1=Banfield (1958)
2=Christensen (1971)
3=Holroyd & vanTighem (1983)
4=Roe (1957)
5=Roe (1970)
6=Spry (1963)

6.3 Post 1859 Evidence

After 1859 only mute evidence exists of the past presence of bison in the form of wallows, and skull (Table 7). However, these records extend the distribution further to include the Mistaya, Clearwater, Red Deer, Dormer, Spray, and Glacier River valleys, and the valleys of Tyrell, Stoney, and Baker Creeks (Figure 9).

6.4 Historical Distribution of Bison

This evidence from prehistoric and historic times indicates that bison once ranged most of the major valleys of Banff and many smaller side valleys as well (Figure 9). The bison were not confined to the lower valleys but in summer ranged into the upper subalpine (Holroyd & Van Tighem 1983) and the alpine (Banfield 1958, Christensen 1971). They likely wintered largely in the lower valleys except for a few old bulls who may have spent the winters isolated in the passes (Banfield 1958). However, winter distribution is difficult to establish. Attempts have not been made to determine the season of death from the bison remains collected. In addition, as little winter travel occurred in the likely wintering areas before the disappearance of bison from the park, the presence or absence of wintering herds was not recorded.

Although bison densities in the mountains could not approach those on the prairies, bison were once quite numerous in Banff National Park. There are no real number estimates by which to quantify this, but the evidence of the large number of bison crania found, the overwhelming majority of remains of this species found in the archaeological sites, and the number of historical reports, lead one to assume that bison were once a significant presence in the Rocky Mountains (Banfield 1958, Christensen 1971). However, by the 1860s, bison had disappeared from Banff National Park and were rapidly decreasing in the rest of North America as well. Although the reason for the early disappearance of bison from the Rocky Mountains is not well understood, increased hunting pressures, severe winters, and disease are thought to be the major contributing factors (Holroyd & Van Tighem 1983).

Table 7. Post 1859 evidence of bison in Banff National Park

General Location	Skull	Wallow	*Source
Glacier Lake	X		4
Howse River	X		5
Mistaya River	X	X	3
Mt. Sarbach	X		4
Waterfowl Lakes	X		1
Clearwater River	X(2)		3
Indianhead Cabin		X	1
Indianhead Cabin	X		4
Tyrell Creek	X		4
Tyrell Flats	X		4
Scotch Camp		X	1,2,3
12.9 km W. of Scotch Camp	X(2)		4
Panther River	X		4
9.7 km S. of Dormer Cabin	X		4
Cascade River	X		1,2
Cascade River	X		3
Stoney Creek	X		4
Ink Pots	X		6
Baker Creek	X		4
Spray River	X		1
Spray River	X		3
19.3 km up the Spray R.	X		4
8 km W. of Banff Townsite	X		4

*Sources:
1=Banfield (1958)
2=Christensen (1971)
3=Holroyd & vanTighem (1983)
4=van Zyll de Jong (1986)
5=collected by author, July 1987
6=note to file Buffalo 62/7-A2, Banff National Park. September,1970

6.5 Return of Bison to Banff National Park

Bison remained absent from Banff National Park for almost forty years until 1897 when three plains bison were donated to the new park, then Rocky Mountains Park. The donation came from T. G. Blackstock, a Toronto lawyer, who arranged to have the animals shipped to Banff from the Colonel Charles Goodnight herd of Texas (Luxton 1975, Ogilvie 1979, Lothian 1981). It appears the gift was somewhat unexpected, and upon their arrival at Banff in October, the bison bull and two cows were placed for the winter in a makeshift paddock built on grounds formerly occupied by the North West Mounted Police. Some of the old police buildings were used for shelter, and a supply of hay was purchased (Lothian 1981).

The following year, 1898, Lord Strathcona donated 13 additional bison, Manitoba stock from the McKay-Alloway herd, to the park for display at Banff (Coder 1975). When the bison arrived from Winnipeg, the herd, now numbering 16, was placed in a newly built paddock 2.4 km east of the Canadian Pacific Railway station at Banff. The paddock was 200 ha, with adequate summer pasture and a good supply of water. Semi-enclosed sheds were built for shelter and hay was purchased to supplement winter forage (Lothian 1981).

The herd had increased to 31 animals by 1899 and continued to do well in the years that followed (Ogilvie 1979). To prevent inbreeding, new genetic stock was provided for the herd occasionally. Two bulls were exchanged with a herd owned by Austin Corbin of Newport, New Hampshire in 1904, and seven Banff bulls were exchanged for 16 bulls from the Pablo herd transported to Elk Island National Park in 1907 (Coder 1975, Lothian 1981). In 1909 the herd had increased to 107 animals and 77 of these bison were shipped to Wainwright (Coder 1975, Lothian 1981). A final shipment of 10 animals was made to Wainwright in March, 1914 (Coder 1975, Lothian 1981).

6.6 Banff Zoo

The Buffalo Paddock was a constant attraction for park visitors (Foster 1978), and in 1900 the Superintendent of Banff National Park, Howard Douglas, began to add other animal species to the paddock. Five elk and 12 pronghorn antelope (*Antilocapra americana*) were introduced to the paddock in 1900, the beginnings of what was to become the Banff Zoo (Lothian 1981). In 1901 Douglas continued to supplement the species in the paddock with more animals and birds. Several Persian sheep (*Ovis sp.*), three coyotes (*Canus latrans*), a timber wolf (*Canus lupus*), two cougars (*Felix concolor*), a badger (*Taxidea taxus*), and two golden eagles (*Aquila chrysaetos*) were added to the zoo in 1904. The next year, an aviary was constructed on the grounds of the Banff museam in town, and the paddock birds were transferred there in 1906. Cages for the accommodation of some of the smaller mammals in the paddock were added to the aviary in 1907, and in 1908 the remaining birds and small mammals were moved to the location on the museum grounds.

The larger mammals, however, remained in the Buffalo Paddock. Moose (*Alces alces*), elk, deer, bighorn sheep (*Ovis canadensis canadensis*), Angora goats (*Capra hircus*), and even six Yak (*Bos grunniens*), a gift from the Duke of Bedford in 1912 (Luxton 1975), were kept for a time in the Buffalo Paddock. The Banff Zoo reached its zenith in 1914 with 50 mammal and 36 bird species. After that time the number of species began to decline. In 1937 the Banff Zoo was declared by the National Parks administration at Ottawa to be "no longer a desired park feature" (Lothian 1981), and it was abolished. Most of the native animals were liberated or donated to zoos along with the exotic species. However, the bison and the Buffalo Paddock remained.

6.7 Plains Bison in the Buffalo Paddock

The number of plains bison maintained in the Buffalo Paddock decreased gradually over the years as the paddock was reduced in size from 200 to 40 ha[19]. Herd size was

[19]Unless otherwise noted, information regarding herd size was obtained from tally sheets and memoranda on file at the Banff Administration Building, Banff National Park. Files consulted were Paddock Animal Reports - Quarterly (Ref. No. 230-1

controlled through slaughter of surplus animals for Banff Indian Days and park work camps, and by shipment of live animals to various Indian Reserves, national parks, wildlife parks, and zoos. Bulls from Elk Island National Park were added to the herd in April 1946, April 1951, June 1955, March 1959, December 1960, and June 1976 to prevent inbreeding.

The peak bison population occurred in 1909, when the herd numbered 107. After the reduction of this population through shipments to Wainwright, the number of bison in the paddock declined until 1923, when only 30 head remained (Billyard 1979). These 30 head were destroyed when an outbreak of tuberculosis occurred and were subsequently replaced with 18 plains bison from Elk Island National Park in 1930 (Billyard 1979). The herd increased to 39 animals by 1935 and was maintained at that level until the fall of 1937 when it was culled to 9 animals. That winter, three calves were introduced to the federally owned Ya Ha Tinda Ranch on an experimental basis. However, the bison strayed and the experiment was terminated in the spring of 1940[29].

From 1938 to 1945, the summer bison population ranged from 10 to 20 animals. However, range conditions were deteriorating. In the fall of 1945, B. I. Love stated that a smaller herd would be sufficient for exhibition, and recommended that the herd be reduced immediately to six animals and maintained thereafter at less than 10[30]. For the next few years, overwinter populations averaged 12 animals.

The condition of the paddock range continued to deteriorate due to overgrazing, encroachment of aspen forest, destruction of grassland by visitors driving vehicles off of established roads, and the loss of several hectares of grazing land to construction of facilities such as the airport and the Trans-Canada Highway. In the fall of 1953, Wildlife Warden, H. Green, recommended that the herd be culled and that the carrying capacity of the paddock be

[28](cont'd) and R-4-7), Buffalo Slaughters (Ref. No. 299B and 62/7-A3), and Buffalo (Ref. No. 232 and 62/7-A2). Additional bison management information was obtained from the Buffalo file (Ref. No. 232 and 62/7-A2) and sources are footnoted below as applicable.

[29]P. J. Jennings, Superintendent, Banff National Park. Memorandum to file. April 1940.

[30]B. I. Love, Superintendent, Elk Island National Park. Letter to J. Smart, Controller, National Parks Bureau, Ottawa. November 26, 1945.

set at eight animals[31]. Experimental grass seeding was also initiated, but results were poor.

Although the winter herd was maintained at eight animals, range conditions did not improve. In 1959, the park superintendent requested that D. R. Flook of the Canadian Wildlife Service conduct an investigation of paddock grazing conditions[32]. Flook estimated the paddock size at 80 ha, with 68 ha available for summer use and 12 ha for winter use only. Overgrazing and aspen regeneration were reducing grass production and availability. Flook therefore recommended that the herd be decreased to a post-calf herd of six and a winter herd of four. The herd was maintained at these levels through to 1961, by which time the paddock had been further reduced to 55 ha[33].

In 1961, the Chief of the National Parks Service indicated to the park superintendent, D. B. Coombs, that the Banff bison herd was too small for exhibition purposes. It was to be increased to 10 or 12 animals and fed hay as necessary[34]. Coombs complied, and the herd was increased to 11 with the introduction of two cows and two calves from Elk Island National Park in June, 1962.

The herd was then maintained at 10 to 12 animals. However, despite feeding, range conditions continued to deteriorate. In 1968, J. Stelfox, a Canadian Wildlife Service Wildlife Biologist, suggested the introduction of moose into the paddock to remove brush encroaching on the pasture[35]. Some moose were captured the following winter and introduced to the paddock. However, they did not fare well, and the experiment was abandoned in 1970 (Billyard 1979).

In 1971 the paddock size was again to be decreased. The park superintendent requested that another range evaluation be conducted by the Canadian Wildlife Service[36]. A

[31]H. U. Green, Wildlife Warden, Banff National Park. Memorandum to G. H. W. Ashley, Chief Park Warden, Banff National Park September 14, 1953.
[32]D. R. Flook, Wildlife Biologist, Canadian Wildlife Service. Letter to G. H. L. Dempster, Superintendent, Banff National Park. June 2, 1959.
[33]D. B. Coombs, Superintendent, Banff National Park. Letter to F. Bransted, Shaunover, Saskatchewan. March 28, 1961.
[34] B. I. M. Strong, Chief, National Parks Service, Ottawa. Letter to D. B. Coombs, Superintendent, Banff National Park. March 28, 1961.
[35]J. D. McFarland, Operations Manager, Banff National Park. Letter to R. T. Hand and E. B. Cunningham, Warden Service, Banff National Park. August 12, 1968.
[36]S. F. Kun, Superintendent, Banff National Park. Letter to G. Scotter, Wildlife

range study was carried out by G. Scotter during the summer of 1971 (Scotter 1972). The Buffalo Paddock was now 40 ha in size with a 32 ha summer pasture and an 8 ha winter pasture. Scotter determined the carrying capacity of the paddock to be five to six adult bison in summer, and one to two in winter. He therefore recommended that the herd be decreased to five, and fed hay during the winter to prevent overgrazing. Scotter also proposed that the Buffalo Paddock facility should be removed as there was "little justification for maintaining a bison herd in Banff National Park." The herd was subsequently reduced to five animals and a proposal put forth to remove the facility. However, the Regional Director, R. P. Malis, recommended postponement of facility removal. Malis indicated that "the present reasons for elimination of all buffalo at Banff would meet stiff opposition from all levels of the public" and should therefore be postponed until a more opportune time such as "when land is required for highway twinning". The facility therefore remained, and the herd was maintained at an overwinter population of five to six animals until 1981, when the plains bison were replaced by the present wood bison herd.

(cont'd) Biologist, Canadian Wildlife Service. June 8, 1971.

R. P. Malis, Regional Director, Calgary. Letter to T. Ross, Superintendent, Banff National Park. April 16, 1972.

7. RESULTS II. REVIEW OF BISON MANAGEMENT FACTORS

7.1 Habitat Requirements of Bison

7.1.1 Climate

The continental climate of Banff National Park is suitable for bison. The most significant influence of climate on bison, notwithstanding the influence of climate on vegetation, is that of winter weather. Prolonged periods of cold temperature, wind, and adverse snow conditions such as deep, dense or crusted snow, have been identified as the major climatic elements which directly or indirectly affect wintering bison.

Bison have a high tolerance for cold, attributable primarily to their thick insulating pelage (Reynolds *et al.* 1982). When compared with three breeds of cattle, the winter pelage of bison showed a greater weight, density, and fineness of hair per unit area, thereby providing a higher quality insulation (Peters & Slen 1964). Bison can withstand intense cold with no apparent discomfort or effect, except for the increased amount of energy required to maintain body temperature. Christopherson *et al.* (1979) observed that the winter metabolic rate of bison in still air at -30 °C was maintained or reduced, apparently because of decreased physical activity. However, with the addition of wind at -30 °C, a lower thermally critical zone was reached with a metabolic rate increase from 700 KJ/kg to 950 KJ/kg. Bison in Wo[illegible]ffalo National Park have been observed by Fuller (1962) to carry on normal activities in temperatures as low as -46 °C. However, Fuller also no[illegible] that extreme cold coupled with even moderate winds (over 13 to 16 kph) caused bison to seek shelter.

In addition to cold temperatures and wind, snow has an important effect on wintering bison. Bison have to remove snow from ground vegetation in order to feed, and must travel through snow from one foraging location to the next. The depth, density, and hardness of snow are important factors. In general terms, ungulate movement begins to be limited when the undisturbed snow column reaches chest height forcing the animal to abandon its natural stride and bound or wallow, greatly decreasing energy effi[illegible] [illegible]n. Camp (197?) found this limit to be 65 to 75 cm for adult bison and 50 to 60 cm for calves. However, mixed herds in Yellowstone National Park regularly forage in snows 60 cm deep, while bulls forage to 90 cm (Houston 1982) and one Yellowstone herd winters successfully in the Pelican Valley which has an average mid-winter snow depth of 100 to 110 cm (Meagher 1976). Feeding by bison can occur to even greater depths in undisturbed snow, and adults in Wood Buffalo National Park have been observed feeding in depths of snow up to 122 cm (McHugh 1958).

It is not only snow depth which is important. Snow density and hardness also affect the ability of bison to forage and travel. In powdery, soft snow, feeding and movement are relatively easy. As the snow column settles with time, or as a result of wind action, snow density increases (Van Camp 1975, Janz & Storr 1977). The denser snow pack provides insecure footing for moving animals and requires a larger expenditure of energy to remove dense snow from ground vegetation. Finally, snow hardness is important. A hardened upper snow layer, known as "windslab", may result due to the mechanical action of wind (Janz & Storr 1977). At temperatures above freezing, sunshine can aid the formation of a hard crust, as can rain or freezing rain. The presence of windslab or crust conditions greatly increases the energy required for animals to travel. Large animals with high foot loadings (unit body weight/unit hoof area) such as adult bison, will break through the crust rather than walking on the surface, resulting in high energy expenditure and possible injury. The amount of energy required to remove snow from ground vegetation is also greatly increased, and in severe cases, foraging may be completely curtailed.

Bison however, are well adapted to winter foraging and have developed energy efficient methods to clear snow and travel through snow (Van Camp 1975, Meagher 1976). The major method of clearing snow is the head swing, followed by the less energy efficient pawing when snow conditions become less favorable (Van Camp 1975). Bison feed by forming craters as they forage outward. A group of bison feeding this way soon form a group crater. The snow within the group crater becomes compacted, allowing easy movement and providing a place which can be used for social interaction, ruminating, resting, and defecation with relatively low energy requirements for movement. The disturbed snow of the group crater soon hardens, making it difficult to return to the area for feed once it has been foraged over once. Any feeding in an old crater site must utilize pawing. Bison also develop a system of well-maintained trails for winter use in order to decrease the energy expenditure required to move between feeding areas (Van Camp 1975). When moving through deep snow, bison travel in a single line, with the lead animal plunging through the snow to create a deep trench through which the others follow (Meagher 1973). In this manner, calves and weakened animals can continue to travel in winter despite poor snow conditions. Thus the formation of group craters and elaborate trail systems are effective behavioral methods for reducing the amount of energy expended to overcome the resistance of undisturbed snow (Van Camp 1975).

For wintering bison in Banff National Park, both the necessity for shelter from winter winds and the existence of favorable snow depth, density, and hardness must be considered. Banff National Park occasionally experiences extreme cold spells in lower valleys which could be co[illegible] for winter bison habitat. High wind conditions also exist, especially in the east-west oriented Lower North Saskatchewan and Lower Bow River Valleys. As a free-ranging herd, the bison would naturally seek the shelter of the forests that line the slopes of most major valleys. However, with a confined herd, the enclosed area must be designed to include adequate cover from winter storms.

Adverse snow conditions are difficult to deal with and to predict. As mentioned previously, precipitation varies widely throughout the park. Year-to-year fluctuations are also quite dramatic, with the maximum snowfall recorded in many localities being about five times the lowest (Janz & Storr 1977). Snowfall also varies with elevation, proximity to the continental divide, and valley orientation. In general, the montane valley bottoms of the Lower Bow and North Saskatchewan River Valleys have shallower snow depths, but as they are east-west valleys, they are more affected by crusting winds and thaw-freeze cycles associated with midwinter chinook winds. Some snow course data are available (Janz & Storr 1977), and one-year average snow depths of a limited number of biophysical Ecosite units were determined by Holroyd & Van Tighem (1983). These data can give a general idea of snow depths to be expected and can therefore be used to identify suitable Ecosites for wintering bison. However, caution must be exercised as snow depths are greatly affected by microsite factors and year-to-year variation.

The present distribution of wintering elk in Banff National Park, can also provide information about winter snow conditions. Although the average chest height of mature bison has been found to be 19 cm shorter than that of elk (Telfer & Kelsall 1979), different foraging and traveling techniques used by bison allow them to winter in areas with snow conditions similar to those tolerated by elk. Therefore, the exclusion of elk from an area by snow conditions should provide an indication that bison use of the area may also be limited. Conversely, the occurrence of wintering elk can be used to predict areas where snow conditions would not be a limiting factor for free-ranging bison. With a confined herd, a study of snow conditions on the selected site could be carried out as necessary and, in any case, feeding could be introduced or increased when snow conditions prevented efficient foraging.

7.1.2 Topography

In general, the topography of Banff National Park is suitable for bison. Bison are quick and agile travelers, capable of moving easily through mountainous terrain. They are able and willing to traverse fallen trees and steep slopes (Meagher 1973), can attain speeds of up to 60 kph in spurts (Fuller 1960, McHugh 1972), and are strong swimmers able to swim large, fast-flowing rivers (Soper 1941, Fuller 1960, Roe 1970, McHugh 1972, Reynolds *et al.* 1982). They do not appear to be limited by altitude (Roe 1970, Meagher 1986), and have been known to climb high into the Rockies (McHugh 1972). Evidence of past bison presence has been reported from about 3903 m in Colorado, 2897 to 3659 m in Wyoming, 3200 m in Montana (Meagher 1986), and in the Upper Subalpine of Banff National Park (Holroyd & Van Tighem 1983), including tracks sighted at 2107 m in Simpson Pass (Roe 1970). Bison in the Henry Mountains of Utah routinely forage up to elevations of 3260 m and on slopes as steep as 40° (*i.e.* 84%)(Van Vuren 1979). Bison generally travel by the most efficient routes and will quickly establish trails to do so (McHugh 1958, Reynolds *et al.* 1982). Bison are not averse to ascending and descending steep grades or travelling in rough country (Soper 1941, McHugh 1958). McHugh (1958) described a bison trail over Mary Lake Divide in Yellowstone National Park which was so steep that a horse with a rider could negotiate it only by following a series of switchbacks superimposed upon the bison trail. David Thompson, an early explorer in Banff National Park, described bison as frequenting the passes of the mountains for the fresh grass, water and freedom from flies. He further commented that when they were found in a narrow place, the bison would take to the rocky hills and go up steep places where they could barely stand (Christensen 1971).

For a free-ranging herd, the topography of [illegible] National Park would present few difficulties. In fact, care would have [illegible] avoid assumptions that topographical barriers could easily control bison movements.

With a [illegible] display herd, topography presents considerations other than those of bison movement. [illegible]ock location and design would have to consider topographical influences on [illegible]d road construction, line of sight and, therefore, visibility of bison, and the physical separation of bison and visitors to prevent both bison harassment and public safety hazards.

7.1.3 Forage, cover, and water

Bison are primarily grazers, with grasses and sedges composing the majority of their diet, forbs being seasonally important in some areas and browse generally incidental (Soper 1941, McHugh 1958, Holsworth 1960a, 1960b, Fuller 1962, Meagher 1973, Banfield 1974, P[illegible]n *et al.* 1974, Van Camp 1975, Cairns 1976, Reynolds 1976, Reynolds *et al.* 1978, Telfer & Cairns 1979, Van Vuren 1979, Cairns & Telfer 1980, Reynolds *et al.* 1982, Meagher [illegible]). A study of bison on the short grass plains in northeastern Colorado identified a diet primarily of grasses in all seasons (Reynolds *et al.* 1982). However, studies in the montane habitat of Yellowstone National Park (Meagher 1973) and the boreal forest habitat of the Slave River Lowlands (Reynolds 1976, Reynolds *et al.* 1978), found that sedges comprised the highest proportion of bison diets in all seasons, while grasses were second. Research from Wood Buffalo National Park has identified sedge as the staple food all year (Fuller 1962), or indicated seasonal use of grass in summer and sedges in winter (Soper 1941). Elk Island National Park studies have also exhibited this seasonal sedge/grass use trend (Holsworth 1960b, Van Camp 197[illegible]). Although generally of minor importance, browse, in particular willow (*Salix* sp.), has been reported to be a major food source in some areas where grasses and sedges are inadequate, seasonally or year round (Reynolds *et al.* 1982, Waggoner & Hinkes 1986). Bison will occasionally forage in chest-deep water for emergent vegetation, in a manner similar to [illegible] or moose (Reynolds *et al.* 1982). In addition, McHugh (1958) reported that bison feed on aspen and lodgepole pine bark, but only rarely, in severe winters.

Habitat selection by bison appears to be governed by their preference for graminoids and their high absolute energy requirements. Studies have shown that bison actively select open grassland areas and low lying sedge swales and wetlands (Meagher 1973, Cairns 1976, Reynolds 1976, Reynolds *et al.* 197[illegible], Telfer & Cairns 1979, Cairns & Telfer 1980, Popp 1981, Norland 1984). Adjacent forest cover can improve the habitat by providing shade, shelter from storms, escape from insects and other disturbances, cover for resting, ruminating, and travel, and by providing limited forage under [illegible] in summer or in winter when snow conditions in the open preclude foraging (Soper [illegible], McHugh 1958, Fuller 1962, Meagher 1973, Meagher 1978, Reynolds *et al.* 1982, Meagher 1986).

The nutrient requirements of bison are not well documented, but can be assumed, for most purposes, to be similar to those of cattle. Extensive studies of beef cattle nutrition have resulted in the creation of handbooks such as The Nutrient Requirements of Beef Cattle (National Research Council 1984) which supply prediction equations and tables to estimate net energy, protein, mineral and water requirements for beef cattle in the various stages of production. No such references exist specifically for bison. Studies have reported the quantity of feed ingested by bison as being 7.4 kg sedge hay/day (Hawley *et al.* 1981b), or a mean daily dry-matter intake of 1.6% (Hawley *et al.* 1981a) to 1.7% (Norland *et al.* 1985) of body weight, or 0.009 kg/kg body weight/day on sedge and 0.001 kg/kg body weight/day on grass (Richmond *et al.* 1977). The quality of feed required by bison has been examined through studies comparing the relative digestion of forages by bison and cattle. High quality forages were similarly digested by bison and cattle (P[illegible]n *et al.* 1974, Richmond *et al.* [illegible]). However, the digestion of low quality forages, with low protein and high fibre content was significantly greater in bison that in cattle (P[illegible] *et al.* 1974, Richmond *et al.* 19[illegible], Hawley *et al.* 1981a, Hawley *et al.* 1981b). The reason for the greater ability of bison to di[illegible] low quality forages is unknown, but may be related to animal species differences i[illegible] recycling or passage rates (Reynolds *et al.* [illegible]).

Therefore, with pres[illegible] knowledge, the nutrient requirements of bison must [illegible] on those of beef cattle, taking into account the greater ability of bison to digest poor quality feed. Jennings and Hebbring (1983) recommend the u[illegible] of stocking rates equivalent to those for cattle, as the greater efficiency of bison grazing allows for a built in buffer. Stocking rates can also be determined [illegible] using average forage intake values for bison, [illegible] estimate of forage productivity and an average bison weight based on the [illegible] sex class composition of the herd.

Bison require water or snow on a daily basis. They prefer open water to snow and will break ice to reach it (McHugh 1958, Jennings & Hebbring 1983). However, they can survive on snow, as evidenced by free-ranging herds, which do not always have access to open water or breakable [illegible] by captive herds such as those at Riding Mountain and Prince Albert National Par[illegible] Rocky Mountain House National Historic Park, which re[illegible] snow once summer wat[illegible] sources are frozen. Bison show no aversion to brackish, stagnant water (McHugh 1958). However, there is no shortage of fresh water in Banff National Park.

In general terms the forage, cover, and water resources of Banff National Park could provide suitable habitat for free-ranging or confined bison. For[illegible] cover and water are readily available to free-ranging bison. The selection of a relocation site for a confined herd could easily incorporate adequate cover and must provide for a [illegible]ummer water source. The open grasslands and sedge fens required by foraging bison are somewhat more limiting

However, suitable vegetation types and Ecosites do exist as described more fully in Section 8.

7.2 Effects of Bison on Environment

7.2.1 Impacts on soil and vegetation

The primary impacts of bison on soil and vegetation result from grazing, wallowing, tree rubbing and the creation and maintenance of trails (Soper 1941, McHugh 1958, 1972, Reynolds *et al.* 1982). As long as the carrying capacity of the range is not exceeded, the effects of bison grazing *per se* are essentially the same as any other ungulate. However, as bison prefer sedges when available, their introduction to an area may result in heavier use of low lying swales and sedge bottoms. Bison are also better able to obtain snow-covered ground vegetation and so may increase winter use of some grasslands. Finally, they require more forage per animal and so may have more impact per animal than other ungulates.

Wallowing by bison results in depressions of bare earth which may be subject to wind and water erosion, especially when located on hillsides (McHugh 1958, Meagher 1973). Wallowing usually occurs in dry sites, but wet muddy wallows may be used (Reynolds *et al.* 1982). Wallows may be used for a single season only and allowed to revegetate, or for [illegible] where continuous use by bison prevents regrowth of vegetation.

Mature trees, saplings, and shrubs can be damaged by horning, rubbing, and thrashing by bison during the rut and at other times (Soper 1941, McHugh 1958, Reynolds *et al.* 1982). In some areas of Yellowstone National Park, McHugh (1958) estimated that as many of 51% of the trees in lodgepole pine stands had been horned by [illegible]. The damage caused by horning and rubbing varies from incidental bark damage to complete stripping of the bark and girdling of the tree. Thrashing and uprooting of younger stands can prevent forest ingrowth at meadow edges and thus contribute to the maintenance of grasslands (Meagher 1973, Reynolds *et al.* 1982).

Finally, well used bison trails which are located in wet areas or on steep, unstable slopes can be the cause of serious erosion and washouts (Soper 1941). Trails on hillsides can serve as drainage channels, effectively lowering the water table in upland areas and subsequently causing a change in the vegetation (Reynolds *et al.* 1982). Areas around water holes or stream crossings can be kept completely devoid of vegetation through repeated trampling (Soper 1941).

The extent of these impacts on soils and vegetation in Banff National Park would depend largely on bison density in both the free-ranging and confined situations. With a free-ranging herd, the impacts would likely be similar to those of the historical bison population. Impacts would generally be dispersed; however, some wallowing, horning, and rubbing could be concentrated in areas [illegible] good forage, water, or [illegible]. In confined situations, relocation site selection and paddock construction should avoid areas with unstable or erosion-prone slopes.

7.2.2 Interspecific relations

The degree and nature of bison interaction with other wildlife species in Banff National Park would depend on the management alternative chosen. The opportunity for interaction would be greatest for a free-ranging bison herd, moderate for a herd enclosed in a paddock which allowed access to other ungulates, and minimal for a securely confined herd. Although all park species could potentially be affected, the most significant impacts would be those on ungulates and predators.

Bison would compete for space and common resources with all ungulate species in the park including elk, deer, moose (*Alces alces*), sheep, goats, and caribou. However, interspecific competition would be minimized by differences in habitat use and food habits. As dictated by these factors, and by resource availability, the most significant competition would occur between elk and bison, particularly for limited winter range. W[illegible] bison and elk successfully coexist in other areas including Yellowstone and Elk Island National Parks, and the National Bison Range. In the montane habitat of Yellowstone National Park, bison appeared to be more restricted than elk to highly productive wet meadows (Houston 1982). The bison were able to forage in the deeper snow of these areas while obtaining a large quantity of food. In the boreal forest-aspen-meadows habitat of Elk Isla National Park, although elk and bison used simil itats, competition for food was minimal as 64% of the elk diet was composed of browse as compared to 1% fo bison (Cairns 1976, Telfer and Cairns 1979, Cairns and Telfer 1980). On the National Bison Range, elk and bison diets overlapped, but bison avoided the steeper slopes frequented by elk, thereby reducing competition (McCullough 1980).

Similar factors would contribute to enhancing the coexistence of bison and elk in Banff National Park. While competition would be intensified by the limited extent of grassland habitat and the relatively low proportion of browse in the diet of Banff elk, it would be decreased by the greater use of low-lying sedge fens and areas of deeper snows by bison. The carrying capacity of the grasslands for elk would undoubtably decrease. The extent to which this would occur would depend upon the actual partitioning of resou that occurred between the species, and on the size and distribution of the bison herd.

A lesser degree of comp would exist between moose and bison for wetland and shrubland resources. The relatively small p of shrubs in the diet of bison, and sedges in the diet of moose, would minimize th competition. Winter habitat use would also differ as moose are able to winter in areas with snow depths that would preclude wintering by bison, except for occasional bulls.

The interaction of bison with other ungulates can take forms other than competition for common resources. Bison are at the top of the interspecific dominance hierarchy for ungulates, and will displace or even attack other animals (McHugh 1958, Holsworth 1960b). Encounters have been observed primarily in confined or feed lot situations. McHugh (1958) observed bison in Jackson Hole Wildlife Park charge and kill elk, pronghorn, and moose calves. Bison regularly displaced elk from feed hay during the winter and chased elk, at a fast walk, during grazing in the summer. Any aggression by bison, including calves as young as one month, could displace even the largest elk. However, on rare occasions, five and six por w served to be dominant over non-aggressive bison cows or yearlings at the edge of a her Despite these examples, bison generally are indifferent to the presence of other ungulates and will forage within 10 m of other animals. In addition, the well maintained winter trails of bison can be of use to other ungulates and small mammals moving in deep snows, and elk have been observed successfully foraging in deep snows by feeding in abandoned bison craters.

Bison provide a food source for their predators, as well as a large group of scavengers. Wolves are the primary predator of bison, with predation by grizzly bears (*Ursus arctos*) occurring occasionally as discussed in Section 7.3.3.2 (Predation).

The ultimate interspecific influences of bison in Banff National Park would depend on the method of management. A herd confined in an area with no access to other ungulates would have little impact except for the effect of the paddock on animal movement patterns and the exclusion of ungulates from the range. If bison were confined in a paddock that allowed access to other ungulates, the opportunity for species interaction would increase. The effect of ungulate foraging on range conditions and carrying capacity for bison would have to be monitored. Supplemental feeding of bison could attract other ungulates to the area and create opportunities for aggressive interspecific encounters. The provision of excess feed would have to be avoided in order to prevent its consumption by other ungulates once the bison had finished feeding. Confined bison would be vulnerable to predation, a concern which would affect the choice of location for a paddock. If bison were managed as a free-ranging herd, they would compete with elk and moose as previously discussed. The extent to which this competition would be acceptable depends on the management goals set for each species. The introduction of free-ranging bison would provide an additional source of prey for wolves and grizzly bears, and an additional source of food for scavengers. The impact of this introduction on predator populations would depend on the numbers of bison introduced and the eventual size and distribution of the herd.

7.3 Herd Management Considerations

7.3.1 Herding behavior and movements

Bison are gregarious, with only the occasion ider bu ending a gth of me alone. Bison herds separate into two distinct group types, cow or mix and bull groups (McHugh 1958, Fuller 1960, Shackleton 1968, Petersburg 1973, Popp , Reynolds *et al.* 1982, Rutberg 1984, Meagher 1986). The cow or mixed groups co cows, calves, yearlings, two and three year old males, and the occasion mature bu w group ize is variable, with groups of 50 to 200 observed in open grassland habitat groups usually of less than 30 observed in forested habitat (McHugh 1958, Fuller 1960, Shackleton 1968, Van Vuren 1979, Popp 1981, Rutberg 1984). The bull groups are formed largely by bulls four years or older with some three year olds, and the occasional two year old. Bull group size is generally smaller, ranging from lone and paired bulls, to groups of 15 to 20 in open habitat (McHugh 1958, Fuller 1960, Shackleton 1968, Petersburg 1973, Popp 1981). During the rut, a third group type, the breeding group, forms when bulls temporarily join one or more cow groups mixed together. These groups can contain over 400 hundred animals, depending on the size of the base groups (McHugh 1958, Lott 1974, Popp 1981).

Gro cohesiveness is generally higher in cow groups than ull groups McHugh 1958, Shackleton 1968). Cow groups move as a unit, with the movement being initiated and directed by mature females. This direction of movement by cows is also retained in the breeding groups (McHugh 1958 1972, Lott 1974). Bull groups are usually led by the older bulls (Petersburg 1973), but cohesion is low and solitary or small groups of bulls may splinter off and remain alone for a time or join another bull group.

In summer, daily movements between foraging sites are common. Studies have shown average daily movements of 1.65 km in Theodore Roosevelt National Park, North Dakota (Norland 1984), 2.8 km in coastal scrub-grassland on Santa Catalina Island (Lott & Minta 1983), and 3.2 km in a montane valley of Yellowstone National Park (McHugh 1958). These summer range movements are influenced by seasonal vegetation changes, interspersion and size of forage sites, the rut, and the presence of large numbers of biting insects (Meagher 1973). Bison cows move within overlapping home ranges. The size of their home ranges appears to be influenced by plant productivity and environmental homogeneity, as well as by the size of the preserve (Lott & Minta 1983, Van Vuren 1983). Bison cows studied in the Henry Mountains of Utah (Van Vuren 1979, 1983) and on Santa Catalina Island (Lott & Minta 1983), had average home range sizes of 52 and 56 square kilometers, respectively.

Bison often migrate annually from summer to winter range and back again. The migration may be directional, altitudinal, or both. The move may be in response to forage availability and nutritional quality, macroclimatic and microclimatic variation, open water, shelter, and insect harassment (Reynolds *et al.* 1982). Altitudinal movements to lowland winter range in fall and to higher summer range in spring are quite common in mountainous areas (Meagher 1973). Bison have been observed to migrate distances of about 14 to 40 km in montane habitat (McHugh 1958), and as much as about 240 km in boreal forest parkland habitat (Soper 1941). In montane areas of Yellowstone National Park, bison travel along well-defined travel routes from elevations of 1828 to 3049 m (Meagher 1973).

The management of a free-ranging herd in Banff National Park must take into account these movements. As previously mentioned, few topographical barriers deter bison movements and, as the population increases, bison will explore new areas and continue to expand their home ranges (Meagher pers. comm. 1986). The major valleys of Banff National Park in which bison would be likely to winter lead east, out of the park and onto Alberta provincial land. Bison released in the park can be expected to eventually, if not immediately, venture out of the park and onto these provincial lands. Foothill areas adjacent to the park, such as Kootenay Plains, were historic wintering ranges for bison. If bison were to be managed as a free-ranging herd in the park, agreements would have to be reached with the provincial government and with private landowners affected. Issues of concern include protection and/or hunting of bison, monitoring of livestock diseases such as brucellosis, mitigation of bison competition with elk and horses for winter range, and provision of compensation for bison damage to agricultural lands, crops, or facilities.

7.3.2 Ontogeny and reproduction

Bison calves are born in spring, with the calving season generally extending from mid-April through May and early June, depending on the timing of the rut the previous fall. The gestation period for bison is nine to nine and one-half months long (Reynolds *et al.* 1982) and has been estimated at 285 days (Haugen 1974). Twin births occur but are rare (McHugh 1958, Fuller 1962, Roe 1970, Haugen 1974, Reynolds *et al.* 1982, Meagher 1986). The primary sex ratio usually is slightly in favor of males (McHugh 1958, Fuller 1962, Meagher 1973, Haugen 1974, Reynolds *et al.* 1982).

Bison calves may weigh 15 to 25 kg at birth (Rutberg 1984), and increase to 135 to 180 kg by eight to nine months (Meagher 1973). Newborn calves are bright reddish tan to orange, but begin to darken at about two and one-half months, attaining a uniform dark coloring by four months (Engelhard 1970, McHugh 1972, Meagher 1986). There is little difference in appearance between sexes at birth. However, males tend to develop slightly larger body size, larger hump, and longer, more conical horns by the end of the first year (Engelhard 1970). Bison calves are precocious, standing and nursing within an hour of birth (Engelhard 1970). They remain close to their mothers for the first week, but by one month tend to gather in calf subgroups to rest and play. They continue to return to their dams to suckle and during major herd movements (Engelhard 1970). Calves are nursed for at least seven to eight months (McHugh 1958), and are usually weaned by the end of the first year (McHugh 1958, Egerton 1962, Engelhard 1970, Van Vuren 1979).

Female bison attain physical maturity earlier than males. Studies suggest cows attain maximum weight at three years (Halloran 1968) and full horn curvature by three to five years (McHugh 1958). McHugh (1958) observed bulls to attain near maximum mass by five or six years with small yearly increments in growth in the following few years. Other studies have suggested that bulls attain maximum mass at 10 to 12 years (Halloran 1968), and mature horn curve and thickness by seven to eight years (Fuller 1959). In wild herds, the onset of old age occurs at 12 to 15 years, with few animals surviving longer than 20 years (Fuller 1962, Meagher 1973). In captivity, the life-span increases, and animals have been known to live up to 40 years (McHugh 1958).

Sexes are dimorphic with males generally being larger and stouter, with longer hair on their head, neck, and chaps, and stouter, more evenly curving horns (Meagher 1986). A plains bison bull can weigh close to 1000 kg and stand almost two meters at the shoulder. The smaller females can weigh up to 600 kg, with a shoulder height of about 1.6 meters (Table 8).

Although a few female bison first conceive as yearlings, sexual maturity is more commonly attained at two to four years of age (Fuller 1962, Halloran 1968, Meagher 1973, Lott 1974, Reynolds *et al.* 1982). Similarly, some males show sperm in the epididymis as yearlings with most being sexually mature by age three (Fuller 1962). However, because of herd social structure, males usually do not breed until age six (McHugh 1958, Lott 1974, Meagher 1986).

The breeding season generally occurs between July and October (Soper 1941, McHugh 1958, Fuller 1962, Meagher 1973, Banfield 1974, Reynolds *et al.* 1982, Meagher 1986). Actual breeding however, is more strongly seasonal and varies from herd to herd. This variability in rut may be related to variation in climate, photoperiod, habitat, population density, and genetic expression (Reynolds *et al.* 1982). As a result of the wide variability in timing of the rut, it is difficult to predict the breeding season and subsequent calving period of bison in Banff National Park. Based on an average gestation period of 285 days, and the first observation of each new calf in 1986 (May 9, 18, 26, and August 13), the breeding season of the Banff National Park herd in 1985 was July 29 to November 2. The major breeding occurred in the first two weeks of August. However, one cow was bred late, at the start of November, 1985.

The rut is characterized by increased group size as cow groups mix and are joined by bulls. Sexual and agonistic behavior by rutting bulls is intense and occurs throughout the day and night with periods of increased activity in early morning and evening. The activities of rutting bull bison have been described by various authors including McHugh (1958), Fuller (1960), Egerton (1962), Shackleton (1968), Herrig & Haugen (1969), Meagher (1973),

Table 8. Body size and weight for adult plains bison.

Sex	Total Length (cm)	Tail Length (cm)	Hind Foot (cm)	Height at Shoulder (cm)	Weight (kg)
Male	304-380	33-91	58-68	167-186	544-907
Female	213-318	30-51	50-53	152-157	318-545

(after Meagher 1986)

Petersburg (1973), and Lott (1974). Sexual behavior by bulls includes the sexual investigation, tending, and breeding of cows. The tending bond is the basic breeding pattern of bison. A temporary monogamous relationship exists in which the bull sexually isolates the cow. The tending bond may last from a few seconds to several days depending on the sexual receptivity of the cow and the ability of the bull to maintain dominance over the cow and over competing bulls. Agonistic behavior, characterized by roaring, wallowing, horning, threat posturing, and fighting, occurs to establish the dominance required for tending and subsequent breeding of cows. Bull bison also show elevated aggression toward vehicles and people during the rut (Herrig & Haugen 1969, Petersburg 1973). Following the rut, the bulls separate from the mixed herds to form bull groups or remain alone for the winter.

Pregnancy rates vary according to age, with the maximum productivity occurring in animals between age three and the onset of old age (Fuller 1962). The incidence of pregnancy declines gradually after cows reach 12 years, and markedly after 24, although 40 year old cows have been observed with calves (McHugh 1958). Observed pregnancy/calf-production rates indicate that, in free-ranging herds, cows normally produce two calves every three years (Table 9).

During the calving season, subgroups of pregnant cows and cows with new calves may form within or separate from the main cow groups. Cows may leave the herd for one or more days to calve, or remain within it (McHugh 1958, Egerton 1962, Engelhard 1970). This may be influenced by the availability of cover habitat and the presence of predators. Cows maintain close contact with their calves for the first week or two after which the calf may begin to spend time with other calves. However, the cow-calf bond remains strong and cohesion is sufficient to identify pairs for up to one year (McHugh 1958). Cows aggressively defend their calves from perceived danger, and cow groups are generally less approachable when young calves are present (Soper 1941, McHugh 1958, Engelhard 1970).

Table 9. Pregnancy/calf-production rates observed for four free-ranging bison herds.

Pregnancy/Calf-Production Rate for Adult Cows	Location of Herd	Source
67%	Wood Buffalo Nat. Park	Fuller 1962
67%	Yellowstone Nat. Park	Meagher pers. comm. 1986
60 calves /100 cows	Henry Mountains, Utah	van Vuren 1979
61 calves /100 cows	Mackenzie Bison Sanct.	Wood Bison Recov. Team 1987

7.3.3 Mortality factors

7.3.3.1 Severe winter weather

Severe winter weather has been identified as a major factor affecting populations of free-ranging bison in Yellowstone (Meagher 1973, 1976) and Wood Buffalo (Fuller 1962) National Parks. Historical accounts point to severe winter conditions as a source of major die-offs (Soper 1941, Fuller 1962, Roe 1970, Dary 1974, Reynolds *et al.* 1982), and winterkill may have contributed to the overall decrease of bison in the late 1800s (Holroyd & Van Tighem 1983). Winterkill results from a combination of weather factors, reduced forage availability, and physiological condition of individual animals (Meagher 1976). Although severe winter weather is an unpredictable source of mortality, winterkill is a major population regulating factor in Yellowstone National Park and has been found to occur to some extent every year (Meagher 1973). By way of example, mortality for the winter of 1981-82 was approximately 25% of the Yellowstone population, 40% yearlings, 14% unknown, and 46% equally old and mature of both sexes (Meagher pers. comm. 1986[18]). Winterkill would similarly be an important source of mortality for free-ranging bison in Banff National Park.

7.3.3.2 Predation

Predation is another cause of bison mortality. Wolves (*Canis lupus*) are competent predators of free-ranging bison (Soper 1941, 1942, McHugh 1958, Fuller 1960, 1962, Oosenbrug & Carbyn 1985) and circumstances have suggested occasional predation on bison calves and adults by grizzly bears (*Ursus arctos*) (McHugh 1958, Meagher 1973). While wolf predation can be significant, studies indicate that predation alone is not a major population controlling factor. A decline in the Slave River Lowlands, Northwest Territories herd beginning in the early 1970s, was at first attributed to wolf predation. However, a study in 1976-77 showed that, while wolf predation accounted for about 31% of the adult and subadult mortality and approximately 27% of calf mortality, hunting

[18]Dr.Mary Meagher, Research Biologist, Yellowstone National Park, Montana

accounted for an additional 39% of the adult and subadult mortality (Van Camp 1987). Despite a wolf control program during the winters of 1977-79 and a reduction in hunting, the population continued to decrease. A study in Wood Buffalo National Park (Oosenbrug & Carbyn 1985) indicated that wolves were responsible for 25% of a 52% annual mortality rate for calves and 32% of a 9% annual mortality rate for adult bison. Despite these high mortality figures, the authors identified low calf production as the single most important factor currently influencing the status of the bison of Wood Buffalo National Park.

The small wolf population in Banff National Park would likely have no appreciable effect on a large free-ranging herd. This is the case in Yellowstone National Park where wolves are rare and do not travel in packs (Meagher 1973). However, it is possible that with increased numbers and pack formation, wolves could have considerable impact on a small or confined herd in Banff National Park. This would depend upon the location of the bison herd and the availability of alternate prey species. Grizzly predation would be incidental for free-ranging bison but must be considered in the selection of possible relocation sites.

7.3.3.3 Disease

Anthrax, tuberculosis, and brucellosis are three important diseases of bison. Sporadic anthrax (*Bacillus anthracis*) outbreaks have caused appreciable mortality in herds from the Northwest Territories and Wood Buffalo National Park. Between 1962 and 1978, the death of at least 1086 animals in these areas was attributed to anthrax (Choquette *et al.* 1972, Reynolds *et al.* 1982). However, anthrax does not appear to be a major factor in the population dynamics of these northern herds (Bison Disease Task Force 1988). The risk of further outbreaks remains, as anthrax spores have continued to contaminate and persist in the soils and water of northern Canada (Reynolds *et al.* 1982).

Tuberculosis is a chronic, infectious disease, caused in bison by *Mycobacterium bovis*. It is present in Wood Buffalo National Park and the Slave River Lowlands, but has been eradicated from Elk Island National Park since 1971 (Reynolds *et al.* 1982), and has never been detected in Yellowstone National Park (Meagher 1973). Testing in Wood Buffalo National Park from 1950 to 1974 showed an average tuberculosis infection rate of 40% (range 15 to 56%) (Broughton 1987). In the Slave River Lowlands, tuberculosis infection rates varied from 25 to 40% in tests done between 1964 and 1974 (Broughton 1987). Little is known about the effects of tuberculosis on bison populations. However, Broughton (1987) estimates that tuberculosis in the Slave River Lowlands probably causes at least a 15% loss of productive capacity in terms of factors such as feed efficiency, weight gain and milk production. In a 1952-56 study at Hay Camp, Wood Buffalo National Park, Fuller (1962) estimated that adult mortality caused by tuberculosis may have been 4 to 6%. The incidence of tuberculosis in the herd was 40% at that time. Later testing of the Claire Lake herd showed reduced incidence of tuberculosis (14.5%, 19.1%, and 13.5% incidence in 1957-59, respectively) (Choquette *et al.* 19[illegible]1), but no estimates of the impact on [illegible] mortality were made. Tuberculosis did not appear to affect the productivity o[illegible]y infected herd at Buffalo National Park, Wainwright, Alberta, and its overall importance as a [illegible] for free-ranging herds remains unclear (Reynolds *et al.* 1982, Meagher 1986).

Brucellosis is an infectious disease caused in bison by the bacteria ***Brucella abortus***. It has been nearly eliminated from confined bison herds. However, it still persists in the free-ranging bison of northern Canada and Yellowstone National Park (Reynolds *et al.* 1982). Brucellosis testing of these free-ranging herds has shown infection rates from 6 to 62%, varying widely between years and between subpopulations (Meagher 1973, Choquette *et al.* 1978). Testing in Wood Buffalo National Park from 1950 to 1974 showed an average brucellosis infection rate of 30% (range 6 to 62%), while the average infection rate in the Slave River Lowlands between 1964 and 1974 was 38% (Broughton 1987).

Brucellosis is of particular importance as it is a serious disease of cattle. In cattle, brucellosis causes abortion, temporary sterility, frequent returns to service, metritis, and lowered milk production (Choquette *et al.* 1978). Recent research has shown that, under experimental conditions, brucellosis causes similar effects in bison (Bison Disease Task Force 1988). Slaughter studies conducted in Elk Island and Wood Buffalo National Parks in the 1950s identified a reduced productivity which authors indicated may have been attributable to brucellosis-caused abortions (Corner & Connell 1958, Fuller 1962). In the long term, brucellosis may have significantly reduced the reproductive capacity of the Wood Buffalo National Park and Slave River Lowlands herd (Broughton 1987). However, studies in Yellowstone National Park, where the incidence of brucellosis was over 50% in some subpopulations, concluded that brucellosis there had little effect, if any, on herd productivity (Meagher 1973). As bison seldom show clinical signs of brucellosis infection, it has been postulated that they may have acquired a natural immunity to the disease as an evolutionary response to the presence of *B. abortus* (Meagher 1973, McCorquodale & DiGiacomo 1985).

The most common mode of brucellosis transmission is through oral contact with aborted fetuses and placentas (Witter 1981, McCorquodale & DiGiacomo 1985). This occurs on wintering and calving grounds where feed and water may subsequently become contaminated. The disease can also be spread by venereal contact, bloodsucking parasites, and ingestion of edible tissues or contaminated milk. Brucellosis can be transmitted from bison to cattle (Bison Disease Task Force 1988), and the presence of brucellosis in the free-ranging bison herds of northern Canada and Yellowstone National Park has caused and continues to cause concern among livestock producers and various agricultural agencies. In the early 1970s, Yellowstone National Park was called upon to eradicate brucellosis from its bison, a task that would necessitate the elimination of almost the entire herd (Meagher 1974). In response to this concern, Yellowstone instituted a boundary control program to ensure no contact of bison and domestic stock. However, in recent years, bison have begun to return to their historic range, including a wintering area near Gardiner, Montana, north of the park. As a result, concern over the spread of brucellosis to domestic livestock has once again arisen (Meagher pers. comm.

1986). Likewise in Canada, a close look is currently being taken at the incidence of disease in northern bison herds and its implications for future management. In 1986, the Bison Disease Task Force was established to prepare an evaluation of the problem of brucellosis and tuberculosis in bison in northern Canada. Concerns included the possible spread of these diseases to livestock, other wildlife including the threatened wood bison, and man. A number of management options have been put forth by the Task Force for review and action by the Bison Disease Steering Committee and the various agencies involved (Bison Disease Task Force 1988).

For bison in Banff National Park, the maintenance and introduction of disease-free stock should ensure that the spread of disease does not become a problem. However, there are no guarantees, as diseases may be introduced to the bison by domestic stock, other wild ungulates, insects, predators and scavengers. If free-ranging bison were to be infected with a disease such as brucellosis, the control of herd movement outside park boundaries would become important.

7.3.3.4 Other diseases and parasites

Bison are host to many species of ectoparasites and endoparasites. The effects of parasitism can range from minimal irritation to acute or chronic disease resulting in death (Reynolds *et al.* 1982). While the effects on wild herds are minimal (Meagher 1986), confinement and on-ground feeding may enhance occurrence. Bison producers use a variety of livestock methods to treat bison for gastrointestinal nematodes, lungworms, and flukes (Jennings & Hebbring 1983). Fly problems can be reduced by feeding insecticides mixed in mineral supplements or by spreading insecticides in wallows.

Bison suffer from a range of other pathological conditions, but they are generally of incidental occurrence and do not seriously affect mortality rates in bison populations (Reynolds *et al.* 1982). Some bison producers vaccinate against diseases such as colostridium and leptospyrosis, and occasionally treat conditions such as pink-eye and hoofrot (Jennings & Hebbring 1983).

7.3.3.5 Accidents

A certain number of bison mortalities can be attributed to accidents. Accidental drowning can occur during the crossing of rotten ice, flooding rivers, or by being trapped during abnormal spring flooding (Reynolds *et al.* 1982). These occurrences can sometimes involve hundreds of animals and result in considerable mortality (Fuller 1962, Roe 1970). Forest fires in northern bison ranges rarely cause appreciable [illegible] (Soper 1941, Fuller 1962). However, prairie wildfires in the past have decimated [illegible] herds (Roe 1970).

An additional cause of mortality for free-ranging bison in Banff National Park could be bison-vehicle collisions along railways and roadways. A few bison fatalities resulting from vehicles have occurred in northern Canadian herds and Yellowstone National Park (Fuller 1962, Reynolds *et al.* 1982, Meagher pers. comm. 1986). In Yellowstone National Park, about two bison-vehicle accidents occur each year, caused largely by drivers familiar with the roads, driving at speeds too fast for good visibility (Meagher pers. comm. 1986). In Jasper National Park, two of the animals from the failed wood bison re-introduction in 1978 were killed by trains and one by a truck (Holroyd & Van Tighem 1983). Although fencing of the twinned Trans Canada Highway in Banff National park has reduced wildlife-vehicle collisions, incidents still occur along unfenced roadways and the railway.

7.3.4 Population structure and growth

The age-sex class distributions of five bison herds are shown in Table 10. The population structures of the free-ranging herds only approximate those that would be found under natural population regulation, as at the time of studies, all four herds were influenced by either slaughter or hunting for population control and management. The population structure of the National Bison Range herd provides an example of a herd that is managed to maintain a healthy, vigorous population and provide a suitable age and sex class distribution for visitor viewing. In a stable population the proportion of calves in [illegible] herds may be [illegible]

Table 10. Age-sex class distribution for five bison herds.

*Herd	(%) Calves	(%) Yearlings	(%) 2-3 Year Olds		(%) Adult Females	(%) Adult Males
WBNP	16	9	15		39	21
YNP	22	17	16		28	16
UTAH	21	13	no data		36	30
			(%) 2yr	(%) 3yr	(%) 4-10yr	(%) +10yr
NBR	25	15	10-15	10	25-30	<10
					(57 fem:43 male)	
			(%) Subad. Females	(%) Subad. Males	(%) Adult Females	(%) Adult Males
SLR	19.7	3.7	0.7	2.4	55.7	17.6

*Location of herd, management at time of study, and source.
W3NP: Wood Buffalo National Park
Free-ranging with annual slaughter (Fuller 1960)
YNP: Yellowstone National Park
Free-ranging with annual slaughter (Meagher 1973)
UTAH: Henry Mountains, Utah
Free-ranging with annual public hunt (van Vuren 1979)
NBR: National Bison Range
Pasture rotation with annual slaughter (Rutberg 1984)
SLR: Slave River Lowlands
Free-ranging with hunting (Van Camp & Calef 1987)

to 20%, with 25% indicating a population undergoing increase (Meagher 1973). In a 1964-65 study in Yellowstone National Park, Meagher (1973) observed calf mortality to be minimal, with overwinter mortalities of 19% for yearlings and 31% for one year olds. In contrast, Fuller (1962) and Oosenbrug & Carbyn (1985) in their studies in Wood Buffalo National Park observed just over 50% calf mortality.

When favorable conditions exist, bison herds can increase rapidly to carrying capacity levels. The wood bison herd introduced to the Mackenzie Bison Sanctuary, Northwest Territories, increased from 16 animals to over 1000 in the first twenty years, an average annual increase of 25% (Reynolds *et al.* 1985). The growth of the herd can be described by an exponential equation with a growth rate of 0.215 and $r^2 = 0.985$ (Wood Bison Recovery Team 1987). Similar rapid population expansion was seen with the Yellowstone National Park bison herd following the termination of herd reductions in 1966. The herd increased steadily from 400 animals until carrying capacity was reached at 2000 animals (Meagher pers. comm. 1986). The more intensively managed plains and wood bison herds of Elk Island National Park have increased at an average annual rate of 17% and 26%, respectively (Blyth pers. comm. 1986[19]). The growth of the Elk Island National Park wood bison herd from 31 animals in 1969 to 111 in 1977 can be described by an exponential equation with a growth rate of 0.188 and $r^2 = 0.992$ (Wood Bison Recovery Team 1987).

Management of bison as a free-ranging or confined herd in Banff National Park must consider the consequences of population growth. Maintenance of desired herd size and structure is relatively simple with a confined herd. The captive Banff herd is at present highly productive, with a 100% pregnancy rate and no mortality. Herd size is controlled through biannual removal of offspring, and replacement breeding stock can be obtained from Elk Island National Park. It would be difficult to control the size or structure of a free-ranging bison population, except perhaps through hunting outside park boundaries or the introduction of new stock. Population modeling should be carried out to predict the growth pattern to be expected for a free-ranging herd in Banff National Park.

[19] C. Blyth, Park Warden, Elk Island National Park.

7.3.5 Supplemental feed, nutrients, and water

Supplemental feeding may be required during the winter for a confined herd with limited range. Bison producers report success with various hays and concentrated cattle feeds (Jennings & Hebbring 1983). Winter feeding in a park setting should not be automatic, but rather based on forage carryover and range condition, or in response to the occurrence of severe winter weather conditions, such as snow crusting which prevents efficient grazing. Feeding increases domesticity, encourages spread of disease, can cause overuse of portions of range, and results in elevated intraspecific competition and, therefore, stress.

Mineral requirements not met in the bison diet can be provided through the use of mineral licks by free-ranging animals and through the provision of mineral supplements for captive herds (McHugh 1958, Jennings & Hebbring 1983). As there is some indication that native forages may be deficient in selenium (Shaw & Reynolds 1985), consideration should be given to analysing the nutrient content of forage available to a confined herd and/or providing selenium in a mineral supplement.

Bison must have access to ponds, streams, or artificial water sources. Artificial sources can include troughs or ponds filled by water truck, artesian well systems, or by mechanically or electrically powered pumps. Artificial sources should be located so as to encourage even use of the range. In winter bison can survive on snow, but if they are being artificially fed, water should also be provided. This may necessitate breaking ice in ponds or frozen streams, hauling water, or ensuring continuous or timed interval flow with artesian or pump well systems to prevent freezing.

7.3.6 Facilities and equipment

Facilities and equipment for handling bison continue to evolve as the bison industry develops. Equipment originally designed for cattle has been adapted over the years by ranchers, wildlife sanctuary and park managers, and finally by livestock equipment manufacturers. Information on the latest technologies can be obtained from organizations such as the Alberta Game Growers Association, Canadian Bison Association, the National

Buffalo Association, and the American Bison Association, and from managers of public herds and numerous bison producers across Canada and the United States.

The facilities and equipment required for the management of a confined herd in Banff National Park are limited. Fencing is a primary concern. Options for fencing range from the present fencing, 2.4 m heavy gauge paige wire, to four strand barbed wire which is used by some bison producers. The management objectives for a confined herd would dictate the type of fencing required. If the exclusion of other ungulates was desired, a fence similar to the one now in place would be necessary. The present fence eliminates most use by other ungulates, although elk occasionally gain access to the Buffalo Paddock, likely over sections of fence which are in need of repair. Alternatively, if access to other ungulates was to be allowed, or even encouraged, a number of other fence designs could be suitable.

Although some ranchers successfully pasture bison in 1.2 m barbed wire fences, and experience at Elk Island National Park has shown 1.2 m fences to deter the entrance of bison into elk traps (Olsen, pers. comm. 1986[40]), 1.5+ m fences are generally considered more suitable for bison. Bunnage (1985) recommends six strand, 1.5 m fences for young stock and for mature stock that are accustomed to the pasture. Barbed wire is not recommended as it appears to have no deterrent effect on bison, and can cause injury. High tensile, smooth wire is gaining favor, particularly in conjunction with an offset electrical wire, which seems to work well with bison. Stronger holding pastures are required for new stock and heavy gauge paige wire fences, at least 1.5 m high, are recommended. The bison herd at Rocky Mountain House National Historic Park is enclosed by similar fencing, 1.4 m paige wire topped by a single strand of barbed wire at 1.5 m (Gaudet, pers. comm. 1987[41]). This fence has successfully contained the herd, except for a calf which slipped under the fence in a low spot.

An example of fencing designed specifically to hold bison and allow other ungulates free passage exists on the National Bison Range. Two non-domesticated herds of plains bison are rotated through a series of eight internal pastures while elk, white-tailed deer, mule

[40]W. Olsen, Park Warden, Elk Island National Park.
[41]D. Gaudet, Rocky Mountain House National Historic Park.

deer, pronghorn antelope, bighorn sheep, and mountain goats are allowed free passage. To facilitate this, the internal fences are constructed with 1.2 m of heavy-gauge woven wire strung 30.5 to 40.5 cm up from the ground, for a total fence height of 1.5 m (Malcolm, pers. comm. 1986[42]). Some fences have a barb along the top of the woven wire, but it is not believed to be necessary. Steel posts are used for all line fences with wooden posts at corners and braces. The fences are generally effective in holding bison. Problems have arisen during herding or when bulls were pastured on opposite sides of a fence. The bison will go through the fence if pushed or will jump it, usually hitting it about three-quarters of the way up and then going over (Malcolm, pers. comm. 1986). However, under similar circumstances, bison have even managed to get through the heavy duty Watchman wire fences at Elk Island National Park (Bunnage 1985). The other ungulates of the National Bison Range move freely under or over the internal fences. Bull elk easily jump the fences flat-footed and cows either jump the fences or, quite often, go under spaces as small as 40.5 cm. Mr. Malcolm has observed mixed cow-calf groups of up to 15 elk pass under the fences in a matter of seconds. If one location is used frequently for this type of under fence passage, a depression results that could allow movement of bison under the fence. The National Bison Range is presently considering the installation of braces at key places such as these, constructed with wire from the ground up to the cross brace, forcing elk to cross in the empty space above the brace. It is possible that bison will also learn to use these crossings, and the necessary brace height to discourage this has unfortunately not yet been established. Bison calves can cross under the internal fences, but rarely wander far, and once past their first winter they are generally too large.

Cattle guards or Texas gates may also be required, although it is best to avoid them if possible as bison, especially mature bulls, appear to be adept at crossing or leaping them, easily spanning distances of at least three m. The previous bison bull at the Banff Buffalo Paddock was able to cross the Texas gate, and similar occurrences have been recorded at the National Bison Range (Lott 1974), and Wind Cave National and Custer State Parks

[42] J. Malcolm, Manager, National Bison Range, Moiese, Montana.

(Petersburg 1973). There are several designs of Texas gates being successfully used at various park and private facilities. However, it is difficult to identify the *best* gate, as a structure which has successfully contained a bison herd for years, may be immediately crossed by a particularly agile or adventuresome bison introduced to the facility. In the case of private herds, this problem can usually be solved by the removal of the individual. However, as this is not as easily done with park herds, it is likely better to install the most extreme Texas gate available.

Limited handling facilities would be required for a confined herd in Banff National Park. Such facilities are necessary for handling during herd culling, for treatment of or preventative measures against disease, and possibly in the future for mandatory disease testing. To increase the efficiency of bison handling, to minimize the stress to the animals, and to ensure the safety of bison and handlers, the present Banff National Park facilities should be expanded and adapted for bison, and new facilities built if the herd is relocated. Sorting pens, an alley divided by sliding gates, a bison squeeze, and loading ramp are required. A system similar to that of Waterton Lakes National Park, or patterned after those of a number of small bison producers would be sufficient. Corral systems must be sturdy, and are usually built of either heavy planking or steel pipe. Many bison handlers recommend that the sides of pens and alleys be covered with planking or plywood to limit the vision of bison and reduce disturbance during handling. The walls of the handling facilities should be at least two m in height. Alleys should be built with sliding cutoff gates, and corners should be 45 degrees or rounded, rather than square. A squeeze with a head gate is recommended. Squeezes designed specifically for bison are available and should be used.

7.4 Human Dimensions of Bison Management in Banff National Park

7.4.1 The wildlife viewing context

The provision and management of wildlife viewing opportunities has recently become identified as a goal for wildlife management. Over the last fifteen years it has become evident that a growing number of North Americans are interested in direct contact with and observation of wildlife, in particular, nonconsumptive uses of wildlife (Burger 1979, More 1979, Wilkins & Peterson 1979, Shaw & Cooper 1980, Jackson 1982, Lyons 1982, Filion *et al.* 1983, Boyle & Samson 1985, Kellert & Brown 1985, Shaw *et al.* 1985). A comprehensive survey conducted by Statistics Canada in 1982 identified wildlife related activities as one of the most prevalent forms of recreation undertaken by Canadians fifteen years of age and over (Filion *et al.* 1983). In 1981, 3.6 million Canadians, 19.4% of the survey population (Canadians 15 years of age and over), participated in primary nonconsumptive use of wildlife through trips or outings taken specifically for that purpose. A further 8.1 million Canadians (43.9%) participated in secondary nonconsumptive use of wildlife through enjoyment gained by encountering wildlife during trips or outings taken primarily for business or pleasure. Similar percentages were obtained in a 1980 survey conducted in the United States (Shaw & Mangun 1984). These numbers indicate a potentially large demand for nonconsumptive wildlife viewing opportunities and also a potentially large impact on resources. Agencies responsible for private, urban, municipal, provincial, state, and federal wildlife resources are beginning to incorporate the needs of nonconsumptive users into their management strategies. They are actively seeking ways to facilitate the wildlife viewing experience and yet protect other resource values and uses.

Researchers and managers are developing strategies for effective management of wildlife viewing. To provide the best wildlife viewing experience possible, the manager must be aware of the desired attributes of a wildlife viewing experience, the factors which affect user interaction with wildlife, and the subsequent satisfaction gained from the encounter. User groups may have preferences as to the species, age, gender, grouping, proximity, and behavior of animals observed, the physical, social, and managerial setting of the observation, and the type, degree, and duration of interaction with the animal. These preferences reflect the knowledge, attitudes, motivations, and value systems of the nonconsumptive user group, which in turn also affect interaction and satisfaction. Many researchers have identified the need for this sort of human dimensions information to enhance the understanding and management of nonconsumptive wildlife users (Hendee & Potter 1971, More 1979, Kellert 1980, Shaw & Cooper 1980, Lyons 1982, Boyle & Samson 1985, Driver 1985, Kellert & Brown 1985). To date only a limited number of studies has been conducted to specifically address the issues of nonconsumptive wildlife use. However, managers and researchers can draw from the results and methodologies of studies concerning the socio-psychological aspects of leisure and recreation in general, and research addressing the human dimensions of the consumptive wildlife activities of hunting and fishing. The methodologies of these studies can be adapted to conduct studies of the nonconsumptive wildlife user to delineate the attributes of the viewing experience which will result in viewer satisfaction.

The impacts of nonconsumptive wildlife use on resources must also be identified. A much larger body of information exists for this more biological component of the management issue. While the impacts may include damage to soil and vegetation, the impacts of primary concern are those on wildlife. Several recent reviews have outlined the effects of nonconsumptive recreation on wildlife (Cornish *et al.* 1980, Ream 1980, Vaske *et al.* 1983, Boyle & Samson 1985). As described in these reviews, the impacts of observers on wildlife can include harassment, loss of habitat, habituation, reduced productivity and even death. Researchers have identified a variety of factors that influence the response or vulnerability of wildlife to encounters with humans. The wildlife species and its feeding and breeding characteristics, the type, degree, and length of the encounter, the age and general health of the animals in question, the number of animals in the group, the availability of refuges from disturbance, the past experience of the animals with humans, and the season and weather conditions are all important factors. It is necessary for wildlife managers to recognize these factors and carefully assess the degree of vulnerability of wildlife species present in an area which receives or is to be managed to accommodate wildlife viewing pressures.

This study provides an opportunity to examine another facet of nonconsumptive wildlife use. While studies have been conducted to identify the desired attributes of wildlife viewing, little work has been done to actually quantify the attributes provided by a given wildlife management scenario. The observation of bison in the Buffalo Paddock possesses many of the elements of a wildlife viewing experience, despite the confined nature of the herd. In fact, its confined nature eliminates a number of variables such as the presence of other wildlife species, the use of the area for other activities, and large variations in wildlife numbers or locations. The Buffalo Paddock, therefore, provides a somewhat controlled situation in which to describe the attributes of the bison viewing opportunity, to quantify visitor use, and to examine bison-visitor interaction. Information obtained can be used to evaluate the alternatives for bison management, to identify qualities for relocation sites, and to recommend design, interpretation, habitat, and management considerations for visitor viewing of captive and, to some extent, free-ranging bison. The methods developed can be adapted and expanded for evaluating wildlife viewing opportunities and predicting visitor use and interaction with wildlife in other situations.

7.4.2 Bison-human interaction

7.4.2.1 Bison handling

The reaction of bison to handling has been studied at Wood Buffalo (Hudson *et al.* 1976) and Elk Island National Parks (Blyth, pers. comm. 1986). Reactions to the stress imposed by handling can be both behavioral and physiological, with the effects ranging from temporary to fatal. The most obvious behavioral manifestations of handling stress are redirected aggression in the form of head butting, goring, pushing, and kicking, and frantic attempts at escape. Both can result in serious injury. Fear induced immobility is another behavioral response which slows the movement of animals through the facility, thereby increasing the stress imposed upon them. Milder behavioral responses indicating stress include running away, wallowing, tail lifting, urination, vocalizations, and pawing the ground. Physiological manifestations of handling stress include hyperthermia, neurogenic shock, and spontaneous abortion. Bison may also exhibit delayed reactions to stress for several weeks after handling. Some examples of delayed reaction are capture myopathy (white muscle stress syndrome), infection of wounds, and stress-induced diseases similar to the shipping-fever complex of domestic animals, all of which can be fatal. Although most aggression during handling is directed towards other bison, several horses and workers have been chased and some gored by bison during handling operations (McHugh 1972, Dary 1974, Reynolds *et al.* 1982).

Caution, skill, and adequate facilities are necessary to safely handle bison. Even with a small herd, such as exists at present in Banff National Park, some handling facilities, as described in Section 7.3.6, are required to reduce stress and prevent injuries to the bison and handlers. Measures which have been found to reduce handling stress and injury include conducting operations during cool weather or sprinkling animals with water, designing an efficient system to minimize the length of time spent by animals in the handling facilities, sorting animals by dominance or age-class, moving individual animals mainly by prodding rather than by excessive shouting so efforts stimulate the desired animal without increasing the emotional tension of the entire herd, and keeping animals visually separated from handlers when possible. Low-stress handling in Banff National Park would be simplified by the small size of a captive herd. However, some animals may remain several years, necessitating repeated handling. Ranchers have found that bison learn quickly, and in repeat handling situations, animals must be treated carefully so as to prevent the development of extremely panicky or aggressive reactions to handling.

7.4.2.2 Bison observation or chance encounters

The reaction of bison and bison herds to man in the observer or park visitor role, varies from shy timidity to stolid indifference, and from frantic flight to overt aggression. In a national park setting, the effects of bison-human interaction on both the animal and the park visitor are important. Resource protection and public safety concerns would have to be addressed for either a confined or free-ranging bison herd in Banff National Park.

As previously stated, the impacts of observers on wildlife can include harassment, habitat loss, habituation, and reduced productivity. Harassment, as defined by Ream

(1980) includes events that cause excitement and/or stress, disturbance of essential activities, severe exertion, displacement, and sometimes death. Harassment can be either intentional or unintentional. Several authors suggest that the major impacts of nonconsumptive use on wildlife result from observers who unknowingly produce stressful situations for wildlife. As reported by various researchers, bison are susceptible to harassment by human observers.

The most commonly reported reactions of bison to humans are flight and aggression. The degree of wariness and distance of flight seems to be variable. A hunted population of bison studied by Van Vuren (1979) in the Henry Mountains of Utah were extremely wary when humans were present. Detection by either sight or smell usually caused them to stampede for up to 5.0 km with an average flight distance of 1.8 km. These bison tolerated human presence to 400 m, but only if the bison were on a steep slope above the person. The Hayden herd of Yellowstone National Park studied by McHugh (1958) paid little attention to people walking 0.8 to 1.3 km away, if neither noise nor scent could be detected. However they became alarmed if people approached closer, and would stampede without hesitation at the scent of humans, even if they were not visible. Soper (1941) found that bison in open areas of Wood Buffalo National Park would allow people to get within 100 m and would then flee. In a study of nordic skier interaction with ungulates in Elk Island National Park, Ferguson (1980) noted that escape behavior by bison occurred more often when skiers stopped to watch than when they continued skiing. This variation in response by bison may be related to their degree of familiarity or previous experience with people, the nature of the interaction with people, whether or not the bison are hunted, and the type of escape terrain available to them.

Other variations in behavior exist between bull and cow groups. Bulls and bull groups are generally less wary than cow groups and their flight distances are shorter (Soper 1941, McHugh 1958, 1972, Petersburg 1973). McHugh (1958) observed flight distances of less than 90 m for bulls in Yellowstone National Park and from 60 to 300 m for cows. This trait means that bulls are often the primary display animals in parks. However, it also means that they are involved in more aggressive encounters with observers than are cows. Their seeming indifference tempts observers to get so close, that there is little chance of escape if a bull does decide to react aggressively. As well, aggressive behavior by bull bison towards both vehicles and people is elevated during the rut (Soper 1941, Herrig & Haugen 1969, Petersburg 1973). Cow groups are less approachable during and after calving, when they move away more quickly, and flee a greater distance (McHugh 1958, Engelhard 1970). However, cows will also behave aggressively towards people, particularly when they feel their calves are being threatened (McHugh 1958, Fuller 1960). As their calves mature, cow groups become more approachable, instances of aggression decrease, and flight distances lessen. McHugh (1958) observed the flight distance of the Hayden herd in Yellowstone National Park to decrease from 300 to 450 m in the summer, to 90 to 180 m in November, to as low as 60 m in December.

Bison likely exhibit other signs of harassment that are not reported by most observers because they are less obvious. These signs could include previously described indicators of stress such as wallowing, tail lifting, and vocalizations, or behavioral modifications such as altered feeding and herd movement patterns. If feeding patterns are altered to the point where bison avoid areas in which they are exposed to people, the loss of habitat can occur. The wariness of cow groups can be seen as a form of habitat loss. Areas near roads and/or frequented by people are rarely used by cow groups with young calves.

Habituation of wildlife to humans can have beneficial as well as detrimental effects. Habituated animals experience lower stress levels when in contact with humans. However, they also lose their fear of man and can become more aggressive. Increased mortality on roads, vulnerability to poaching, and nuisance problems can result. Similar to other wildlife species, bison become more easily habituated to vehicles than to humans on foot, and will neither flee as often nor as far from them (Fuller 1960, Engelhard

1979, Van Vuren 1979). Under domesticated circumstances, bison can become approachable, but never really become completely tame. There are several cases of "tame" bison eventually turning on and even killing their owners and handlers (Roe 1970, Dary 1974).

Harassment, habitat loss, and habituation can all lead to reduced productivity at the individual, or in severe cases, at the population level. Actions that produce extreme stress on pregnant cows or interfere with the breeding, birthing, or care of young calves, are likely to reduce productivity of a captive or free ranging biso[illegible]

Bison human interactions that affect the safety of visitors [illegible]o of concern to park managers. One of the reactions of bison to harassment or stress is aggression. The degree of aggression bison display towards people can range from threat posturing (vocalizations, elevation of the tail, pawing, wallowing, side presentation, head nodding), to bluff charges, to full scale charges accompanied by hooking, goring, and trampling. Aggressive reactions by bison generally occur when people approach them "too closely". However, this critical distance seems to be extremely variable, and direct approach towards bison at any distance is risky without adequate means of escape. Many people have been only bluff-charged by bison, but others have been chased, butted, and gored resulting in injuries varying from minor cuts and bruises to severe lacerations and death (McHugh 1972, Dary 1974, Meagher pers. comm. 1986).

Although several encounters are believed to have occurred between bison and visitors in Canadian national park herds, few serious incidents have been recorded. On record are two gorings, one in Prince Albert National Park (Anions, pers. comm. 1987), and one in Waterton Lakes National Park in July 1984 (Tilson, pers. comm. 1986). In Elk Island National Park, reports of aggressive free-ranging bison are received about three to five times per year. These situations are normally managed by trail closures. However, one unusually aggressive bull was destroyed in 1983-84 (Graham, pers. comm. 1987)[41] Many less serious incidents in these and other parks go unrecorded because

[41]Mr. D. Graham, Park Warden, Elk Island National Park.

visitors are essentially unhurt or because they have disobeyed signage requesting that they remain in their vehicles and therefore do not wish to report the incident.

A number of serious bison-human encounters have occurred over th[illegible] Yellowstone National Park (Meagher pers. comm. 1986). In 1971, the park recorded its first bison caused fatality. However, in general the occurrence of aggressive encounters was still fairly low, with about one injury being recorded every three to four years. By the late 1970s, the injury rate had increased to one injury in every two years and in [illegible] there were twelve incidents, including one fatality. No incidents were recorded in [illegible], but in 1985 ten bison-human encounters had occurred by the end of July. The [illegible] issued a warning pamphlet in July of 1985 which seemed effective in preventing further encounters that summer. Dr. Mary Meagher, a research biologist at Yellowstone National Park, attributes the increase in bison-human interaction to increased visitor numbers combined with the presence of more bison close to roads, and more bulls frequenting the housing areas. The gradual expansion of bison habitat is a product of the niching-in process which has occurred as the population has increased to carrying capacity in the park. The pamphlet appears to be helping at present to reduce bison-human conflicts in Yellowstone National Park by warning visitors of the danger of wild bison and cautioning them to keep their distance. The distribution of a warning pamphlet has also been implemented at Elk Island National Park to inform visitors of the presence of free-ranging bison and the dangers of approaching the animals.

Bison-vehicle collisions could present a public safety concern if a free ranging herd were established in a high traffic area (see Section 7.3.3.5). Measures taken to reduce the incidence of vehicle-wildlife collisions, such as fence construction, improved visibility, and reduced speed limits, would likely be as effective for bison as for other large ungulates.

To effectively manage bison-human interactions in Banff National Park [illegible] information and awareness would be necessary. In a confined or free ranging situation harassment and public safety concerns could be addressed through information, interpretation, and facility design. However, as with any other large ungulate, some risk of harassment, vehicular accidents, and visitor encounters with aggressive animals would always remain.

8. RESULTS III. ANALYSIS OF BISON HABITAT

8.1 Ecosite and Winter Range Identification

As discussed in Section 7.1.3, studies have identified grasses and sedges as the primary foods of bison, with sedges being particularly important in winter. Therefore, in the first step of the Ecosite identification outlined in the methodology, vegetation types were identified which were comprised of at least 20% grass and grass-like species. The results of this broad selection procedure included all vegetation types that could contribute even marginally to the bison diet. The process identified 37 vegetation types, thirteen of which had grass or grass-like cover to at least 50% (Table 11). Of these 37 types, fifteen are closed forest, five open forest, five shrub, one low shrub-herb, and ten herb-dwarf shrub vegetation types. Based on these vegetation types, 52 Ecosites were then identified (Table 12). As these Ecosites range from marginal to primary bison forage habitat, each must be examined individually. While, for some Ecosites, all dominant vegetation types are suitable (*e.g.* BV1: C9, C18, C19), for other Ecosites, suitable vegetation types may comprise only one half (*e.g.* CA4: C19 C20) to two-thirds (*e.g.* AT1: C3, C6, C19) of the dominant vegetation types (see Tables 11 and 12 for explanation of codes). Other Ecosites with wet dry patterns, namely AZ1, BK6, CA1, CV1, MC1, and PL5, only have suitable vegetation types on the wet portions, representing only 30% of mapped units for all but MC1, where it is 80%. Another exception is found with Ecosite PR4 where suitable vegetation types exist only on southerly exposures. The habitat types represented by these 52 Ecosites also vary widely, including closed forests (24), open forests (2), shrub meadows (4), grasslands (4), wet herb meadows and sedge fens (3), and combination habitats composed of open and closed forest, shrub, and herb-dwarf shrub vegetation types (15).

Due to the opportunity for site manipulation and supplemental feeding, all of these Ecosites could be considered for the identification of paddock relocation sites. However, this level of Ecosite identification was not sufficiently precise for examining the availability of forage habitat for free-ranging bison. The forested Ecosites and forested portions of

Table 11. Vegetation types with at least 20% cover for grass and grass-like species.

Closed Forest Vegetation Types	
C1	Douglas fir/hairy wild rye
*C4	white spruce/prickly rose/horsetail
C6	lodgepole pine/buffaloberry/showy aster
C9	lodgepole pine/dwarf billberry
C16	aspen/hairy wild rye-peavine
C17	balsam poplar/buffaloberry
C18	lodgepole pine/buffaloberry/grouseberry
C19	lodgepole pine/buffaloberry/twinflower
*C22	aspen/hairy wild rye-showy aster
C26	white spruce/buffaloberry/fern moss
C27	white spruce/prickly rose/fern moss
*C28	balsam poplar/horsetail
*C32	Engelmann spruce/horsetail/feathermoss
C33	Engelmann spruce/hairy wild rye
C36	lodgepole pine-white spruce/willow/hairy wild rye
C37	white spruce/buffaloberry/feathermoss
Open Forest Vegetation Types	
O3	white spruce/shrubby cinquefoil/bearberry
O5	Douglas fir/juniper/bearberry
*O6	Engelmann spruce-subalpine fir/willow/ribbed bog moss
O11	spruce/labrador tea/brown moss
*O18	Engelmann spruce-subalpine fir/willow/hairy wild rye
Shrub Vegetation Types	
*S1	dwarf birch-shrubby cinquefoil-willow/brown moss
S7	willow/horsetail
S10	willow-dwarf birch-shrubby cinquefoil
S11	willow/timber oatgrass
S12	willow/hairy wild rye
Herb-Dwarf Shrub Vegetation Types	
*H2	black alpine sedge-everlasting
*H5	hairy wild rye-wild strawberry-fireweed
H6	junegrass-pasture sage-wild blue flax
*H7	wheatgrass-pasture sage
H9	mountain marigold-globeflower
*H11	water sedge-beaked sedge
H13	Richardson needlegrass-junegrass-everlasting
*H14	hairy wild rye-junegrass-bearberry
H15	mountain avens-curly sedge
*H19	bluebunch wheatgrass-hairy wild rye-showy aster
Low Herb-Shrub Types	
L1	shrubby cinquefoil/bearberry-northern bedstraw

*at least 50% cover

Table 12. Ecosites for which vegetation types with at least 20% cover for grass and grass-like species are dominant or codominant.

AL1	lodgepole pine forest (C19)
AT1	lodgepole pine forest (C3, C6, C19)
AZ1	Dry 70%:
	Engelmann spruce-subalpine fir open forest (O10)
	Wet 30%:
	wet shrub thicket (S8)
	wet herb meadow (H9)
BK1	Dry 70%:
	lodgepole pine forest (C18, C19)
	Wet 30%:
	wet spruce open forest (O11)
	wet shrubby meadow (S1)
	birch fen (S3)
BK4	Dry 70%:
	lodgepole pine forest (C18, C19)
	Wet 30%:
	wet spruce open forest (O11)
	wet shrubby meadow (S1)
	birch fen (S3)
BK6	Dry 70%:
	Engelmann spruce-subalpine fir forest (C13)
	Wet 30%:
	wet spruce open forest (O11)
	wet shrubby meadow (S1)
	birch fen (S3)
BV1	lodgepole pine forest (C9, C18, C19)
CA1	Dry 70%:
	Engelmann spruce-subalpine fir forest (C14,C13,C21)
	Wet 30%:
	wet spruce open forest (O11)
	wet Engelmann spruce-subalpine fir open forest (O14)
	wet shrubby meadow (S1)
	birch fen (S3)
CA4	lodgepole pine fores C20)
CN1	dry shrub thicket (S
	moist shrub thicket
CV1	Wet 80%:
	wet spruce open forest 11)
	wet Engelmann spruce-subalpine fir open forest (O14)
	>wet shrubby meadow (S1)
	birch fen (S3)
	Dry 20%:
	Engelmann spruce-subalpine forest (C13)
	lodgepole pine forest (C20, C29)
FR1	lodgepole pine forest (C6, C19)
GA1	lodgepole pine forest (C3, C6, C19)

(Cont.)

Table 12. (Continued)

GT2	Northerly:
	lodgepole pine forest (C6, C19)
	Southerly:
	dry grassland (H14)
	low shrub-herb meadow (L1)
HC1	moist Engelmann spruce forest (C32)
	wet Engelmann spruce-supalpine fir open forest (O6)
	>wet shrubby meadow (S1)
	birch fen (S3)
HC2	sedge fen (H11)
HC4	wet shrubby meadow (S1)
	birch fen (S3)
	wet shrub thicket (S11)
	sedge fen (H11)
HD1	aspen forest (C16)
HD2	spruce open forest (O3)
HD3	white spruce forest (C2, C26, C27)
	white spruce-Douglas fir forest (C5)
HD4	grassland (H6)
	>lodgepole pine forest (C3)
IB1	lodgepole pine forest (C18, C19, C29)
MC1	Wet 80%:
	spruce open forest (O11)
	birch fen (S3)
	Dry 20%:
	lodgepole pine forest (C29)
	Engelmann spruce-subalpine fir forest (C30)
ML2	lodgepole pine forest (C18, C20)
NT2	wet shrub thicket (S8)
	moist shrub thicket (S4, S11)
NT3	wet herb meadow (H9)
	cottongrass fen (H10)
	sedge fen (H11)
NY1	lodgepole pine forest (C6)
	Douglas fir forest (C1)
NY3	Northerly:
	white spruce-Douglas fir forest (C5)
	lodgepole pine forest (C19)
	Southerly:
	Douglas fir open and closed forest (O5, C1)
	low shrub-herb meadow (L1)
PL5	Dry 70%:
	Engelmann spruce-subalpine fir closed and open forest (C15, O10)
	subalpine larch-subalpine fir forest (C23)
	Wet 30%:
	wet shrub thicket (S8, S11)
PP1	lodgepole pine forest (C19, C3, C6)

(Cont.)

Table 12. (Continued)

PP6	Engelmann spruce-subalpine fir open forest (O18)
	white spruce open forest (O17)
PP7	shrubby meadow (S9)
	shrub thicket (S10)
PR2	lodgepole pine forest (C6, C18, C19)
PR3	lodgepole pine forest (C18, C19)
PR4	Northerly:
	Engelmann spruce-subalpine fir forest (C13, C14)
	Southerly:
	lodgepole pine forest (C3, C6, C19)
PR6	lodgepole pine forest (C11, C18, C19, C29)
PT1	lodgepole pine forest (C6, C19)
PT3	lodgepole pine forest (C3, C6, C19)
PT5	Dry 60%:
	lodgepole pine forest (C6, C11, C19)
	Wet 40%:
	black spruce-lodgepole pine forest (C8)
	spruce open forest (O11)
SB3	lodgepole pine forest (C3, C6, C19)
SB5	grassland (H14)
SP1	lodgepole pine forest (C18, C19)
TA3	white spruce forest (C2, C26, C27)
TR1	dry shrub thicket (S10)
	moist shrub thicket (S12)
	Engelmann spruce-subalpine fir open forest (O18)
TR2	grassy tundra (H4)
	dry grassland (H14)
VD2	lodgepole pine forest (C19, C20)
VL1	sedge fen (H11)
	>wet shrubby meadow (S1)
	wet shrub thicket (S7)
VL3	wet white spruce forest (C4)
	>shrubby meadow (S1)
	wet shrub thicket (S7)
VL4	wet white spruce forest (C4)
VL5	wet shrub thickey (S7)
WF4	Engelmann spruce forest (C33)
WF7	grassland (H14)
	shrub thicket (S10)
	grassy tundra (H4)

Ecosites would pro   only minimal amounts of forage, and would   used by bison largely a cover and travel r   at. Primary bison forage habitat would be provided by the grassland and sedge fen Ecosite and portions of Ecosites. Therefore, the second stage of the Ecosite identification process was conducted to identify these Ecosites. Nine vegetation types that are grasslands and sedge fens were identified (H2, H5, H6, H7, H11, H13, H14, H15, H19), however, only three of these vegetation types (H6, H11, H14) occupied major portions of Ecosites. Ecosite selection based on these three vegetation types identified nine Ecosites capable of providing *primary* bison forage habitat (Table 13).

There are however, constraints found with each of these nine Ecosites that must be recognized and, as previously mentioned, could be evaluated by on-site study as required. For example, the sedge fens of the HC2, HC4, NT3, and VL1 Ecosites may be inaccessible during periods of high water and of limited winter use in the event of a high water freeze. The areal extent of some sedge fens in sedge fen +SC complex units may be limited since the SC area may have little or no vegetation cover, and may occupy 20 to 80% of a tract. As the HD4 grasslands are extremely restricted in area, and occur in heavily developed, high-use areas, their availability to bison is limited. The steepest slopes of the GT2 (South), SB5, TR2, and WF7 grassland Ecosites, that range to 42° (*i.e.* 90%), may not be fully utilized by bison even though bison are known to forage on slopes up to 40°(*i.e.* 84%). The forage value of the mixed sedge fen Ecosites (HC4, NT3), would depend on the site-specific proportion and productivity of the sedge component, and the location of the Ecosite in relation to other bison forage habitat types. In addition, the shrub components of the HC4, VL1 and WF7 Ecosites, willows in particular, may provide suitable bison forage in the absence of adequate grasses and sedges. Finally, there is a seasonal element   d in Ecosite suitability, as some of the Ecosites would be inaccessible to bison in winter.

For a free-ranging bison herd, the critical forage habitat component would be the presence of suitable winter range. Winter snow depth would generally confine bison to the Lower Subalpine and Montane in the winter. For the purpose of identifying possible winter range, Ecosites with maximum snow depths of less than one meter were deemed to be

Table 13. Matrix of open grassland and sedge fen vegetation types and corresponding Ecosites showing Ecosites with suitable winter snow depths.

Ecosite	Vegetation Type H6	H11	H14	Suitable Winter Snow Depth
GT2			X	X
HC2		X		X
HC4		X		X
HD4	X			X
NT3		X		
SB5			X	X
TR2			X	
VL1		X		X
WF7			X	

suitable. Of the nine *primary* forage habitat Ecosites, six have suitable snow depth characteristics for wintering bison (Table 13). It must be recognized that this Ecosite selection by snow depth only provides a rough guideline to identifying winter range. Subject to local crusting conditions, or in combination with severe winter weather or increased snow density, one meter of snow could be excessive for foraging and traveling bison.

Based on the distribution of these six Ecosites in Banff National Park, and considering the existence of other marginal habitat and the degree of present winter use by elk, three areas were identified to be suitable for wintering bison (Figure 10). The sedge fen-stream channel complex (VL1+SC) and grassy slopes (NY3) of the lower Howse and North Saskatchewan Rivers could provide adequate winter habitat for a small number of bison. Historical reports record bison wintering in the Howse valley as far west as "Kootenay Park" at Glacier River. The number of bison that the area could support depends upon the productivity and areal extent of sedge cover on the river flats. This would have to be determined by field survey. Suitable bison winter range also exists in the lower Red Deer River valley. The grassy slopes (GT2, SB5) combined with sedge fens and grasslands scattered in the open spruce forest (HC1) and shrub meadows (HC4, PP7), could provide bison forage. Although snow depths are greater here, they are not excessive, as elk winter successfully in the valley. Given favorable snow conditions, additional habitat would be provided by the shrubland portions of the BK4, BK6, and PP6 Ecosites of the valley bottom. The third possible winter range identified is the Bow River valley below Castle Mountain. Grassland and grassy slopes (HD4, NY3, SB5) and the sedge fens (VL1) and shrublands (HC4, VL1, VL5) of the Bow River floodplain would provide the major bison forage habitat. The grassland openings of the aspen forests (HC1) and shrubland component of the VL3 Ecosite would also be important. These three areas provide the largest continuous areas of suitable winter habitat. However, other areas such as the middle Cascade watershed and the Panther and Dormer River valleys could provide additional winter bison range.

All three of these valleys have been identified as historical bison range. However, it is not clear whether they were used in winter by cow-calf groups or only by bulls. Favorable

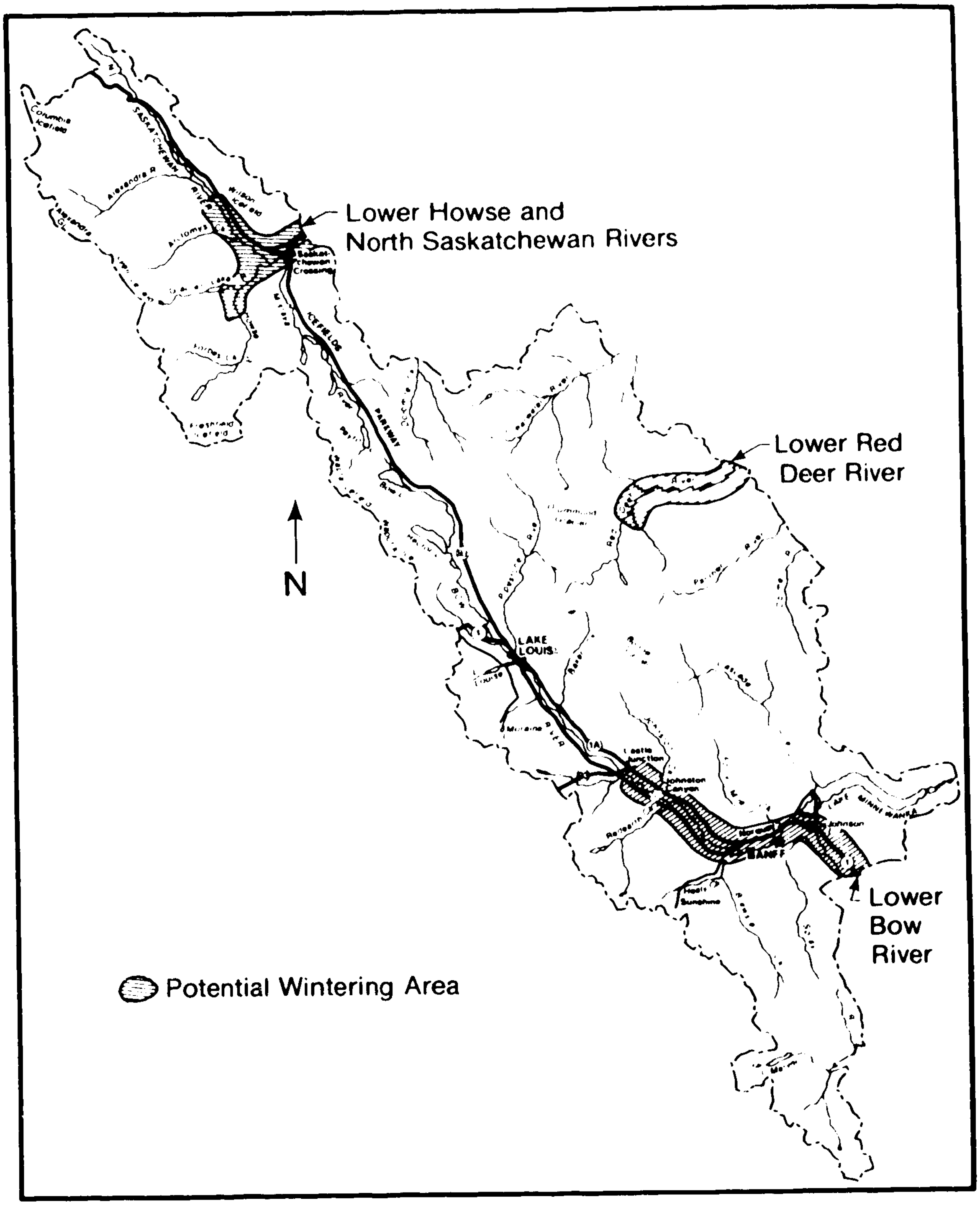


Figure 10. Location of potential wintering areas for free-ranging bison in Banff National Park.

winter habitat lies in the foothills outside each of these valleys, and a free-ranging bison herd would likely expand its winter range to include these areas. As discussed in Section 7.3.1, this range expansion outside the park would require that several issues of concern be addressed. The land which lies outside the park on the Red Deer River is somewhat of a special case, as it is federally controlled. Government horses for use in the local national parks are raised on the Ya Ha Tinda Ranch. Habitat here is suitable for bison, however, the ranch is already used by wintering horses and elk. The presence of free-ranging bison in the Bow or North Saskatchewan River valleys could present conflicts with present visitor use. It is also in these two valleys that bison could be involved in bison-vehicle collisions and opportunities for aggressive encounters with visitors would be most frequent.

As the ELC is not site-specific, the level of information and accuracy provided is obviously lower than that which could be achieved with an in-depth field habitat study. However, this interpretation of ELC data provides the background information required for the general review of alternatives, and provides a framework for preliminary evaluation of bison habitat that can be used by resource managers. Field studies could later be conducted on the most promising sites to provide site-specific information on plant species composition, site-productivity, and associated carrying capacity estimates, local snow conditions and their influence on seasonal forage availability, and the predicted degree of interspecific competition and conflicts with present land use as dictated by expected bison use patterns.

8.2 Paddock Relocation Site Selection and On-site Reconnaissance

To determine the feasibility of the fifth alternative, relocation of the Buffalo Paddock, a number of possible paddock sites were identified and described. The purpose of this exercise was not to select the best relocation site, but rather to provide background information for the review of alternatives regarding the nature of suitable sites available. Ten areas were identified as possible relocation sites (Table 14, Figure 11) and initial on-site reconnaissances were conducted as described in Section 5.2.2.

Table 14. Possible paddock relocation sites.

Carrot Creek
Cascade Pits
Hillsdale Meadows
*Indian Grounds
Johnson Lake
*Lower Bankhead
*Muleshoe
*Old Dump Site on Two Jack Road
*Second Vermilion Lake
*Upper Bankhead

*Eliminated after initial reconnaissance.

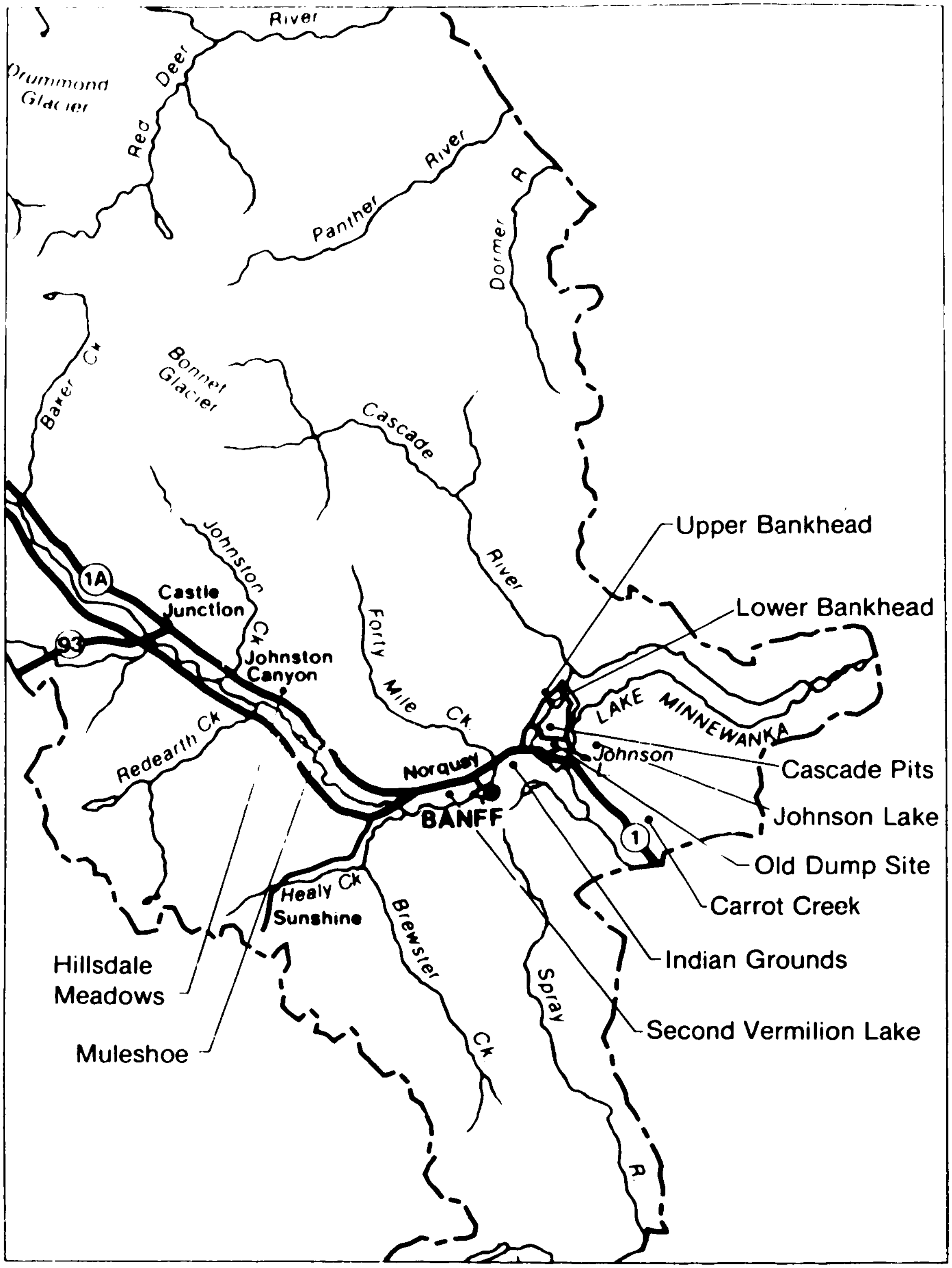


Figure 11. Location of possible paddock relocation sites in Banff National Park.

All ten locations could meet the forage and cover requirements of bison with varying degrees of site rehabilitation, clearing, thinning, and supplemental feeding. Improved water sources would be necessary for some of the sites, but installation is feasible in al However, initial reconnaissance revealed that not all of the sites would fulfill the primary advantages of the relocation alternative, namely, eliminating the barrier to wildlife movement in the congested Banff Townsite area and providing a facility for visitors to view bison in a natural setting. Six sites were therefore eliminated as outlined below.

The historical coal mining sites of Upper and Lower Bankhead contain old building foundations, slag heaps, equipment, and interpretive exhibits. These physical structures and the present visitor use of the sites would be incompatible with bison viewing and interpretation. Therefore, the sites were eliminated from further consideration.

The Old Dump Site on Two Jack Road is the level, reclaimed surface of a garbage dump, intersected by the road. The area has obviously been mechanically cleared and has abrupt forest edges on all sides. The site is situated on a hillside with moderately steep forested slopes above and below. The downhill slope of the covered dump is extremely steep. These factors combine to limit the area available for paddock construction to the presently rehabilitated area. This would allow only a small paddock and present an artificial environment which would at best be a display-type paddock. As this would not provide a quality bison viewing experience, this site was eliminated

The construction of a paddock on the Indian Grounds would impact present wildlife use and create a barrier to wildlife movement. The area is small and relatively open and the fence would be highly visible, presenting a less natural setting for bison viewing. As this site makes no improvement in wildlife movement in the Banff Townsite area and does not provide as good a viewing opportunity as the present Buffalo Paddock, the site was eliminated.

The Muleshoe and Second Vermilion Lake sites include aspen forest and wet meadow habitat. The Muleshoe site is intersected or bordered by the Bow Valley Parkway, the Canadian Pacific Railway, and a power line right-of-way, and includes a picnic area. The Second Vermilion Lake site is intersected by the Vermilion Lakes Road which receives considerable pedestrian and cyclist traffic and lies between Second Vermilion Lake and the ...way. The wetland areas of both sites are subject to flooding, further ...n and construction of necessary facilities. The configuration of the ...and present development would make it impossible to design a paddocks ...ow visitors to view bison in a natural setting. Conflicts with other visitor uses would also arise. Therefore, these sites were eliminated.

A second reconnaissance was then conducted on the remaining four sites; the Carrot Creek, Cascade Pits, Hillsdale Meadows, and Johnson Lake sites[44]. For each site, the ability of the site to meet bison requirements, the degree of environmental compatibility expected with the introduction of a paddock, the way the site addressed visitor use concerns, and the cost effectiveness of the relocation were described. The general configuration of the four sites is described below and summary descriptions are provided in Tables 15 through 18.

The Carrot Creek site is located 14 km east of Banff on the Trans-Canada Highway. It is based on 75 ha of aspen forest (HD1) surrounding a recently abandoned trade waste pit. Lodgepole pine forest (PT1 and AT1) surrounds the core on the east, west and north sides and the Trans-Canada Highway forms the south boundary. Carrot Creek flows through the site. A summary description of this site is presented in Table 15.

The Cascade Pits site is located along the Two Jack Lake Road, five km east and north of Banff. The site is based upon a 10 ha abandoned gravel pit. The Cascade River flows through open spruce forest (HD2) to the north and west of the site. The site is bounded by an aspen forest (HD1) covered slope and the Minnewanka/Two Jack Lake Road to the west, a lodgepole pine-white spruce (NY3, AT1) covered slope to the east, and the Two Jack Lake Road to the south. A summary description of this site is presented in Table 16.

The Hillsdale Meadows site is located in the mouth of a small valley 18 km west of Banff along the Bow Valley Parkway (1A Highway). A 25 ha grassland (HD4) forms the

[44]The Johnson Lake and Hillsdale Meadows sites, and the present Buffalo Paddock were reviewed with Mr. H. Reynolds of the Canadian Wildlife Service (Edmonton, Alberta).

Table 15. Summary for second-round reconnaissance of Carrot Creek paddock relocation site.

Location of Site: Carrot Creek

1. Bison Requirements
  a) Forage medium; aspen forest with some open meadows beginning to infill with white spruce, lodgepole pine forest with little forage, some clearing/thinning required; open meadow following revegetation of old trade waste pit; likely will have to provide supplemental feed
  b) Cover high; aspen forest; some lodgepole pine forest along edge of site could be included
  c) Water high; Carrot Creek along the NW side of site could be included in paddock

2. Environmental Compatibility
  a) Wildlife medium; would eliminate moderate present use by ungulates; would be a barrier to local movement
  b) Vegetation/Soil medium; portions previously disturbed; clearing/thinning required for habitat and visibility; few problems with construction or erosion forseen; fence construction will impact creek
  c) Visual/Aesthetic high; not visible from TCH

3. Visitor Use
  a) Compatibility with Present/Planned Use low; Carrot Creek hiking/skiing trail passes through site; possible future site of Visitor Centre
  b) Predicted Visibility of Bison medium; periodic thinning of cover required
  c) Aesthetic Quality of Setting high; will provide a natural environment for bison viewing; design should seek to lessen visual impact of power line right-of-way
  d) Access low; approximately 14 km from Banff; not on regular scenic tour route

4. Cost Effectiveness
  a) Construction high; fencing, road, handling facilities, feed storage, interpretation, clearing/thinning, revegetation, special fencing needs to include creek for water source, reroute Carrot Creek trail
  b) Maintenance medium; distance from Banff increases cost; facility maintenance, supplemental feeding, periodic thinning

---

Table 16. Summary for second-round reconnaissance of Cascade Pits paddock relocation site.

Location of Site: Cascade Pits

1. Bison Requirements

a) Forage medium; former gravel pit presently being revegetated so forage depends upon success and on species planted; white spruce forest with little forage; supplemental feed until vegetation established and likely after

b) Cover low; white spruce forest surrounding site, but difficult to design so bison are not separated from escape cover by road; revegetation should include establishing some cover in centre of site

c) Water high; Cascade River along N edge of site could be included in paddock; pond in center of site but winter reliability unknown; ice may have to be broken for bison

2. Environmental Compatibility

a) Wildlife medium; would eliminate use by other ungulates which would occur after revegetation; would present partial barrier to movement up and down Cascade River

b) Vegetation/Soil high; site previously disturbed; some recontouring may be required to maintain good visibility if Cascade River is included in paddock; few problems with construction or erosion forseen if revegetation successful; fence construction will impact river

c) Visual/Aesthetic low; visible from Two Jack Lake Road

3. Visitor Use

a) Compatibility with Present/Planned Use high; no present use except picnic area across the road; would eliminate opportunity for viewing other wildlife which would use area after revegetation

b) Predicted Visibility of Bison high; however there would be conflict between providing sufficient cover and secure access to water and providing good visibility

c) Aesthetic Quality of Setting low; lack of natural cover would lessen aesthetic appeal of site; fences visible

d) Access high; approximately 5 km from Banff; on regular scenic tour route

4. Cost Effectiveness

a) Construction medium; fencing, road, handling facilities, feed storage, interpretation, revegetation including establishment of cover: some recontouring and special fencing needs if include river for water source

b) Maintenance high; facility maintenance, supplemental feeding

---

basis of the site along with 40 ha of aspen forest (HD1) to the southeast and some lodgepole pine forest on the valley floor (FR1, GA1, PT1). The site is bounded by lodgepole pine covered slopes to the northwest (GA1) and northeast (PT1) and the Bow Valley Parkway along the southwest side. An intermittent stream flows through the site. A summary description of this site is presented in Table 17.

The Johnson Lake site encompasses an area northeast of Johnson Lake, which is located 10 km east and north of Banff, off the Two Jack Lake Road. The site is based upon 40 ha of aspen forest (HD1) and 25 ha of sedge fen wet shrub meadow and open spruce forest habitat (PT5) located along a small creek which flows through the site. Lodgepole pine covered slopes rise gradually from the site on the north (PT5, NY1) and east (PT1, PT5) sides. The site is bounded by the access road to Johnson Lake on the west side and a lodgepole pine-Douglas fir covered ridge and Johnson Lake to the south. A summary description of this site is presented in Table 18.

Relative merit values were assigned for each variable and are indicated in the summary tables and illustrated in matrix form in Table 19. The matrix provides a systematic basis for comparing relocation sites. The best site could be identified by assigning number values to the merit rankings and weights to the various categories and/or variables within categories. The end result of such an exercise is dependent upon the weighting factors chosen. As these factors reflect management priorities, policy objectives, cost constraints, and resource (physical and manpower) limitations, this exercise was not carried out at this time. Rather, the brief description of the various sites and the relative merit matrix provide sufficient information for the review of alternatives in a form which could be later expanded if required. A subjective evaluation of Table 19 suggests that the present site is the best location for a paddock, particularly if the wildlife movement problem could be alleviated.

Table 17. Summary for second-round reconnaissance of Hillsdale Meadows paddock relocation site.

Location of Site: Hillsdale Meadows

1. Bison Requirements
  a) Forage high; productive natural grassland with moderate previous disturbance; aspen forest with few small meadows, logepole pine forest with little forage; supplemental feed may be required to maintain range quality
  b) Cover medium; aspen forest and lodgepole pine forest; design would have to insure bison are not isolated from escape cover by road
  c) Water low; small stream through site not reliable; ensured water source required

2. Environmental Compatibility
  a) Wildlife low; area is productive grassland and receives significant use by elk; would present a barrier to local movement and may decrease use of grasslands in immediate vicinity; may suffer predation by wolves
  b) Vegetation/Soil medium; limited thinning of forest cover may be required for visibility; few problems with construction or erosion forseen except for possibile wallowing on south-facing slopes along W side of site if included in paddock
  c) Visual/Aesthetic low; visible from Bow Valley Parkway

3. Visitor Use
  a) Compatibility with Present/Planned Use medium; hiking trail to Johnson Canyon passes through site; other ungulates can often be viewed in area; contains a range enclosure study plot
  b) Predicted Visibility of Bison high; periodic thinning of cover may be required
  c) Aesthetic Quality of Setting medium; will provide a natural environment for bison viewing however fence along Bow Valley Parkway will be visible
  d) Access medium; approximately 18 km from Banff; on regular scenic tour route

4. Cost Effectiveness
  a) Construction high; fencing, road, handling facilities, feed storage, interpretation, establish water source, some thinning, reroute trail
  b) Maintenance medium; distance from Banff increases costs; facility maintenance, supplemental feeding, periodic thinning

Table 18. Summary for second-round reconnaissance of Johnson Lake paddock relocation site.

Location of Site: Johnson Lake

1. Bison Requirements
 a) Forage low; wetland with sedge and shrub, water regime uncertain, some wetland areas appear to be drying up and as succession occurs will loose sedge component, problems with inaccessability during flooding or high water freeze; aspen, lodgepole pine, and white spruce forests with little forage, possible clearing required; supplemental feed would likely be required
 b) Cover high; aspen, lodgepole pine, and spruce forests
 c) Water high; small stream through site; winter reliability unknown but likely ok; ice may have to be broken for bison
2. Environmental Compatibility
 a) Wildlife medium; would eliminate moderate present use by ungulates; would create a barrier in combination with penstock and Two Jack Canal
 b) Vegetation/Soil low; disturbance of aspen forest and wetland areas with little previous impact; clearing and thinning of forest cover; continuing impact on water regime; fence and road construction in wetland areas
 c) Visual/Aesthetic medium; portion of facility visible from Johnson Lake Road

3. Visitor Use
 a) Compatibility with Present/Planned Use medium; hiking/skiing trail passes through site; would eliminate some trails and area associated with Johnson Lake day use area
 b) Predicted Visibility of Bison low; even with clearing and periodic thinning of forest cover, the configuration and varied topography of the site make good visibility unlikely
 c) Aesthetic Quality of Setting medium; will provide a natural environment for bison viewing however clearing and construction will visually impact site
 d) Access medium; approximately 10 km from Banff; on regular scenic tour route

4. Cost Effectiveness
 a) Construction low; fencing, road, handling facilities, feed storage, interpretation, clearing/thinning, reroute trail, special materials and design needed for construction in varied terrain/wetland a:
 b) Maintenance low; facil maintenance more expensive in varied terrain/wetland area, supplemental feeding, periodic thinning

---

Table 19. Matrix of relative merits for paddock relocation sites evaluated by second-round reconnaissance.

	Carrot Creek	Cascade Pits	Hillsd. Meadows	Johns. Lake	Present Paddock
Bison Requirements					
Forage	M	M	H	L	M
Cover	H	L	M	H	H
Water	H	H	L	H	H
Env. Compatibility					
Wildlife	M	M	L	M	L
Vegetation/Soil	M	H	M	L	H
Visual/Aesthetic	H	L	L	M	H
Visitor Use					
Use Compat.	L	H	M	M	H
Predicted Visib.	M	H	H	L	M
Setting Quality	H	L	M	M	H
Access	L	H	M	M	H
Cost Effectiveness					
Construction	H	M	H	L	H
Maintenance	M	H	M	L	H

*relative merit
L=low
M=medium
H=high

9. RESULTS IV. BUFFALO PADDOCK STUDY

9.1 Attributes of the Bison Viewing Opportunity

9.1.1 Bison observations conducted

During the 12 week study period, a total of 280 loops were conducted as specified by the schedule. Time for loop completion varied from 22 to 60 minutes with a mean loop time of 37.2 minutes (SD=6.82) (Table 20). Loop completion time depended primarily on the number and length of bison sightings conducted during the loop. Mean time for loops with no sightings was 32.6 minutes (SD=3.04, range 28 to 42 min.), compared to a mean loop time of 39.8 minutes (SD=6.99, range 22 to 60 min.) for loops with one or more sightings. In total, 10,390 minutes (173.2 hours) were spent conducting loops in the Buffalo Paddock over the study period.

Bison were observed on 64.3% of the 280 paddock loops conducted (95% CI 64.3±5.6). While only one sighting was recorded for most of the successful loops (156 loops or 86.7%), there were 22 loops (12.2%) with two sightings, and two loops (1.1%) with three sightings, for a total of 206 bison sightings. *Loop sighting success*, or the occurrence of one or more bison sightings on a loop, was found to be significantly related to *loop hour* (x^2=27.04 df=14 p<.05). The association was weak (Lambda=0.0900). However, as illustrated in Figure 12, the chance of sighting bison was generally greater in the morning hours. *Loop sighting success* was highest, 94.4%, at 0600 hours, and then decreased to 68.4% at 1200 hours (Figure 12). In the afternoon and evening *loop sighting success* was variable with the lowest chance of seeing bison occurring at 1600 and 1700 hours (42.1% loop sighting success). *Loop sighting success* was not significantly related to *observed sky conditions*, *observed precipitation conditions*, or to the *day of study* (p> .05).

The 206 bison sightings varied in length from two to ten minutes ($\bar{x}$=9.45 min., SD=1.67), with the target sighting length of ten minutes being achieved for 88.3% of all sightings. The average sighting time for the 180 *first sightings*, or those that occurred first

Table 20. Mean time for loop completion.

	Mean No. Minutes	Standard Deviation	Min.	Max.	Total Time Minutes\Hours
Loops with no sightings (n=100)	32.6	3.04	28	42	
Loops with 1,2,or3 sightings (n=180)	39.8	6.99	22	60	
All loops	37.2	6.82	22	60	10390\173.2

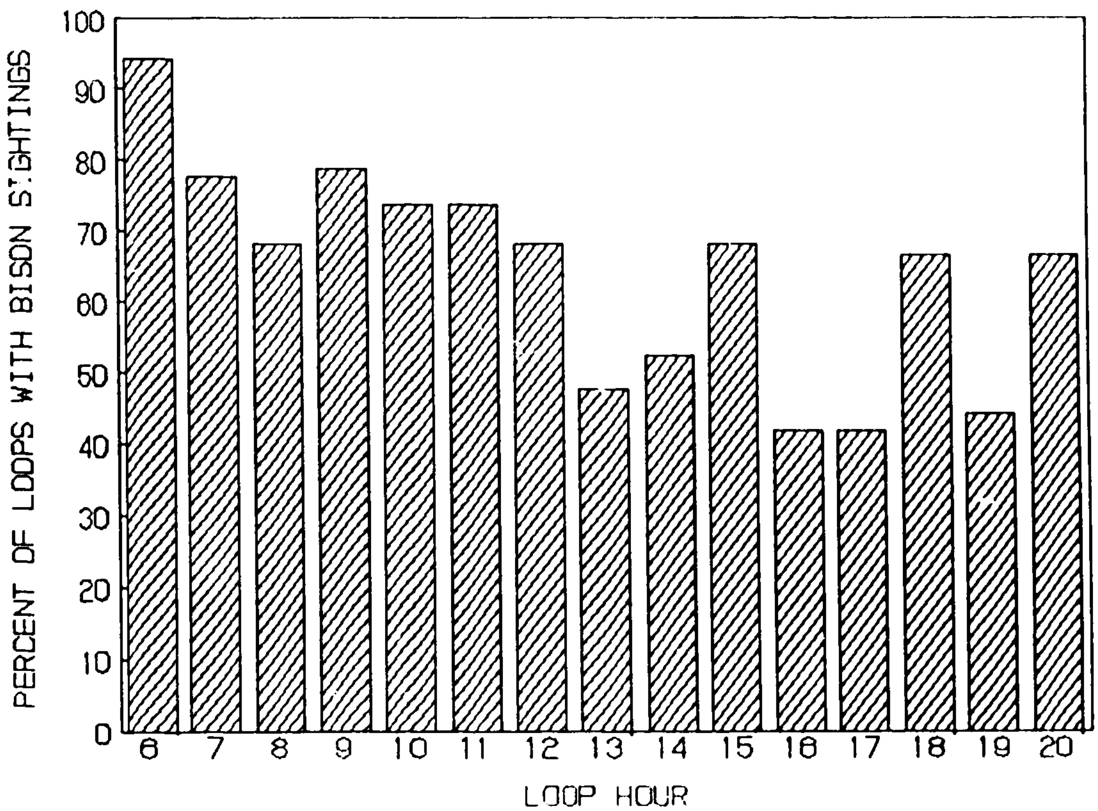


Figure 12. Sighting occurrence BY *loop hour*.

during successful loops, was slightly longer ($\bar{x}=9.52$ min., SD = 1.53, range 2 to 10 min.), with ten-minute sightings being achieved for 89.4% of all *first sightings*. In total 1946 minutes (34.4 hours) were spent observing bison, with 1713 of these minutes occurring on *first sightings*. The number of bison seen per *first sighting* varied from one to eight, with the sighting of six (23.9%) or seven (22.2%) animals being most common and 84.4% of all *first sightings* having four or more animals (Figure 13)[47].

9.1.2 Characteristics of bison sightings

During each sighting, bison observations were recorded by ***bison minute***; the observation of one bison for one minute. In this manner, observations were recorded for a total of 7457 ***bison minutes***. The view of the bison for each ***bison minute*** was described by recording four categorical variables indicating how far away the bison was, what percent of the bison was visible, what screening if any interfered with visibility, and what major activity of the bison was observed.

Bison were rarely (1.5% of ***bison minutes***) observed from a distance closer than 11 meters (Figure 14). The frequency of observations in the other distance categories decreased as distance increased, with observations at 11-50 meters being most common (44.4%), followed by the 51-100 meter category (32.9%), and the greater than 100 meters category (21.2%).

The views of bison were highly obstructed, with the animal observed being less than one-quarter visible in 51.1% of all ***bison minutes*** (Figure 15). The 25-49% visible category accounted for an additional 19.8%, for a total of 70.8% of all ***bison minutes*** spent observing less than one-half of a bison. Conversely then, bison were at least one-half visible for only 29.2% of all ***bison minutes***, with complete views accounting for 4.3%, three-quarter to 99% views accounting for 15.4%, and 50-74% views accounting for 9.4% of all ***bison minutes***.

---

[47]The number of bison in the Buffalo Paddock increased from five to eight over the study period. Two calves were born in May, and initial sightings occurred on days seven and thirteen. The adult male bison, which was absent from the paddock at the beginning of the study, returned on day 68.

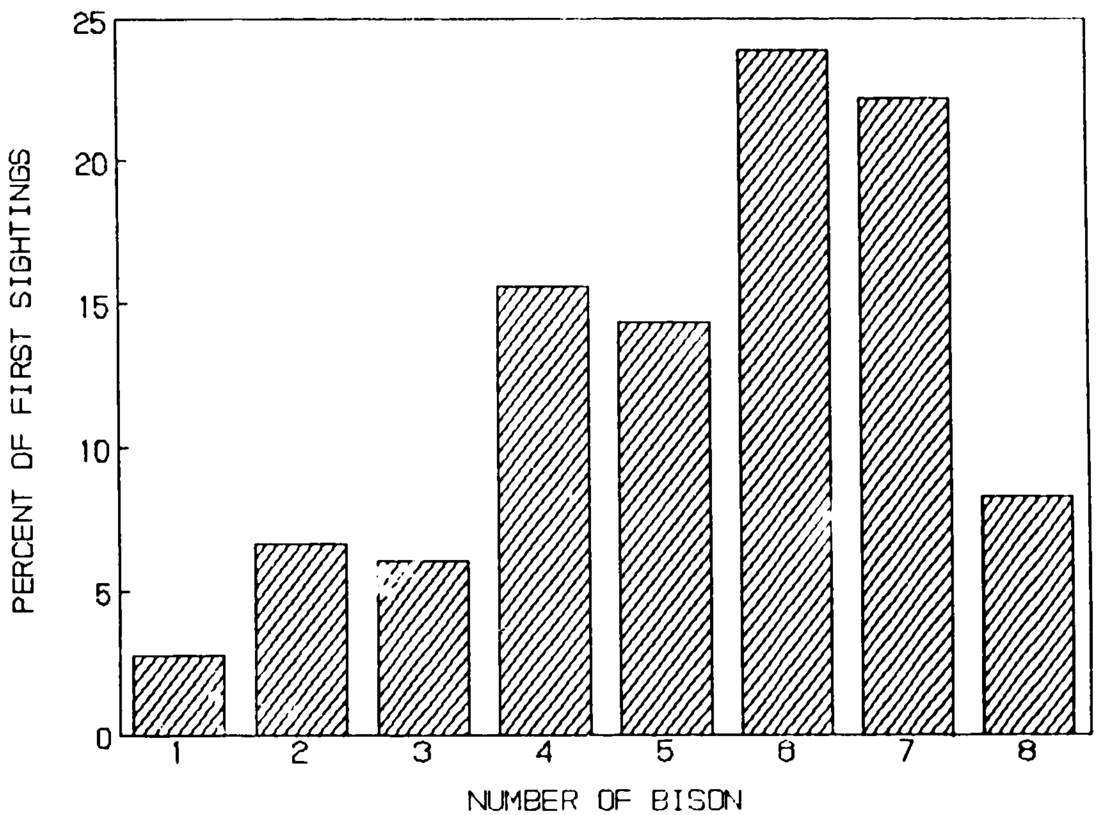


Figure 13. Number of bison observed per *first sighting*.

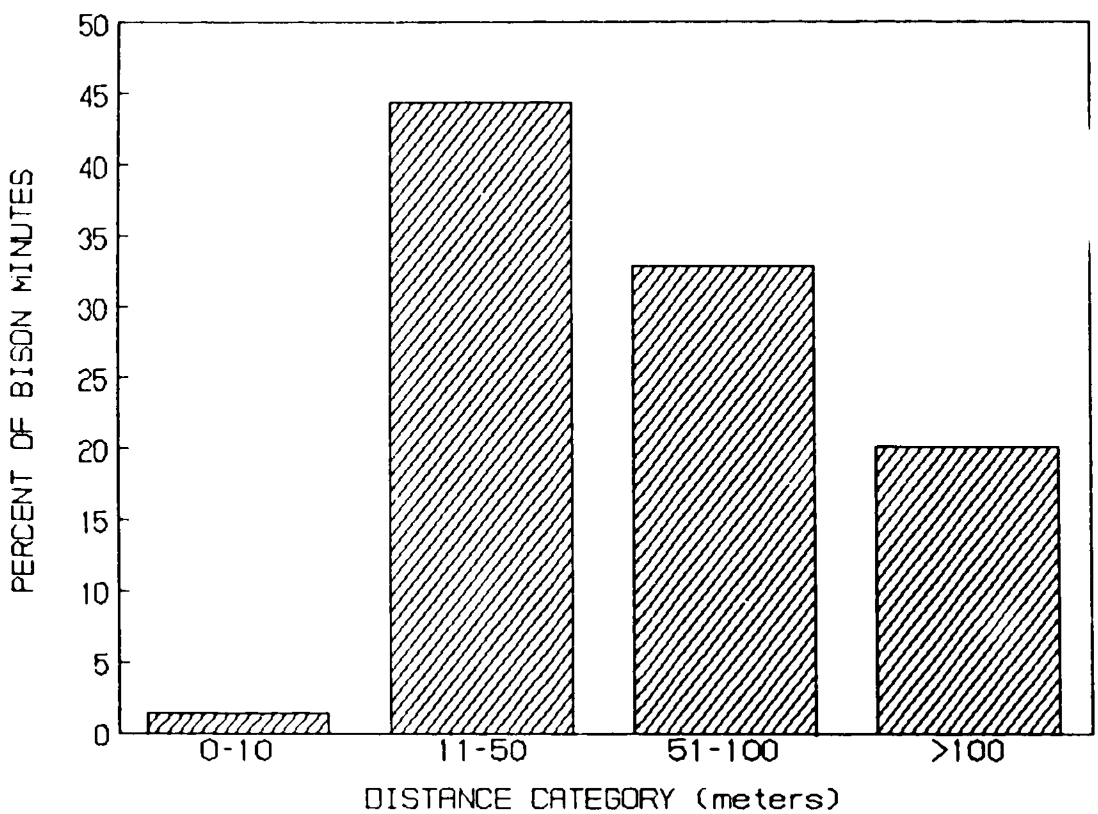


Figure 14. Percentage occurrence of *distance away* categories.

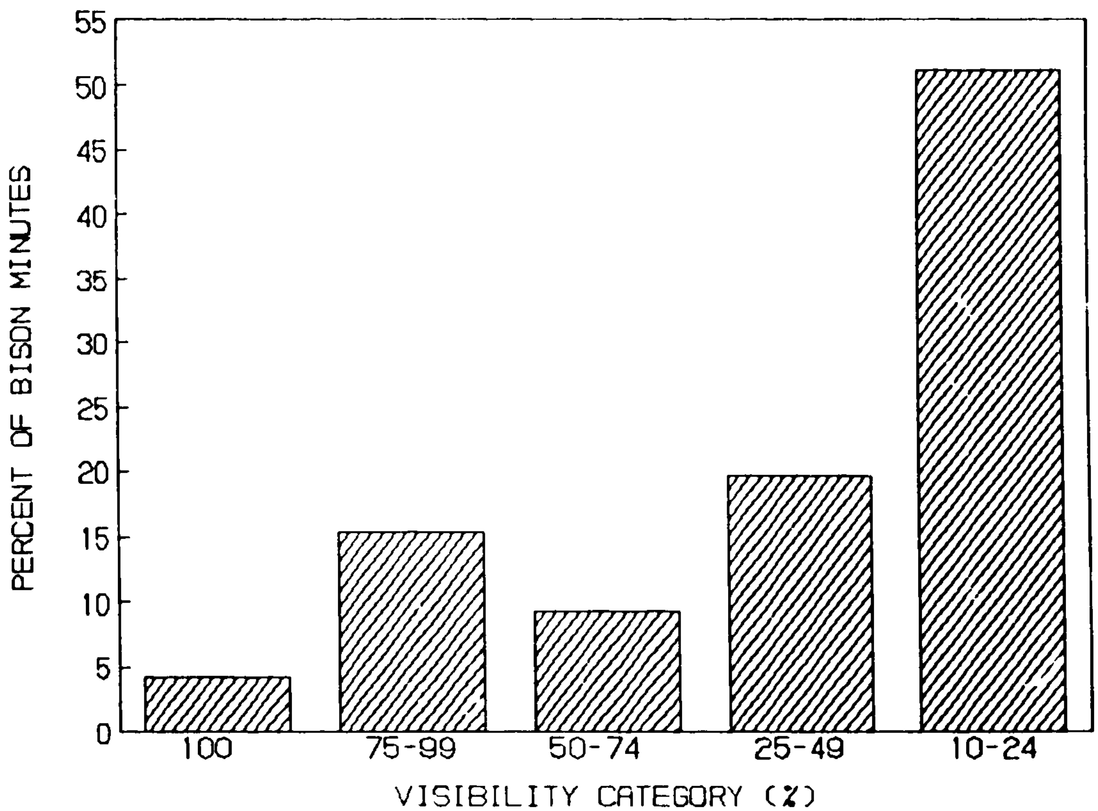


Figure 15. Percentage occurrence of *percent visible* categories.

The most common screening medium was vegetation. It was recorded as the only screening medium for 70.2% of all ***bison minutes*** and in combination with other screening mediums, namely topography (10.0%), bison (7.6%), and topography and bison (1.1%) for a further 18.7% of ***bison minutes***. The remaining screening was identified as bison (4.2%), topography (2.4%), and cars (0.4%). Summarizing the combined screening medium categories by dividing cases equally among the separate screening components yields summary percentages of 79.3% for vegetation, 8.3% for bison, and 7.7% for topography (Figure 16). Only 4.2% of the ***bison minutes*** were without screening of any kind.

Observed bison activities were recoded into seven major categories; ***feed, walk, run, stand, lay down, groom*** and ***unknown*** (due to poor visibility). The most common major activity category was ***lay down***, recorded for 35.9%, of all ***bison minutes*** followed closely by ***feed*** at 34.4% (Figure 17). Together these two categories accounted for 70.3% of observed bison activity. ***Stand*** and ***walk*** represented 16.7% and 9.9% of observed activity respectively and ***run, groom***, and ***unknown*** comprised the remaining 3.1%.

To further describe the bison viewing opportunity, the two ordinal bison observation variables, ***distance away*** and ***percent visible***, were examined using Kendall's tau-b (τ-b) rank correlation. The associations between ***distance away, percent visible, day of study, loop hour, observable sky condition***, and ***observable precipitation condition*** were explored. The correlation matrix is presented in Table 21. Significant τ-b coefficients ($p < .05$) were found for all variables tested with ***distance away*** and for all variables except ***loop hour*** tested with ***percent visible***. The strongest association was found between ***percent visible*** and ***distance away*** (τ-b= .22). The relationship was moderately positive with the percent of the animal screened increasing as ***distance away*** increased. ***Distance away*** and ***percent visible*** were very weakly associated with observable weather. As cloud cover increased, bison were observed further away (τ-b= .03), but were less screened (τ-b= -.02). As rain intensity increased, bison were observed closer (τ-b= -.03), but were more screened (τ-b= .04). These relationships cannot be directly interpreted as they are confounded by the relationship of observable weather to the ***day of study***, and they are a function of the physical characteristics

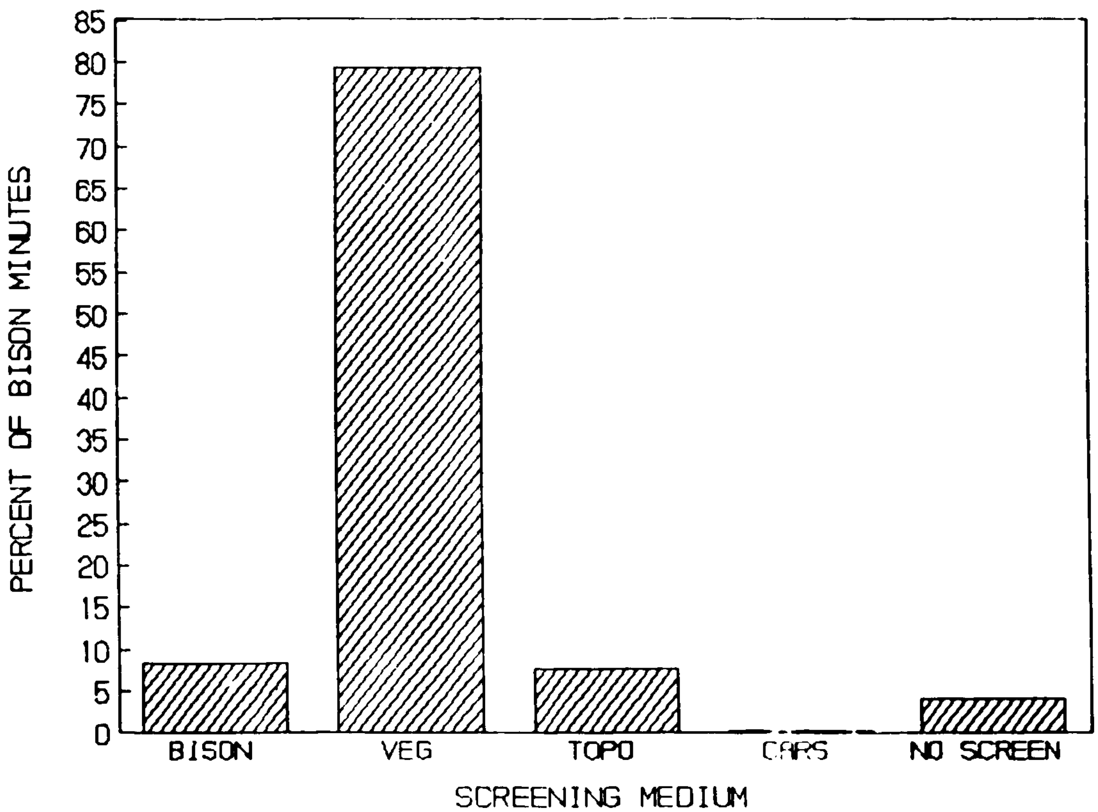


Figure 16. Percentage occurrence of screening mediums.

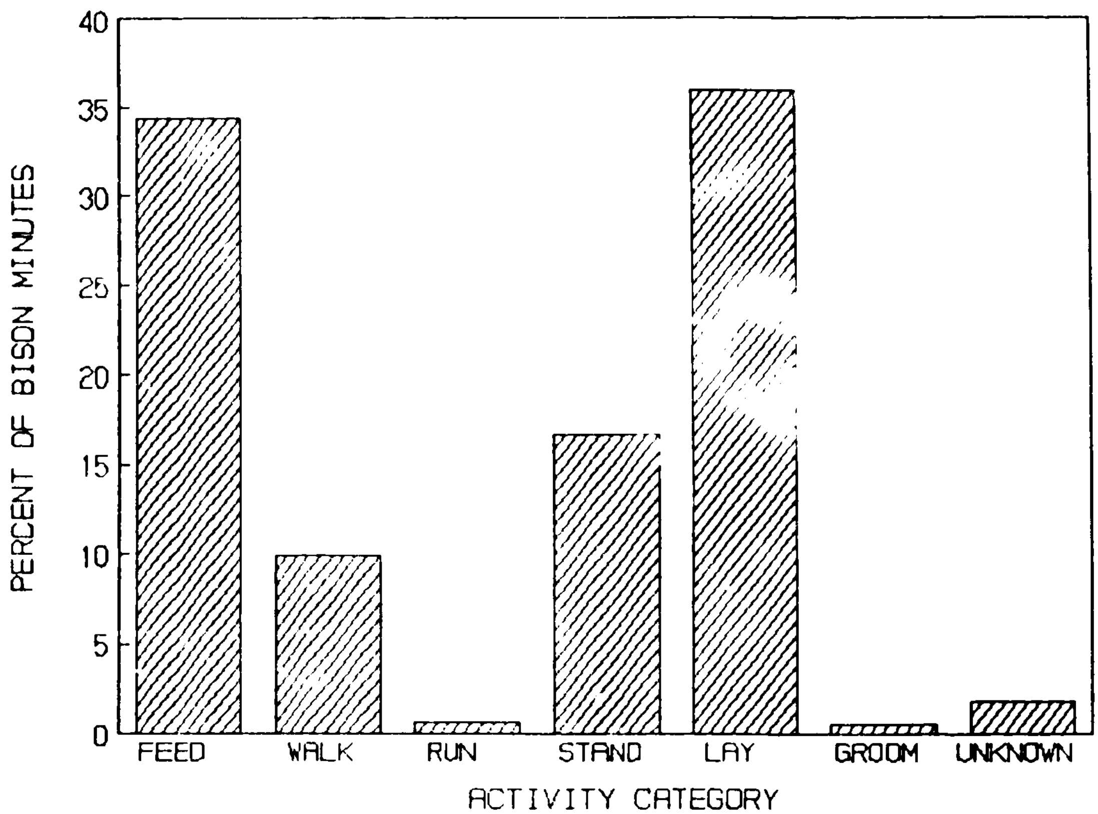


Figure 17. Percentage occurrence of major bison activities.

Table 21. Kendall's tau-b correlation matrix for bison observation variables *distance away* and *percent visible*.

	Loop Hour	Sky Condit.	Precip. Condit.	Distance Away	Percent Visible
Day of Study	.0321 (280)	.0718 (203)	.1008* (203)	-.1283* (7440)	-.0190* (7446)
Loop Hour		.0245 (203)	-.0213 (203)	.1652* (7440)	-.0032 (7446)
Sky Conditions			.4151* (202)	.0251* (7356)	-.0196* (7362)
Precip. Conditions				-.0319* (7347)	.0348* (7353)
Distance Away					.2240* (7430)

*Significant tau-b (p<.05)

Note: With increasing category values, the hour of the day gets later, sky gets cloudier, rain intensity increases, distance gets further away, and percent visibility decreases.

and location of the sites used by bison during different types of weather and the activities performed there. For example, during cool overcast weather, bison would feed in open meadows in the centre of the paddock resulting in further distances and less screening. During heavy rain, bison would bed down in an area of moderately heavy aspen close to the road, resulting in closer distances and more screening. ***Distance away*** and ***percent visible*** showed weak (τ-b = -.13) and very weak (τ-b = -.02) negative association with day of study, indicating closer observation distances and less screening as the study progressed. A weak positive association between ***distance away*** and ***loop hour*** (τ-b = .17) showed increasing observation distance throughout the day.

The overall trends of the relationships between ***distance away*** and ***loop hour*** and ***distance away*** and ***day of study*** are illustrated in Figures 18 and 19. The mean value of the ordinal ***distance away*** scale was calculated for each ***loop hour*** and for each ***week of the study*** and the relationship plotted. The ***distance scale average*** value is the least (bison are closest) at 0600 hours and gradually increases during the morning and early afternoon to a peak at 1600 and 1700 hours (Figure 18). The ***distance scale average*** then decreases again in the evening hours, but bison are still observed at a greater distance than in the morning hours. As illustrated in Figure 19, the ***distance scale average*** value increases from Week 1 to Week 2 and then gradually decreases to a minimum value in Week 9. The ***distance scale average*** then increases again over the last three weeks of the study.

9.2 Visitor Use of the Buffalo Paddock

9.2.1 Daily visitation

Daily visitation of the Buffalo Paddock was recorded as the number of vehicles that passed the paddock traffic counter between 0800 hours on that day and 0800 hours on the next day of the study. Traffic counter readings were adjusted daily to account for researcher entries and known non-visitor entries such as park warden, construction, and maintenance vehicles. For four periods when the traffic counter was not working properly, estimates of

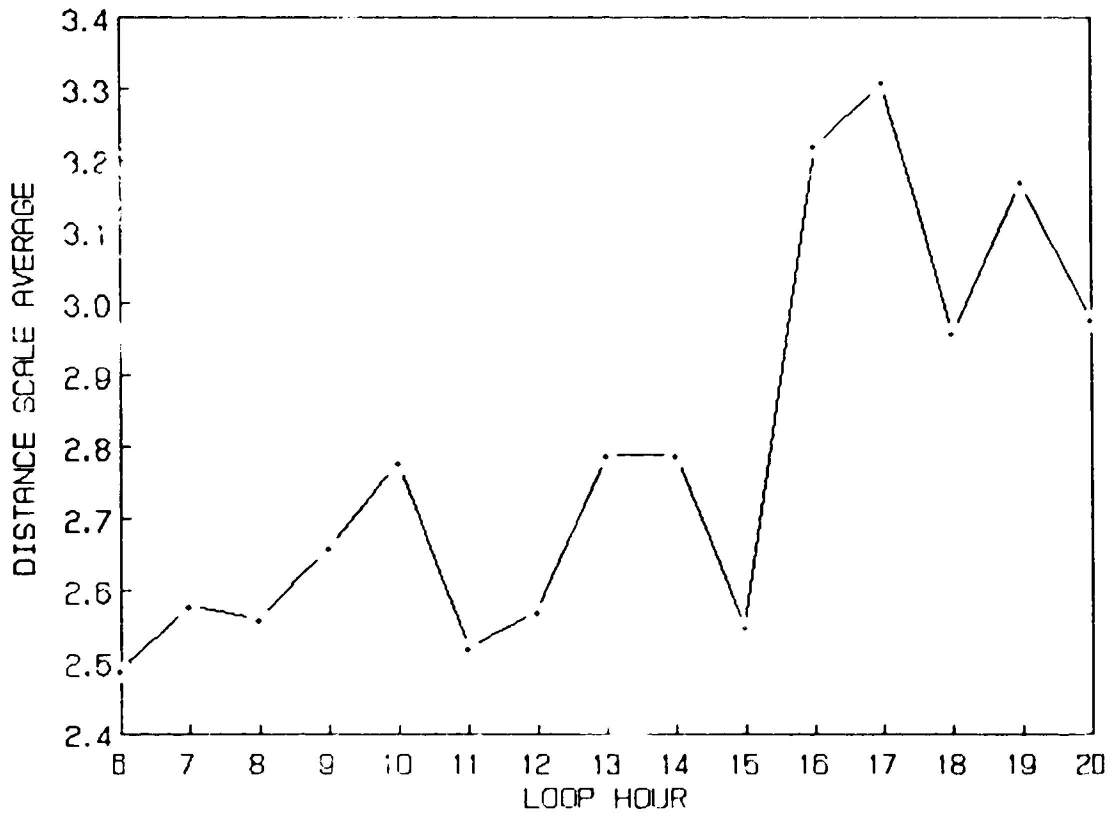


Figure 18. *Distance scale average* BY *loop hour.*

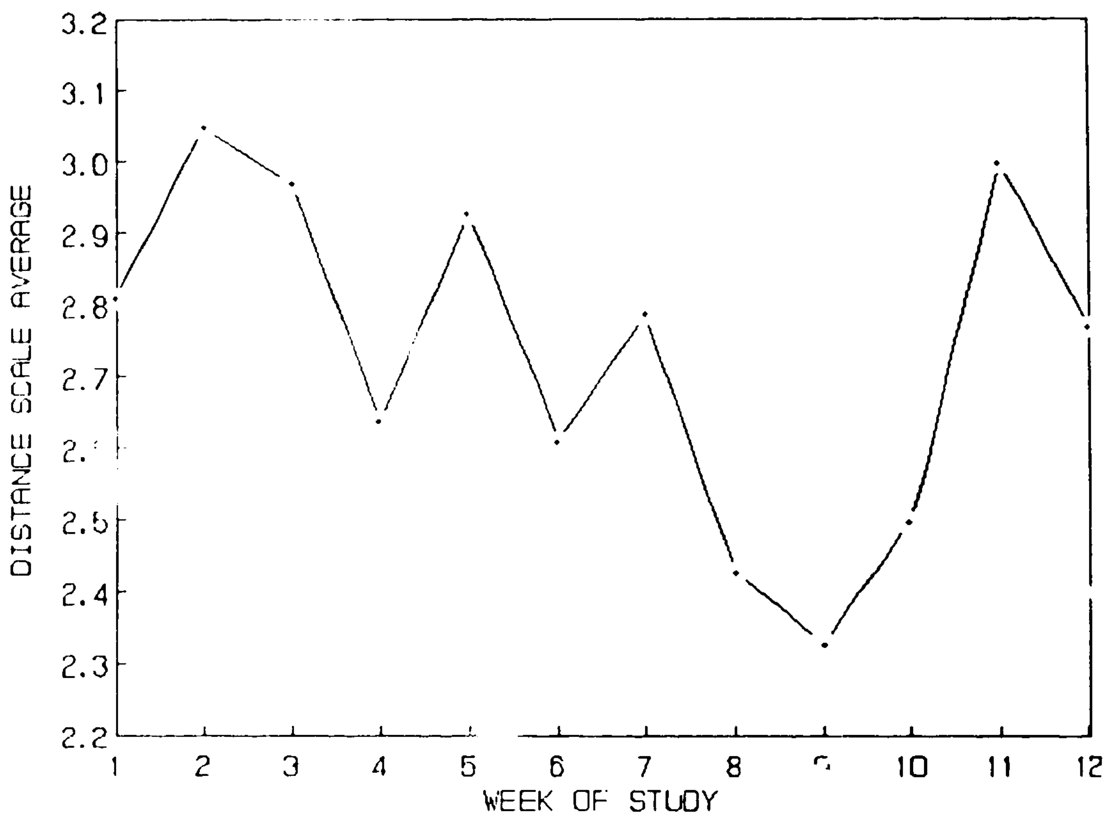


Figure 19. *Distance scale average BY week of study.*

visitor vehicle entries were made by averaging the visitor vehicle counts for the two identical time spans previous and the two following. Overall, the counter was 97% accurate when compared to visual counts. Differences can be attributed to factors such as extremely slow-moving vehicles pulling trailers being counted as two vehicles instead of one, bison or coyotes walking in front of the counter's electronic eye, and the occasional equipment malfunction.

Total visitation estimated in this manner was 25,767 visitor vehicles (Table 22). This total visitation included four days when the Buffalo Paddock was closed to visitor traffic for most of the day due to construction on the access road. Visitation on these days was only 2, 4, 5, and 50 vehicles. Including these days when the Buffalo Paddock was closed, the mean ***daily visitation*** was 306.8 visitor vehicles (SD = 140.22) with a minimum of 2 and a maximum of 525 visitor vehicles. If the four minimum values are excluded, the mean ***daily visitation*** is 321.3 (SD = 126.97) with a range from 72 to 525 visitor vehicles.

The relationships of ***daily visitation*** with ***day of study*** and with ***day of week*** were tested using Kendall's tau-b correlation and the Chi-square test of independence respectively. ***Daily visitation*** and ***day of study*** showed a significant ($p < .05$), moderately strong positive association (τ-b = .65) while ***daily visitation*** and ***day of week*** were not significantly related ($p > .05$). ***Daily visitation*** generally increased over the study period to a maximum of 525 vehicles on Day 57 (Wednesday, July 9), after which ***daily visitation*** declined and remained steady to the end of the study period (Figure 20). Two ***daily visitation*** peaks occurred in conjunction with the long weekends of May and August. The maximum ***daily visitation*** associated with these weekends occurred on Day 5, Sunday, May 18 (257 vehicles), and Day 82, Sunday, August 3 (520 vehicles).

9.2.2 Traffic observation periods conducted

During the study period, 256 traffic observation periods (TOPs) were conducted. TOPs lasted from two to 60 minutes, with a mean TOP length of 23.90 minutes (SD = 7.89). A total of 6118 minutes (102.0 hours) were spent observing traffic over the study period.

Table 22. Mean daily visitation recorded by traffic counter.

	Mean No. Vehicles Enter	Standard Deviation	Min.	Max.	Total Vehicles Enter
All days (n=84)	306.8	140.22	2	525	25767
Excluding days paddock closed (n=80)	321.3	126.97	72	525	---

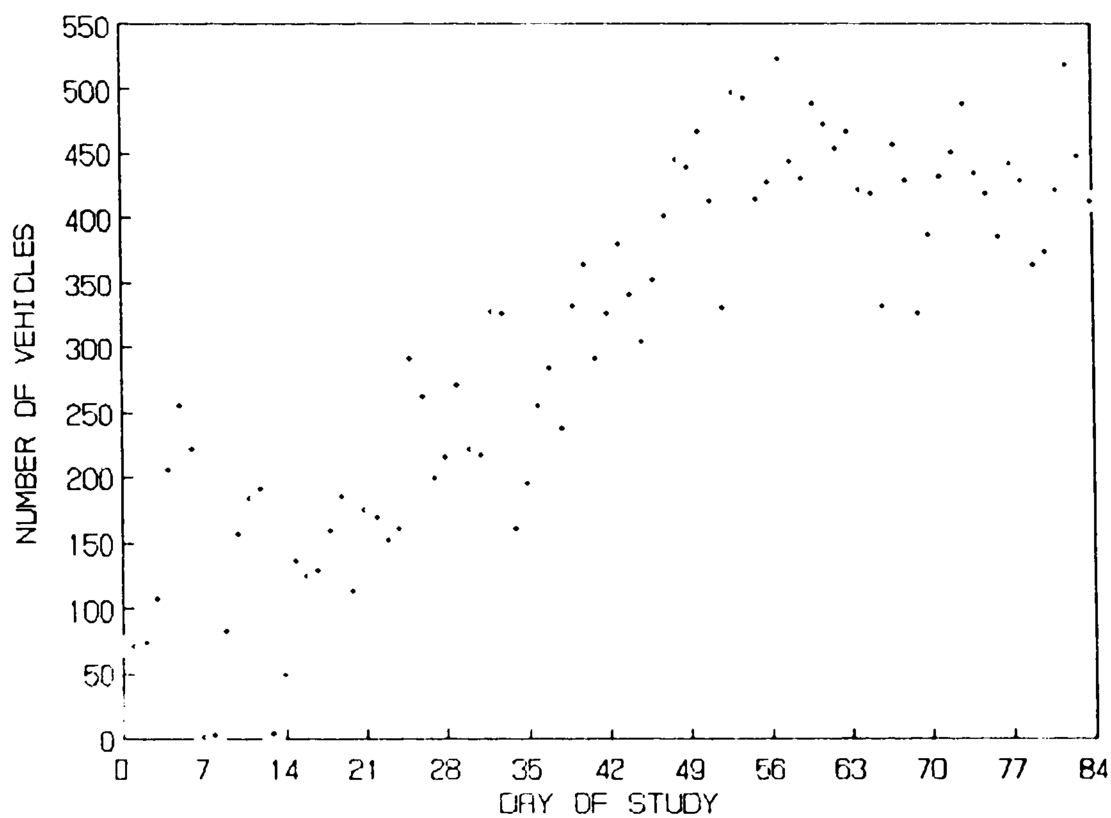


Figure 20. *Daily visitation* of the Buffalo Paddock.

The number of vehicle visits per traffic observation period varied from zero to 55 with a mean of 11.2 vehicle visits (SD=8.64)(Table 23). Total vehicle visits recorded during the traffic observation periods was 2866.

Of vehicles observed during traffic observation periods, 93.0% were classified as private vehicles with 14.8% of these specified as being rentals from Alberta or British Columbia (Table 24). The remaining seven percent was comprised of bus tours (6.1%), other tours (0.2%), and motorcycles, cyclists, and non-visitor vehicles (0.7%). For all buses recorded, 70.4% were identified as belonging to one of three tour companies: Brewster Transportation and Tours (29.1%), Greyhound (24.4%), and Pacific Western Transportation (16.9%).

Vehicle license plates were recorded for 2741 vehicles. Of those plates recorded, 55.9% were from Alberta (13.3% Alberta Rentals) and 11.4% from British Columbia (0.8% British Columbia Rentals)(Table 25, Figure 21). The remaining Canadian provinces and territories, with the exception of Prince Edward Island which was not represented, made up a further 11.0%, for a total of 78.3% Canadian (14.1% Canadian Rentals) license plates. Plates from the United States comprised another 21.0% with the most common states being California (4.4%), Washington (3.3%), Florida (1.1%), Oregon (1.0%), and Minnesota (0.9%). The remaining 0.7% of plates were from Europe and Mexico, as well as buses with multiple plates.

For each vehicle visit, time of entry, time of loop one, time of loop two (if applicable), and time of exit was recorded. The length of time for completion of the first loop was obtained for 1263 (44.1%) vehicles (Table 26). The mean completion time for the first observed loop was 8.7 minutes (SD=2.71), with a range from 4 to 33 minutes (Table 27). Of the remaining vehicles, 766 (26.7%) were only observed beginning the first loop, 788 (27.5%) vehicles were only observed ending the first loop, and 49 (1.7%) vehicles were observed entering the gate and exiting by driving around the island or backing out of the paddock before beginning the first loop. The length of time for completion of the second loop was obtained for 79 (2.8%) vehicles. The time for second loop completion ranged from

Table 23. Mean vehicle visits observed during traffic observation periods, loops, and sightings.

	Mean No. Vehicles Observed	Standard Deviation	Min.	Max.	Total Vehicles Observed
Traffic Obs. Periods (n=256)	11.2	8.64	0	55	2866
Loops (n=280)	9.5	7.61	0	34	2650
Sightings (n=206)	3.2	3.18	0	18	651
Stop	2.4	2.96	0	18	489
Not Stop	0.8	1.45	0	8	162

Table 24. Percentage occurrence of vehicle types during traffic observation periods, loops, and sightings.

Type of Vehicle Observed	Traffic Observation Period	Loop	Sighting
Private	93.0 14.8 Rental 85.2 Non-Rental 100.0	92.6	93.1 74.4 Stop 25.6 Not-Stop 100.0
Bus Tour	6.0 29.1 Brewster 24.4 Greyhound 16.9 PWT 29.7 Other 100.0	6.7 32.6 Brewster 20.2 Greyhound 11.2 PWT 36.0 Other 100.0	5.8 92.1 Stop 7.9 Not-Stop 100.0
Other Tour	0.2	0.2	0.3 50.0 Stop 50.0 Not-Stop 100.0
Motor-cycle	0.2	0.2	0.3 50.0 Stop 50.0 Not-Stop 100.0
Bicycle	0.3	0.2	0.3 0.0 Stop 100.0 Not-Stop 100.0
Non-Visitor	0.2	0.2	0.2 100.0 Stop 0.0 Not-Stop 100.0
Total	100.0 (n=2866)	100.0 (n=2650)	100.0 (n=652)

Table 25. Vehicle licence plates recorded during traffic observation periods

Province or State of Issue and Vehicle Type	% of Vehicles Observed
Alberta	
Private	38.1
Private Rental	13.3
Other	4.5
Total Alberta	55.9
British Columbia	
Private	9.8
Private Rental	0.8
Other	0.8
Total B.C.	11.4
Ontario	[illegible].5
Saskatchewan	3.4
Manitoba	2.1
Quebec	1.[illegible]
Northwest Territories	0.[illegible]
New Brunswick	0.[illegible]
Nova Scotia	0.1
Newfoundland	0.0
Yukon	0.0
Total Canada	78.3
California	4.4
Washington	3.3
Florida	1.1
Oregon	1.0
Minnesota	0.9
Other U.S.	10.3
Total U.S.	21.0
Other (Mexico, Europe, Multiple Plates e.g. buses)	0.7
Total Recorded	10[illegible] (n=2[illegible])

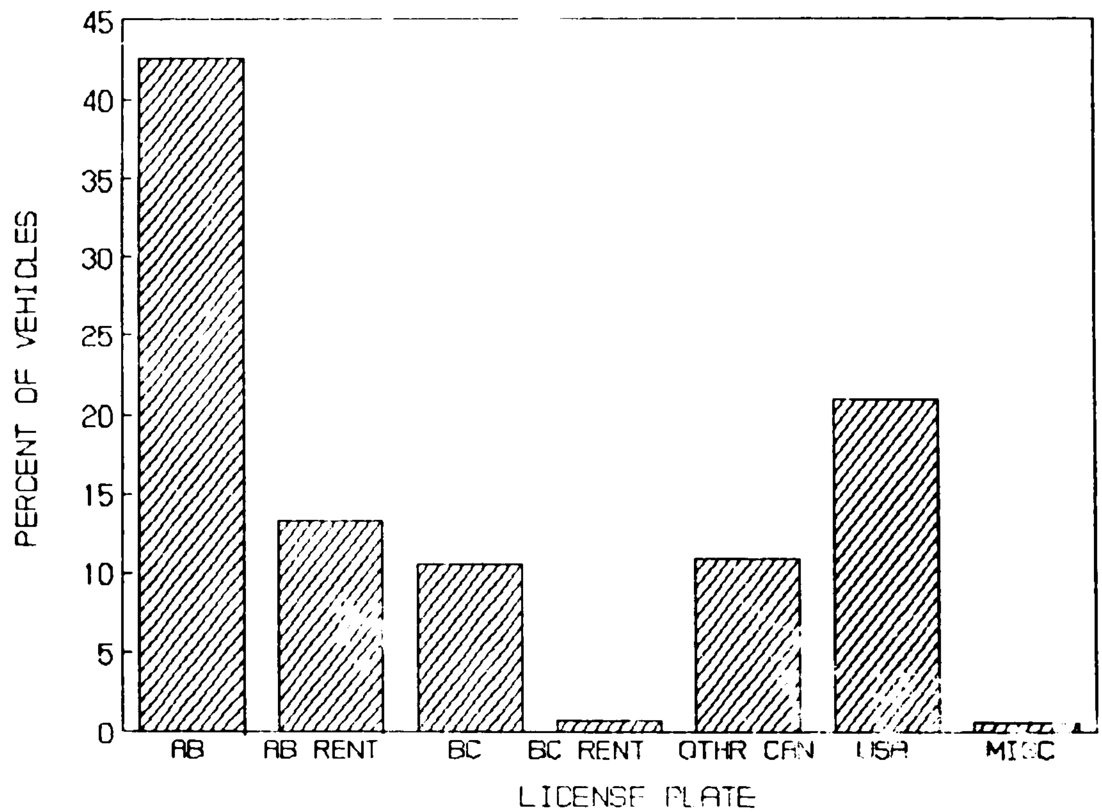


Figure 21. Percentage occurrence of vehicle licence plates recorded during traffic observation periods.

Table 26. Vehicle visits observed during traffic observation periods.

	% of Vehicle Visits Observed (n=2866)				
	Begin Only	End Only	Around Island or Back Out No Loop	No Second Loop	Complete Loop Observed
First Loop Observed	26.7	27.5	1.7	----	44.1
Second Loop Observed	2.0	----	0.1	95.2	2.8

Table 27. Mean loop completion times recorded during traffic observation periods.

	Completed Loop Times			
	Mean No. Minutes	Standard Deviation	Min.	Max.
First Loop Observed	8.7	2.71	4	33
Second Loop Observed	10.3	3.76	4	24

4 to 24 minutes with a mean time of 10.3 minutes (SD=3.76). An additional 56 (2.0%) vehicles were observed beginning the second loop, but 2727 (95.2%) vehicles were observed to exit before beginning a second loop, and 4 (0.1%) vehicles were observed passing the island as if to begin a second loop, but backing up and exiting instead.

9.2.3 Loop and sighting vehicle observations

In addition to vehicle observation during TOPs, 2650 vehicles were observed during loops with a mean of 9.5 vehicle visits per loop (SD=7.61) and a range of [illegible] to 34 vehicle visits (Table 23). These loop vehicle visit totals include vehicle visit totals recorded for all of the sightings conducted during the loop. Of these 92.6% were private vehicles, 6.7% were bus tours, 0.2% were other tours, 0.6% w[illegible]torcycles, cyclists, and non visitor vehicles (Table 24, Figure 22). Of the observed [illegible]urs, 64% were identified as Brewster Transportation and Tours (32.6%), Greyhound (20.2%), and Pacific Western Transportation (11.2%)

During the 206 sightings, 651 vehicles visits were observed and categorized as stopping or not stopping (Table 23). The mean number of vehicle visits observed per sighting was 3.2 (SD=3.18), with a range from zero to 18 vehicle visits. 93.1% of these vehicles were private, 5.8% were bus tours, 0.3% were other tours, and 0.8% were motorcycles, cyclists, and non-visitor vehicles (Table 24). Of these vehicles, 75.1% stopped at the sighting location and 24.9% did not. By vehicle type, 74.4% of the private vehicles (n=606), 92.1% of the bus tours (n=38), 50.0% of the other tours (n=2), 50.0% of the motorcycles (n=2), 0.0% cyclists (n=2), and 100.0% of the non-visitor vehicles (n=1) stopped.

9.2.4 Visitation rates

The rate of vehicle use (vehicles/minute) in the Buffalo Paddock was calculated for vehicles observed during loops and sightings and for vehicles entering the paddock as recorded by the traffic counter during the hour of each loop. The means and ranges of the three visitation rates, ***observed rate for loops***, ***observed rate for sightings***, and ***recorded rate of entrance*** are shown in Table 28. Mean observed visitation rates were 0.26 vehicles/min at

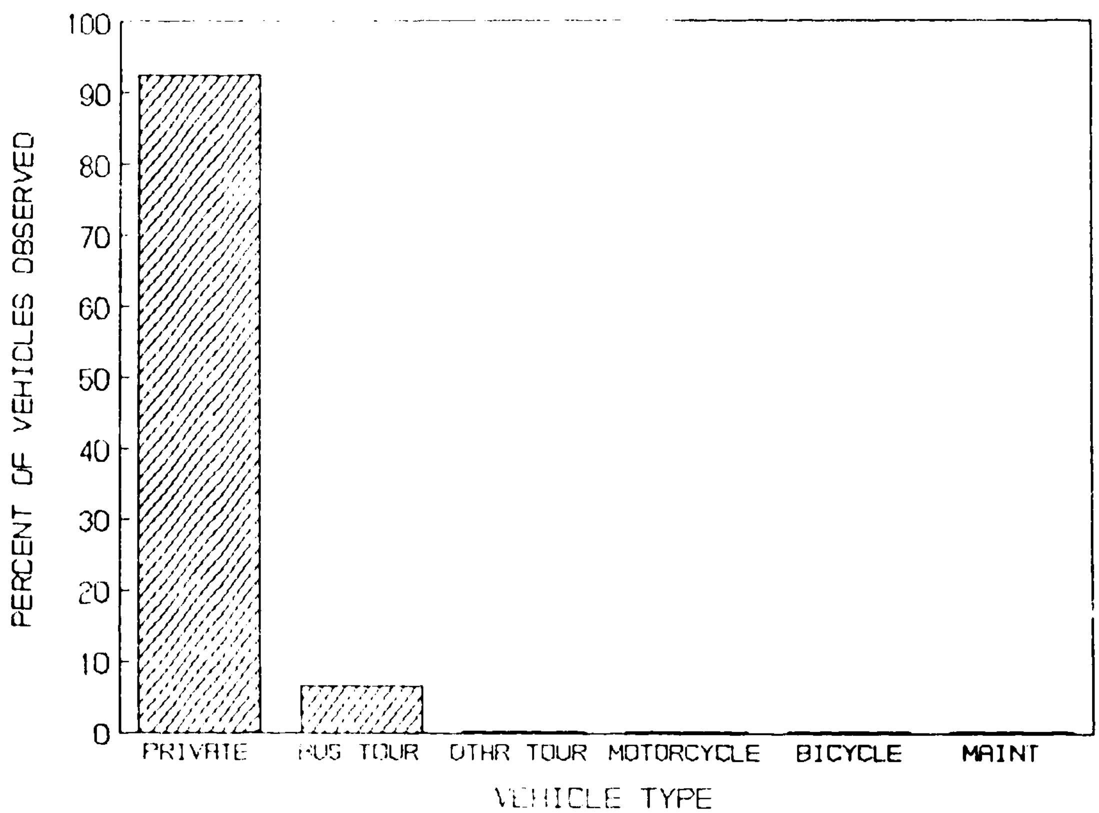


Figure 22. Percentage occurrence of vehicle types observed during loops.

Table 28. Mean visitation rates observed during loops and sightings and recorded by traffic counter.

	Mean Vehicles/Minute	Standard Deviation	Min.	Max.
Observed Rate for Loops (n=2650)	0.3	0.20	0.0	0.9
Observed Rate for Sightings (n=654)	0.3	0.35	0.0	2.0
Recorded Rate of Entrance (n=5315)	0.3	0.25	0.0	1.2

(SD=0.20) for loops and 0.34 vehicles/minute (SD=0.35) for sightings. The mean visitation rate recorded by the traffic counter was 0.33 vehicles/minute (SD=0.25). Overall, the paddock visitation rate was approximately one vehicle every three minutes.

To further describe visitation rates, the three rates were examined using Kendall's tau b rank correlation. The associations between *observed rate for loops*, *observed rate for sightings*, and *recorded rate of entrance* and *day of study*, *loop hour*, *observable sky condition*, and *observable precipitation condition* were explored. The correlation matrix is presented in Table 29.

The visitation rates showed strong positive association with each other. The *observed rate for loops* showed a slightly stronger association with *recorded rate of entrance* (τ-b=.79) than did the *observed rate for sightings* (τ-b=.64).

Significant τ-b coefficients ($p<.05$) were found for all three visitation rate variables tested with *day of study* and *loop hour*. The τ-b coefficients all indicated moderate, positive relationships with visitation rates increasing with *day of study* and *loop hour*. The associations with *day of study* (τ-b=.32 to .40) were stronger than those with *loop hour* (τ-b=.24 to .29).

The shape of the relationships between *recorded rate of entrance* and *day of study* and *recorded rate of entrance* and *loop hour* are illustrated in Figures 23 and 24. The average rates of vehicles entering the paddock were calculated for each *week of the study* and for each *loop hour*, and the relationships were plotted. The relationship between *average entrance rate and week of study* (Figure 23) closely reflects the relationship of *daily visitation* with *day of study* seen previously in Figure 20. After an initial decline from the May long weekend peak, the *average entrance rate* steadily increases to Week 9 (July 9 to 15), dips sharply in Week 10, and then levels off. Figure 24 illustrates the relationship between *average entrance rate* and *loop hour*. Visitation rate increases from a low of 0.01 vehicles/minute at 0600 hours to a peak of 0.56 vehicles/minute, or approximately one vehicle every two minutes at 1100 hours. The *average entrance rate* then declines and levels off at approximately 0.47 vehicles/minute from 1200 to 1500 hours, after which rates decline to 1900 hours. A small increase in

Table 29. Kendall's tau-b correlation matrix for visitation rate variabl[illegible] [illegible]served rate *for loops, observed rate for sightings,* and *recorded rate of* [illegible]

	Loop Hour	Sky Condit.	Precip. Condit.	Obs. Rate Loops	Obs. Rate Sights.	Rec. Rate Entr.
Day of Study	.0321 (280)	.1290* (278)	.1103* (277)	.3582* (280)	.3233* (206)	.3969* (267)
Loop Hour		.0571 (278)	.0407 (27[illegible])	.2782* (280)	.2920* (206)	.2346* (267)
Sky Condit.			.4908* (277)	.1484* (278)	.0214 (203)	.1513* (265)
Precip. Condit.				.0469 (277)	.0223 (203)	.0485 (264)
Obs. Rate Loops					.6925* (180)	.7883* (267)
Obs. Rate Sightings						.6397* (172)

*Significant tau-b (p<.05)
Note: With increasing category values, the hour of the day gets later, sky gets cloudier, rain intensity increases, and visitation rates increase.

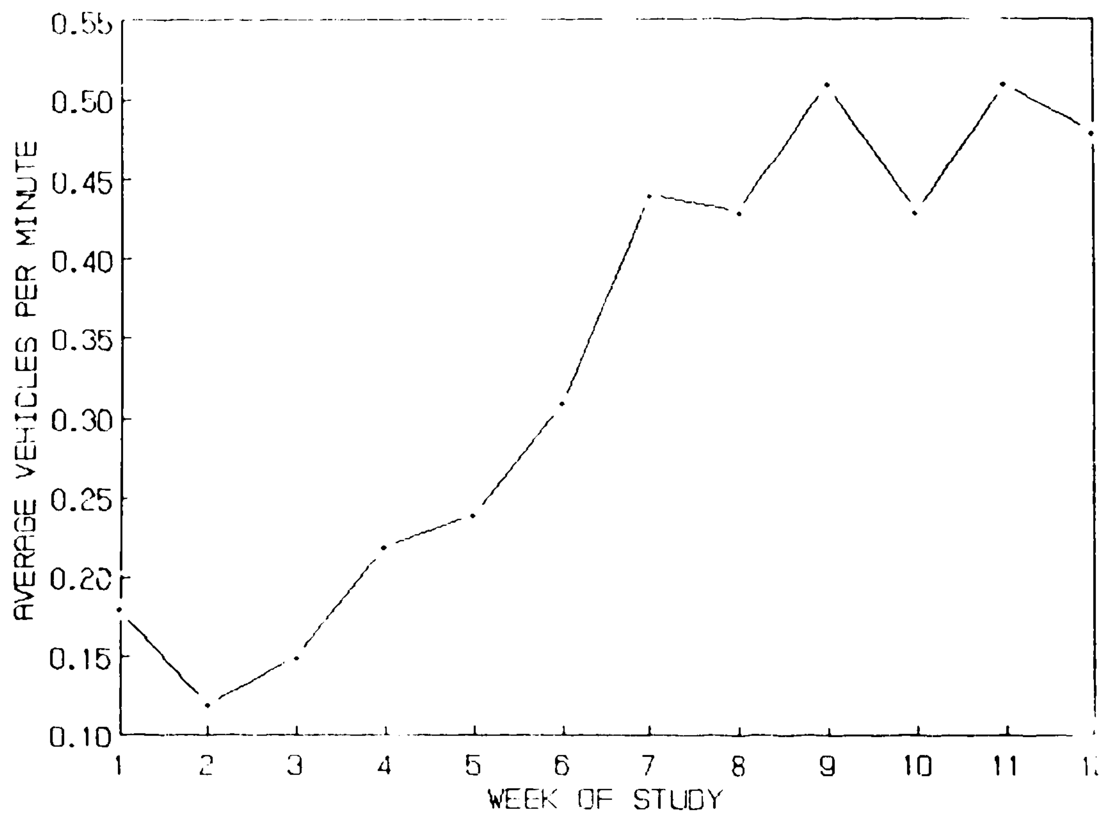


Figure 23. *Recorded rate of entrance* BY *week of study.*

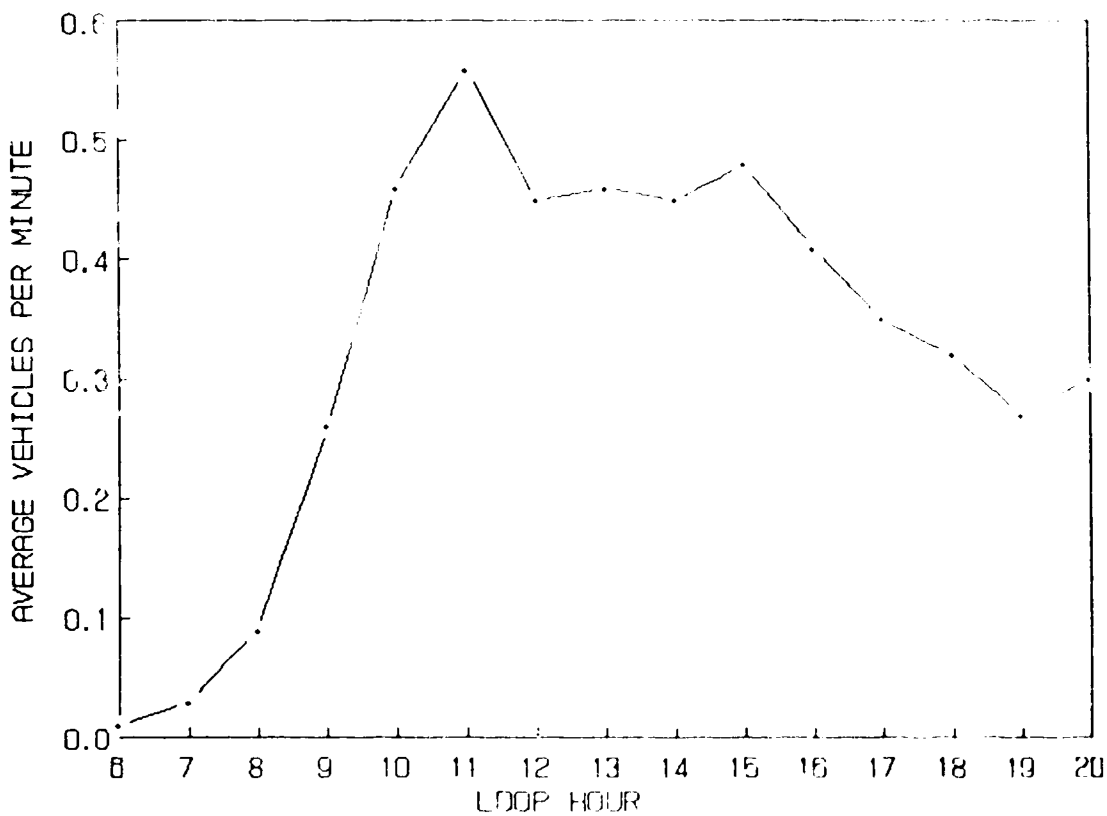


Figure 24. *Recorded rate of entrance* BY *loop hour.*

average entrance rate then occurs at 2000 hours.

Observed rate for loops and *recorded rate of entrance* were also significantly ($p<.05$) associated with *observable sky condition*. The relationships were weakly positive (τ-b= .15) with visitation rates increasing as cloud cover increased. However, these relationships cannot be directly interpreted due to the similar positive relationships of observable weather to *day of study*. Visitation rates were not significantly associated with *observable precipitation condition*($p>.05$).

9.2.5 Tour agency use

The drivers and guides of Mountain Park Tours (MPT) and Brewster Transportation and Tours (BTT) completed 49 and 26 *Buffalo Paddock Tours* forms respectively, describing their tours through the paddock during the study period. Due to incomplete participation by tour staff, forms were not completed for every trip through the paddock. Therefore, only general inferences can be made, based on the forms received.

Both of the tour agencies conducted the majority of their reported tours through the paddock between 0900 and 1200 hours, with only a few mid-afternoon tours and one early evening tour. MPT conducted 55% of its tours at 0900 hours and another 18% at 1000 hours, whereas BTT tours were spread more evenly between 0900(21%), 1000 (25%), 1100 (25%), and 1200 (21%). The completed forms represented the visits of 1666 passengers with MPT and 674 passengers with BTT. The mean number passengers/tour was 37.0 (SD=6.95, range 21 to 60 passengers) for MPT and 27.0 (SD=10.89, range 8 to 48 passengers) for BTT. BTT drivers reported a 83.3% bison sighting success rate, while MPT guides reported bison observed on 69.4% of all recorded tours. The success rate of MPT guides is similar to the average rate for researchers of 64.3%. The BTT drivers success rate is high, even when compared to the researcher's success rate between 0900 and 1200 hours, which averaged 73.7%. The reason for the high BTT success rate is unknown. Perhaps drivers were more inclined to return observation forms when bison were seen, thereby inflating the success rate. Or, perhaps the higher vantage point from bus windows combined with several observers in the vehicle may have in fact resulted in a higher success rate for the BTT bus tours.

Sightings for which bison were described as close or clearly visible represented only 35.2% of all sightings (26.0% of all tours). Reported visitor reactions to close or clear bison sightings were positive, with visitors interested and excited about seeing bison. When sightings were far away or visibility was poor, reactions were still generally positive although many visitors expressed the wish for a better view. On the occasions when bison were not visible, the reported visitor reactions varied from "very disappointed" and "very [illegible]" to "mildly disappointed" and "no reaction".

The tour agencies provided estimates of their [illegible] of the Buffalo Paddock throughout the entire 1986 summer season. MPT guides conducted approximately [illegible] which included the Buffalo Paddock, serving 12,500 passengers (Anderson, C., pers. comm. 1987)[46]. Approximately 70% of these tours took place during July and August. BTT took approximately 6885 passengers through the Buffalo Paddock on its Banff General Drive tour (Sandford, pers. comm. 1987)[47]. In addition BTT provided a rough estimate taken from a representative sample of over 3000 of their charter customers, which indicated that perhaps as many as 28,000 charter passengers visited the Buffalo Paddock in the summer of 1986.

The tour agency drivers and guides generally commented that the Buffalo Paddock was a positive experience for visitors, but expressed the view that the chances of sighting bison should somehow be improved. Ms. Anderson indicated that MPT staff and management support the continued operation of the present Buffalo Paddock, as tour guides enjoy interpreting bison history in the Buffalo Paddock, and visitor response to the visits is most often favorable. Mr. Sandford of BTT described the Buffalo Paddock as as "important part of the Banff experience for most visitors" and recommended that any changes to the paddock enhance the natural habitat through visual separation of buildings and fences, and increase bison sighting success to 100%.

---

[46] Ms. C. Anderson, President, Mountain Park Tours, Banff, Alberta.
[47] Mr. R. W. Sandford, Corporate Secretary, Brewster Transportation and Tours, Banff, Alberta.

9.3 Interaction of Visitors and Bison

During each loop and bison sighting, observations were made of visitor compliance with posted warnings and of the interaction of visitors and bison. Although the sign at the entrance to the Buffalo Paddock states that cycles are prohibited, two bicycles (one at a sighting) and four motorcycles (two at sightings) were observed in the paddock during loops. Signage also warns visitors to remain in their vehicles. However, people were observed out of their vehicles on forty loops (14.3%). Twenty of these occasions took place at bison sightings (see below), but the remainder appeared to be for a variety of other reasons; feeding ground squirrels (3), picking flowers (2), taking pictures ([illegible]), walking (4), and standing by vehicles (5).

During each bison sighting, observations were made of the interaction of visitors and bison. Bison generally did not react strongly[45] to the presence of the researcher or visitors provided that people remained inside their vehicles. Bison attempting to cross the loop road were blocked by vehicles on four occasions, and were forced to wait or walk around the vehicles. This caused some confusion for calves, resulting in apparent concern by the bison cows. The bison did not generally react to slow-moving or stopped vehicles with alarm or aggression. However, on two sightings bison were startled into flight by the sudden approach of vehicles: on one occasion a single motorcycle and on the other a group of five vehicles. In addition, bison reacted strongly by rapidly walking away when approached by a vehicle which was driven off the loop road and into the paddock towards them.

During twenty (9.7%) sightings, one or more visitors were recorded as being out of their vehicles. Visitors left the loop road and approached the bison on 10 of these occasions, or 4.9% of all bison sightings. The strongest reaction shown by the bison during each of the twenty sightings is shown in Table 30. As long as visitors remained near their vehicles, bison generally did not show a strong reaction. However, on two occasions, bison walked quickly away from the visitors and on one occasion, a cow bison bluff charged a visitor who stepped

[45]"Strong reaction" was defined as obvious movement away from or towards the source of disturbance. Due to poor visibility, less obvious responses, such as standing alert, were not consistently recorded and so are not reported.

Table 30. Strongest recorded reaction of bison to visitors out of their vehicles during twenty sightings.

	No Visible Reaction	Stand Up	Walk Away	Run Away	Charge	Bluff Charge
Visitors out of vehicles (n=10)	7		2			1
Visitors approach bison (n=10)	1	1	2	3	3	

out of his vehicle only five meters from her.

Bison [illegible] were consistently stronger when [illegible]tors directly approached them. Only on one occasion, wh[illegible] [illegible]ently approached [illegible]ing bison, did the bison show no strong response. Resting bison on a second occasion were obse[illegible]ed to stand and remain alert as the visitors approached to take pictures. Bison moved away from approaching visitors on five occasions, twice at a fast walking pace, and three times running out of sight into forest cover. On three sightings, visitors approaching to within 15, 30, and 50 m of bison were charged by a cow bison. Two of the visitors were charged all of the way back to their vehicles, approximately 80 m, and in the third charging, the bison chased the visitor [illegible] only 20 m, half way back to his car.

On two additional occasions, not on scheduled loops, visitors were observed actively chasing bison. In one incident, a man and teenage girl followed the bison, which left at a rapid walk, through the trees and well into the centre of the paddock. In the second incident observed, a man with a video camera chased the bison out of the trees and down the road towards the research vehicle. A passing cyclist was able to hide behind the research vehicle and then requested a ride out of the paddock.

9.3.1 Summary

The opportunity for viewing bison in the Buffalo Paddock is limited. Sighting success by researchers, who travelled approximately four times slower than visitors, was only 64%. The best sighting opportunities were in the early morning when visitation was lowest. Bison at this time were closer to the loop road than later in the day. Whether this is a factor of bison avoiding the road area during hours when traffic volumes are higher is unknown. Most [illegible]htings (84%) were of four or more bison and lasted at least ten minutes (88%). On average, bison were seen at a distance of 50 meters or less on only 50% of bison sightings. The aspen forest cover greatly reduced bison visibility. Vegetation screening, which accounted for 80% of all screening, was extensive enough that the opportunity to see at least one-half of the animal being observed occurred on only 29% of bison sightings. Bison were observed from closer distances and were less screened as the study period progressed. This may be a result of less secretive behavior by cow bison as their calves mature. Bison were most commonly observed lying down or feeding.

The Buffalo Paddock was visited by 25,767 vehicles [illegible] study period, approximately 6.7% of which were bus tours. Assuming an average [illegible] passengers per bus and 2.5 persons per private and other vehicles, total visitation can be estimated at [illegible] visitors; 60,424 bus tour passengers and 60,102 other visitors. By way of comparison [illegible] the same time period, 181,400 people visited the Cave and Basin, 131,111 people [illegible] Upper Hot Springs Pool and Bath, 72,626 people visited the Banff Museum, and [illegible] people were served at the Banff Townsite Information Centre[49]. Daily visitation in the Buffalo Paddock increased over the study period, generally reflecting park use trends. Most of the paddock visitors drove vehicles with Canadian licence plates (78%), again reflecting park visitation trends. Buses carried a significant number of passengers through the paddock, with Brewster Transportation and Tours, Greyhound, and Pacific Western Transportation being the major identifiable carriers. Visitors spent an average of nine minutes in the paddock with only 5% making a second loop. Their speed was almost four times faster than the research vehicle and so the number of visitors who saw bison is likely somewhat less than the 64% success rate found by the researcher would indicate. On average, approximately three-quarters of the vehicles which were seen during sightings would stop to observe the bison. The people who did not stop likely could not see the bison because of poor visibility. Visitation in the Buffalo Paddock averaged one vehicle every three minutes. However, there was considerable variation, from zero vehicles to two vehicles per minute. Vehicles often ended up travelling in groups which would greatly increase the passage rate experienced at any one point. This inconvenienced visitors who wanted to drive slower and so were continually forced to pull off to the side of the road. It also disturbed bison who were unable to cross the road at will. Visitation rates were highest at mid-day, and an increase in rates was seen as the study progressed and daily visitation totals increased. Use

[49]Banff National Park Visitor Services and Interpretation files.

of the paddock by the two cooperating tour agencies was high, with over 47,000 passengers being conducted through the paddock over the summer season.

Visitors do not fully comply with the posted warnings of the Buffalo Paddock. Cycles were observed in the paddock, although the incidence was low, and not all visitors remained in their vehicles. People were observed out of their vehicles on 14% of the loops and at approximately 10% of the bison sightings. In most cases, people being out of their vehicle did not create a dangerous situation for the visitors, nor did it appear to affect the bison. However, on the occasions when visitors approached bison, bison reacted strongly 90% of the time, with 45% of these reactions being aggressive. There is therefore some concern for both visitor safety and bison harassment in the Buffalo Paddock.

10. SUMMARY AND REVIEW OF ALTERNATIVES

10.1 Summary of Sub-Study Results

The completion of the four sub-studies provided information necessary for a review of the alternatives for bison management in Banff National Park. The major factors are summarized below.

1. Prehistory and History of Bison in Banff National Park
   a. Bison, most likely plains bison, were indigenous to the park area until *circa* [illegible]
   b. Summer bison distribution included most major valleys and many smaller [illegible] valleys, and extended to upper subalpine and alpine habitat.
   c. Historic winter bison distribution is unknown.
   d. Plains bison were reintroduced in 1897 as a captive herd. The herd was maintained until 1981, when the plains bison were replaced with the present herd.
2. Review of Bison Management Factors
   a. Climatic conditions are favorable for bison, although snow conditions limit winter range.
   b. Suitable forage, cover, and water resources exist in the park.
   c. Bison would compete with other ungulates for space and common resources, with the most severe competition occurring between elk and bison for winter range.
   d. Seasonal movement patterns, that would develop as a free ranging bison herd became established, would eventually involve movement out of the park. This would raise several issues of concern including protection and/or hunting of bison, monitoring of livestock diseases, mitigation of bison competition with elk and horses for winter range, and provision of compensation for bison damage to adjacent agricultural lands, crops, or facilities.
   e. Severe winter weather would likely be the primary source of bison mortality. However, wolf and grizzly predation, disease, and bison-vehicle collisions could be contributing factors.

f. A captive herd would require the provision of supplemental feed, nutrients, and water, and the installation of handling facilities and special fencing.

g. Public information, interpretation, and appropriate facility design are necessary enhance visitor experience and minimize public safety hazards and harassment of bison.

3. Analysis of Bison Habitat

a. The interpretation of the ELC data provided a framework for the identification of potentially suitable bison habitat in Banff National Park through use of the ELC maps.

b. There are nine ELC Ecosites potentially capable of providing *primary* forage habitat. Six of these have suitable winter snow depths. A more detailed survey would be needed to estimate carrying capacity.

c. The lower Howse/North Saskatchewan, Red Deer, and Bow River valleys are potential wintering areas for free-ranging bison.

d. Sites located near Carrot Creek, Cascade Pits, Hillsdale Meadows, and Johnson Lake were assessed as potential paddock relocation sites.

4. Buffalo Paddock Study

a. The opportunity for viewing bison is limited, largely due to vegetation screening, and the fact that the best sighting opportunities occur in early morning when visitation is lowest.

b. The Buffalo Paddock receives significant use. There were about 26,000 vehicles or 120,000 visitors during the twelve week study period.

c. About 6% of the vehicles using the Buffalo Paddock are buses, representing at least 50% of the visitors.

d. Improved interpretation and facility design are required to address bison harassment and public safety concerns, and to improve the visitor experience in the Buffalo Paddock.

10.2 Review of Alternatives

The five alternatives are reviewed in this section. The principal strengths and limitations of each alternative are summarized in Table 31.

10.2.1 Alternative 1. Paddock removal and elimination of bison from Banff National Park

The first alternative proposes the removal of the Buffalo Paddock and complete elimination of bison from Banff National Park. The present wood bison herd would [illegible] be relocated outside the park, the paddock facility dismantled, and site rehabilitation carried out as necessary.

The elimination of the Buffalo Paddock would improve movement of ungulates through the area and allow wildlife access to previously enclosed habitat. The management of bison would have no further impact on park resources. However, the remaining structures associated with the public and government horse corrals would still provide barriers to movement and exclude ungulates from usable range.

As this alternative completely eliminates bison from the park, the role of Banff National Park in preserving bison as a species must be addressed. Immediate consideration of this issue is complicated by the distinction that must be made between the plains bison and the currently threatened wood bison. The captive wood bison herd was introduced to and is maintained in Banff National Park in cooperation with the Canadian Wildlife Service as part of the Wood Bison Rehabilitation Program. It provides an isolated breeding herd that contributes to preservation of the wood bison gene pool and produces stock for reintroduction projects. However, as this study addresses the long-term management of bison, it assumes successful completion of the Wood Bison Rehabilitation Program and removal of wood bison from the endangered species list. This will decrease the need to maintain captive wood bison breeding herds and fulfill the commitment of Banff National Park to the Wood Bison Rehabilitation Program. Subsequently, the need to further consider this responsibility is eliminated and the role of Banff National Park in the preservation of bison can be examined on a broader scale.

Table 31. Summary of alternatives: principal strengths and limitations.

#1 PADDOCK REMOVAL AND ELIMINATION OF BISON FROM BANFF NATIONAL PARK.

Strengths:
- remove paddock barrier to wildlife movement
- return paddock habitat to wildlife
- eliminate public safety and bison harassment concerns

Limitations:
- eliminate isolated bison gene pool herd
- remove indigenous species from park
- allow bison no role in park ecosystem
- eliminate viewing and interpretation opportunit..
- eliminate visitor attraction

#2 PADDOCK REMOVAL AND ESTABLISHMENT OF A FREE-RANGING BISON HERD IN BANFF NATIONAL PARK.

Strengths:
- remove paddock barrier to wildlife movement
- return paddock habitat to wildlife
- create unique viewing and interpretation opportunity
- allow bison to reassume role in park ecosystem
- maintain isolated bison gene pool
- maintain indigenous species in park

Limitations:
- eliminate visitor attraction
- reduce viewing frequency
- introduce different public safety concerns
- introduce bison impact to park ecosystem (soil, vegetation, wildlife)
- need to develop co-operative agreements with adjacent lar wners
- possible need to control herd movements and numbers
- reduce certaint   population survival and growth

#3 RETENTION OF PRESENT BUFFALO PADDOCK.

Strengths:
- maintain visitor attraction
- maintain viewing and interpretation opportunity
- allow bison to assume role on confined ecosystem scale
- maintain isolated bison gene pool
- maintain indigenous species in park

Limitations:
- not remove paddock barrier to wildlife movement
- not return paddock habitat to wildlife
- maintain bison in captive situation
- continued public safety and bison harassment concerns

(Cont..)

Table 31. (Continued)

#4 STRUCTURAL MODIFICATION OF PRESENT BUFFALO PADDOCK.

Strengths:
- maintain visitor attraction
- maintain viewing and interp. opportunity
- improve wildlife movememt through area
- opportunity to allow some wildlife access to paddock habitat
- depending on design: may improve viewing opportunity, and decrease public safety concerns and bison harassment
- allow bison to assume role on confined ecosystem scale
- maintain isolated bison gene pool
- maintain indigenous species in park

Limitations:
- provide some barrier to wildlife movement
- not allow wildlife complete access to paddock habitat
- maintain bison in captive situation
- depending on design: may decrease viewing opportunity, and increase/maintain public safety concerns and bison harassment

#5 RELOCATION OF THE BUFFALO PADDOCK.

Strengths:
- remove paddock barrier to wildlife movement
- return paddock habitat to wildlife
- substitute visitor attraction
- allow viewing and interpretation
- maintain isolated bison gene pool
- maintain indigen[illegible] species in park
- allow bison to as[illegible]on confined ecosystem scale

Limitations:
- [illegible] on wildlife movement and habitat, [illegible]ation, and soils elsewhere
- [illegible] on visual and aesthetic environment [illegible]where
- [illegible]c safety and bison harassment concerns
- m[illegible]ain bison in captive situation
- provide lower quality viewing experience than present location
- unlikely to replace visitor attraction attributes of present location

The Canadian Parks Service was a major force in the initial preservation of bison in Canada, and in fact the world. The role of the Canadian Parks Service has lessened over the last century as plains bison, and soon wood bison, have become reestablished in both captive and free ranging herds across North America. The bison herds of Elk Island and Wood Buffalo National Parks still contribute significantly to the preservation of bison. In terms of international species preservation, the ecological value of the captive herds of Riding Mountain, Prince Albert, Waterton Lakes, and Banff National Parks is relatively low. However, they do continue to provide bison gene pools which are federally controlled and so can be protected from disease and hybridization. The ecological value of a herd in Banff National Park to the preservation of the bison species has, therefore, decreased from what it once was, but cannot be entirely discounted.

However, through its commitment to protect and maintain representative natural ecosystems, and its policy of reintroducing formerly indigenous species, the Canadian Parks Service must consider the value of bison as part of the ecosystems of Banff National Park. Bison were indigenous to the park prior to 1860. Although the stronghold of the species was obviously the prairies and foothills, evidence is sufficient to indicate that bison were once a significant presence in the park. The extermination of a large ungulate such as the bison would have had considerable impact on associated vegetation, other ungulates and predator species. The continued absence of bison precludes participation of the species in the naturally evolving ecosystems that park management strives to preserve. Although neither historical population size, nor winter distribution can be firmly established, these factors would affect the magnitude and location, rather that the fundamental nature of the ecosystem impacts of bison. It would, therefore, be desirable to reintroduce bison to at least a portion of Banff National Park, rather than eliminate them as proposed by alternative

Removal of bison from the park would eliminate a valuable opportunity for bison viewing and related education and interpretation. The bison story has high educational and interpretive value. Early North American human history is strongly tied to the bison and the story of the near extermination and subsequent recovery of the species is a powerful illustration of the need for and methods of wildlife [illegible]servation. There are other locations where bison can be viewed and the bison story related. However, the opportunity in Banff National Park is of high value because of the intrinsic interest provided by the role which the park played in bison conservation, the existence of an established bison viewing facility in the park, the naturalness of the [illegible]ing environ[illegible] and the large audience served by [illegible] park. The removal of the Buffalo Paddock would a[illegible] eliminate a popular visitor att[illegible] [illegible] interest in viewing bison.

10.2.2 Alternative 2. Paddock removal and establishment of a free-ranging bison he[illegible] in Banff National Park

The second alternative is to remove the Bu[illegible] Paddock [illegible] establish a free [illegible] herd of biso[illegible] in the park. The removal of the paddock wo[illegible] be accomplished [illegible] previously. The establishment of a [illegible] herd would require on site [illegible] to determine range carrying ca[illegible], [illegible] forage availability, and expected [illegible] competition and environmental impacts. The construction of a temporary paddock [illegible] and maintenance of a breeding herd for a few [illegible] would be necessary. Recent exp[illegible] gained through the establishment of herds within the Wood Bison R[illegible] Program could be appl[illegible] to improve t[illegible] chances of a successful reintroduction.

While this alt[illegible]ative would eliminate the visitor attrac[illegible] provided by the Buffalo Paddock, the establishment of a free ranging herd would provide additional opport[illegible] for [illegible]g and interpretation of bison. Bison would not be as visible as in a confined [illegible] but the sighting of free-ranging bison in the park would be a [illegible] experience. Interpretation of free-ranging bison management in Banff National Park has the potential to reach a wide audience [illegible]vide high-profile education relat[illegible] to the [illegible] of [illegible] in Canada.

The presence of [illegible]ee-ranging bison in Banff National Park would [illegible] safety concerns related to the possible occurrence of vehicle-bison collisions and [illegible] encounters with aggressive bison. [illegible] information and awareness could be used to minimize the harassment of bison and [illegible] occurrence of [illegible] encounters. However, some incidents would undoubtedly occur as bison became established in the park, with the frequency being dependent upon the size and [illegible] of the herd.

The establishment of a free ranging herd would allow bison to reassume a natural role [illegible] evolving ecosystems of the park. Free ranging bison would impact soil and vegetation [illegible] impacts on [illegible] and vegetation would generally be [illegible]spersed and in any case would be similar to those of the original free ranging bison population. Bison [illegible] compete for space and common resources with other ungulates, although differences in habitat use and food habits would minimize this competition. Some [illegible] of grassland carrying capacity for other ungulates, particularly elk, would likely occur. Bison would provide a potential food source [illegible] wolves, grizzly bears, and other predators and scavengers. The ultimate environmental impacts of free ranging bison would depend on the numbers of bison introduced and the [illegible] [illegible]ation of the herd.

Suitable habitat [illegible] wintering bison exists within the park, but the habitat boundaries [illegible] areas of provincial land. It is therefore likely that free ranging [illegible] would eventually, if not immediately, expand their wintering ranges to include habitat [illegible] park boundaries, in a manner similar to that of park elk. Once bison became familiar with this habitat, they might also spend some time there in summer. This likelihood of bison movement onto provincial lands would require that cooperative agreements be made [illegible] adjacent landowners regarding the management of bison.

The uncertainty of population survival and growth is a disadvantage of the free [illegible] alternative. The reproductive success of a free ranging herd, the impacts of winter weather on the population, and the importance of wolf predation cannot be accurately predicted. If the population does expand successfully, impacts on park resources would increase. Of primary concern would be the competition of bison with elk for winter range. The acceptability of this increased competition with elk depends [illegible] management goals for the two species. The eventual spread of bison into high visitor use areas as home range expansion occurs, is also a concern. Habituation and increased opportunity for visitor encounters with bison will allow for improved viewing of bison but will also increase the likelihood of bison harassment, bison-vehicle collisions, and aggressive [illegible] visitor interaction. Control of bison numbers within the park would be difficult [illegible] likely unacceptable. However, the likelihood of bison straying onto provincial [illegible] advantageous if control of [illegible] numbers by hunting becomes [illegible].

10.2.3 Alternative 3. Retention of present Buffalo Paddock

The third alternative proposes the retention of the present Buffalo Paddock [illegible] limited thinning of forest cover to improve bison visibility. Bison handling facilities should also be improved to reduce stress and prevent injury to bison and handlers.

This alternative would not alleviate the wildlife migration problem, nor restore [illegible] habitat to other wildlife. However, the severity of the barrier that the paddock presents to wildlife movement has not been firmly established. The reactions of elk using the corridor between the Buffalo Paddock fence and the Trans-Canada Highway fence is variable. Some elk have been observed displaying signs of stress and panic in the corridor, while others have been observed calmly feeding and proceeding without hesitation to use the underpass.

This alternative would maintain the Buffalo Paddock as a visitor attraction and [illegible] viewing of bison could continue. Bison viewing could be improved by thinning tree cover. However, thinning would have to be carefully conducted in order to preserve [illegible] the aesthetic quality of the bison viewing setting, and maintain sufficient and appropriately located escape cover to improve public safety and minimize bison harassment. Inte[illegible] in the Buffalo Paddock could be expanded to more fully realize the education potential provided by bison management in Banff National Park and to more effectively provide information [illegible]ich would enhance public safety and decrease harassment of bison.

The retention of the Buffalo Paddock requires that the acceptability of maintaining a captive bison herd within Banff National Park be addressed. From a policy standpoint, the decision to allow the degree of natural process and habitat manipulation that is required to maintain a captive bison herd, must be based upon recognition of the inability to maintain the species by natural means. This study suggests that the physical resources of Banff National Park are sufficient to maintain bison by natural means. It is therefore the perceived incompatibility of free ranging bison management with present resource conservation and visitor use goals, and the cost of solving bison management problems, which would prevent [illegible]

From an ecological standpoint, captive reintroduction does not allow bison to assume a natural role in the ecosystems of the park. However, depending on the natural area encompassed by the facility and the opportunity for interaction with other wildlife, naturally evolving relationships may occur on a confined ecosystem scale. The ecological value of these relationships is low relative to free-ranging reintroduction. However, it is high relative to complete elimination of bison from the park. As this particular alternative for captive reintroduction does not allow paddock access to other ungulates, only limited interaction of bison with their environment can occur. Still, bison can exist in a relatively natural setting, with vegetation and climatic conditions representative of a small portion of Banff National Park.

Finally, the human dimensions of retaining a captive bison herd must be considered. Some visitors may perceive the ma[illegible]nce of captive wildlife as being in conflict with the modern philosophy of national park [illegible]agement. [illegible]ever, if the decision were made that the only way to maintain bison in Banff Nation[illegible] as through captive representation, interpretation and education could be used to inform visitors of the reason for the presence of captive [illegible]life. Most park visitors could recognize and appreciate the special management problems associated with maintaining a large ungulate species which has been absent from the park ecosystem for over a hundred years. As previously mentioned, the provision of an opportunity for bison viewing and interpretation in Banff National Park is worthwhile. The fact that this viewing and interpretation occurs in a captive situation may decrease, but does not eliminate, the value to be realized. Although bison visibility in the present Buffalo

Paddock is limited, the aesthetic quality of the actual bison viewing experience is high. Despite the captive nature of the herd, the Buffalo Paddock provides an opportunity for observing bison in a natural setting which is unequalled by most park, zoo, and private facilities in southern Canada. In fact, due to the high degree of development in adjacent areas, the Buffalo Paddock presents a comparatively natural setting in the Banff Townsite area in which to view several wildlife species.

10.2.4 Alternative 4. Structural modification of the present Buffalo Paddock

The primary objective of the fourth alternative, structural modification of the present Buffalo Paddock, is to improve ungulate movement through the area. This could be accomplished by changing the size and shape of the paddock, by altering the paddock fence to allow ungulates to pass through the paddock, or by a combination of the two methods. The change in paddock size and shape would, in general terms, be conducted by widening the corridor between the Buffalo Paddock fence and the Trans-Canada Highway fence. The resultant paddock could be designed to retain the areal extent of the old paddock by expanding towards the airport or reduced in area to the degree that the paddock becomes a display facility. Paddock modification by installing a fence that would allow ungulate passage could be combined with slight adjustments in paddock shape to ensure maximum passage of ungulates. This would decrease the degree of the barrier presented by the paddock and allow ungulates access to paddock range, without creating a small display paddock or an extremely narrow paddock.

The impacts of paddock modification could range from the exclusion of ungulates from the same amount of habitat as the present facility to impacting little area and allowing ungulates access to a significant amount of previously enclosed habitat. Similarly, the habitat available to bison would range from being equivalent to that of the present paddock to a feedlot situation. In a paddock which allowed access to ungulates, range condition would have to be monitored to determine any changes in carrying capacity for bison. Supplemental feeding of bison would have to be conducted in such a way as to avoid aggressive interspecific encounters and prev[illegible] consumption of excess feed by other ungulates.

This alternative possesses the advantages and disadvantages of captive herd management discussed for alternative three. The degree of interaction of bison with their environment varies with the design. A facility similar in size to the present paddock with a fence which allowed access to other ungulates would provide the most opportunity for bison to interact with their environment and other wildlife. Conversely, bison in a small display paddock would have no opportunity for natural interaction.

As with retention of the present Buffalo Paddock, this alternative would allow for viewing and interpretation of bison. However, the opportunity and quality of bison viewing would be affected by the size and design of the paddock. Paddock designs wo[illegible] the way and extent to which they made provisions for the visibility of bison, [illegible]ety of visitors, the security of bison from harassment, and the aesthetic appeal of t[illegible]ock. A paddock which was considerably smaller than the present facility, or, a disp[illegible]e paddock, would provide an artificial setting for bison viewing. This would great[illegible] case the value of the facility as a visitor attraction and as a location for viewing and interpretation of bison. A narrow paddock could raise concerns for visitor safety and bison harassment. Road and fence location would affect the visibility of bison and the aesthetic appeal of the setting. The presence of other wildlife species in the paddock could enhance the wildlife viewing opportunity.

10.2.5 Alternative 5. Relocation of the Buffalo Paddock

The fifth alternative involves the relocation of the Buffalo Paddock. Four sites, Cotton Creek, Cascade Pits, Hillsdale Meadows, and Johnson Lake, have been identified as suitable for relocation. As described in Section 8.2, these sites differ based on their ability to meet bison requirements, the environmental impacts associated with the introduction of a paddock, the way the sites address visitor use concerns, and the relative costs for the relocation.

Relocation would remove the present Buffalo Paddock, thereby improving the movement of ungulates through the area and allowing wildlife access to previously enclosed habitat as described for the first alternative. However, paddock relocation to any of the sites would involve some impact on the local wildlife, vegetation, soil, and visual and aesthetic resources. Relatively high impacts would occur on wildlife at the Hillsdale Meadows site, on vegetation and soils at the Johnson Lake site, and on the visual environment at both Cascade Pits and Hillsdale Meadows.

Paddock relocation would still require maintenance of a captive bison herd, and would thereby provide opportunities for bison viewing and interpretation. However, based on the compatibility with present and planned visitor use, the predicted visibility of bison, the aesthetic quality of the setting, and degree of access, none of the sites could replace the visitor attraction provided by the present Buffalo Paddock or provide an equivalent bison viewing opportunity.

7.3.2 Ontogeny and reproduction

Bison calves are born in spring, with the calving season generally extending from mid-April through May and early June, depending on the timing of the rut the previous fall. The gestation period for bison is nine to nine and one-half months long (Reynolds *et al.* 1982) and has been estimated at 285 days (Haugen 1974). Twin births occur but are rare (McHugh 1958, Fuller 1962, Roe 1970, Haugen 1974, Reynolds *et al.* 1982, Meagher 1986). The primary sex ratio usually is slightly in favor of males (McHugh 1958, Fuller 1962, Meagher 1973, Haugen 1974, Reynolds *et al.* 1982).

Bison calves may weigh 15 to 25 kg at birth (Rutberg 1984), and increase to 135 to 180 kg by eight to nine months (Meagher 1973). Newborn calves are bright reddish tan to orange, but begin to darken at about two and one-half months, attaining a uniform dark coloring by four months (Engelhard 1970, McHugh 1972, Meagher 1986). There is little difference in appearance between sexes at birth. However, males tend to develop slightly larger body size, larger hump, and longer, more conical horns by the end of the first year (Engelhard 1970). Bison calves are precocious, standing and nursing within an hour of birth (Engelhard 1970). They remain close to their mothers for the first week, but by one month tend to gather in calf subgroups to rest and play. They continue to return to their dams to suckle and during major herd movements (Engelhard 1970). Calves are nursed for at least seven to eight months (McHugh 1958), and are usually weaned by the end of the first year (McHugh 1958, Egerton 1962, Engelhard 1970, Van Vuren 1979).

Female bison attain physical maturity earlier than males. Studies suggest cows attain maximum weight at three years (Halloran 1968) and full horn curvature by three to five years (McHugh 1958). McHugh (1958) observed bulls to attain near maximum mass by five or six years with small yearly increments in growth in the following few years. Other studies have suggested that bulls attain maximum mass at 10 to 12 years (Halloran 1968), and mature horn curve and thickness by seven to eight years (Fuller 1959). In wild herds, the onset of old age occurs at 12 to 15 years, with few animals surviving longer than 20 years (Fuller 1962, Meagher 1973). In captivity, the life-span increases, and animals have been known to live up to 40 years (McHugh 1958).

Sexes are dimorphic with males generally being larger and stouter, with longer hair on their head, neck, and chaps, and stouter, more evenly curving horns (Meagher 1986). A plains bison bull can weigh close to 1000 kg and stand almost two meters at the shoulder. The smaller females can weigh up to 600 kg, with a shoulder height of about 1.6 meters (Table 8).

Although a few female bison first conceive as yearlings, sexual maturity is more commonly attained at two to four years of age (Fuller 1962, Halloran 1968, Meagher 1973, Lott 1974, Reynolds *et al.* 1982). Similarly, some males show sperm in the epididymis as yearlings with most being sexually mature by age three (Fuller 1962). However, because of herd social structure, males usually do not breed until age six (McHugh 1958, Lott 1974, Meagher 1986).

The breeding season generally occurs between July and October (Soper 1941, McHugh 1958, Fuller 1962, Meagher 1973, Banfield 1974, Reynolds *et al.* 1982, Meagher 1986). Actual breeding however, is more strongly seasonal and varies from herd to herd. This variability in rut may be related to variation in climate, photoperiod, habitat, population density, and genetic expression (Reynolds *et al.* 1982). As a result of the wide variability in timing of the rut, it is difficult to predict the breeding season and subsequent calving period of bison in Banff National Park. Based on an average gestation period of 285 days, and the first observation of each new calf in 1986 (May 9, 18, 26, and August 13), the breeding season of the Banff National Park herd in 1985 was July 29 to November 2. The major breeding occurred in the first two weeks of August. However, one cow was bred late, at the start of November, 1985.

The rut is characterized by increased group size as cow groups mix and are joined by bulls. Sexual and agonistic behavior by rutting bulls is intense and occurs throughout the day and night with periods of increased activity in early morning and evening. The activities of rutting bull bison have been described by various authors including McHugh (1958), Fuller (1960), Egerton (1962), Shackleton (1968), Herrig & Haugen (1969), Meagher (1973),

Table 8. Body size and weight for adult plains bison.

Sex	Total Length (cm)	Tail Length (cm)	Hind Foot (cm)	Height at Shoulder (cm)	Weight (kg)
Male	304-380	33-91	58-68	167-186	544-907
Female	213-318	30-51	50-53	152-157	318-545

(after Meagher 1986)

Petersburg (1973), and Lott (1974). Sexual behavior by bulls includes the sexual investigation, tending, and breeding of cows. The tending bond is the basic breeding pattern of bison. A temporary monogamous relationship exists in which the bull sexually isolates the cow. The tending bond may last from a few seconds to several days depending on the sexual receptivity of the cow and the ability of the bull to maintain dominance over the cow and over competing bulls. Agonistic behavior, characterized by roaring, wallowing, horning, threat posturing, and fighting, occurs to establish the dominance required for tending and subsequent breeding of cows. Bull bison also show elevated aggression toward vehicles and people during the rut (Herrig & Haugen 1969, Petersburg 1973). Following the rut, the bulls separate from the mixed herds to form bull groups or remain alone for the winter.

Pregnancy rates vary according to age, with the maximum productivity occurring in animals between age three and the onset of old age (Fuller 1962). The incidence of pregnancy declines gradually after cows reach 12 years, and markedly after 24, although 40 year old cows have been observed with calves (McHugh 1958). Observed pregnancy/calf-production rates indicate that, in free-ranging herds, cows normally produce two calves every three years (Table 9).

During the calving season, subgroups of pregnant cows and cows with new calves may form within or separate from the main cow groups. Cows may leave the herd for one or more days to calve, or remain within it (McHugh 1958, Egerton 1962, Engelhard 1970). This may be influenced by the availability of cover habitat and the presence of predators. Cows maintain close contact with their calves for the first week or two after which the calf may begin to spend time with other calves. However, the cow-calf bond remains strong and cohesion is sufficient to identify pairs for up to one year (McHugh 1958). Cows aggressively defend their calves from perceived danger, and cow groups are generally less approachable when young calves are present (Soper 1941, McHugh 1958, Engelhard 1970).

Table 9. Pregnancy/calf-production rates observed for four free-ranging bison herds.

Pregnancy/Calf-Production Rate for Adult Cows	Location of Herd	Source
67%	Wood Buffalo Nat. Park	Fuller 1962
67%	Yellowstone Nat. Park	Meagher pers. comm. 1986
60 calves /100 cows	Henry Mountains, Utah	van Vuren 1979
61 calves /100 cows	Mackenzie Bison Sanct.	Wood Bison Recov. Team 1987

7.3.3 Mortality factors

7.3.3.1 Severe winter weather

Severe winter weather has been identified as a major factor affecting populations of free-ranging bison in Yellowstone (Meagher 1973, 1976) and Wood Buffalo (Fuller 1962) National Parks. Historical accounts point to severe winter conditions as a source of major die-offs (Soper 1941, Fuller 1962, Roe 1970, Dary 1974, Reynolds *et al.* 1982), and winterkill may have contributed to the overall decrease of bison in the late 1800s (Holroyd & Van Tighem 1983). Winterkill results from a combination of weather factors, reduced forage availability, and physiological condition of individual animals (Meagher 1976). Although severe winter weather is an unpredictable source of mortality, winterkill is a major population regulating factor in Yellowstone National Park and has been found to occur to some extent every year (Meagher 1973). By way of example, mortality for the winter of 1981-82 was approximately 25% of the Yellowstone population, 40% yearlings, 14% unknown, and 46% equally old and mature of both sexes (Meagher pers. comm. 1986[18]). Winterkill would similarly be an important source of mortality for free-ranging bison in Banff National Park.

7.3.3.2 Predation

Predation is another cause of bison mortality. Wolves (*Canis lupus*) are competent predators of free-ranging bison (Soper 1941, 1942, McHugh 1958, Fuller 1960, 1962, Oosenbrug & Carbyn 1985) and circumstances have suggested occasional predation on bison calves and adults by grizzly bears (*Ursus arctos*) (McHugh 1958, Meagher 1973). While wolf predation can be significant, studies indicate that predation alone is not a major population controlling factor. A decline in the Slave River Lowlands, Northwest Territories herd beginning in the early 1970s, was at first attributed to wolf predation. However, a study in 1976-77 showed that, while wolf predation accounted for about 31% of the adult and subadult mortality and approximately 27% of calf mortality, hunting

[18]Dr.Mary Meagher, Research Biologist, Yellowstone National Park, Montana

accounted for an additional 39% of the adult and subadult mortality (Van Camp 1987). Despite a wolf control program during the winters of 1977-79 and a reduction in hunting, the population continued to decrease. A study in Wood Buffalo National Park (Oosenbrug & Carbyn 1985) indicated that wolves were responsible for 25% of a 52% annual mortality rate for calves and 32% of a 9% annual mortality rate for adult bison. Despite these high mortality figures, the authors identified low calf production as the single most important factor currently influencing the status of the bison of Wood Buffalo National Park.

The small wolf population in Banff National Park would likely have no appreciable effect on a large free-ranging herd. This is the case in Yellowstone National Park where wolves are rare and do not travel in packs (Meagher 1973). However, it is possible that with increased numbers and pack formation, wolves could have considerable impact on a small or confined herd in Banff National Park. This would depend upon the location of the bison herd and the availability of alternate prey species. Grizzly predation would be incidental for free-ranging bison but must be considered in the selection of possible relocation sites.

7.3.3.3 Disease

Anthrax, tuberculosis, and brucellosis are three important diseases of bison. Sporadic anthrax (*Bacillus anthracis*) outbreaks have caused appreciable mortality in herds from the Northwest Territories and Wood Buffalo National Park. Between 1962 and 1978, the death of at least 1086 animals in these areas was attributed to anthrax (Choquette *et al.* 1972, Reynolds *et al.* 1982). However, anthrax does not appear to be a major factor in the population dynamics of these northern herds (Bison Disease Task Force 1988). The risk of further outbreaks remains, as anthrax spores have continued to contaminate and persist in the soils and water of northern Canada (Reynolds *et al.* 1982).

Tuberculosis is a chronic, infectious disease, caused in bison by *Mycobacterium bovis*. It is present in Wood Buffalo National Park and the Slave River Lowlands, but has been eradicated from Elk Island National Park since 1971 (Reynolds *et al.* 1982), and has never been detected in Yellowstone National Park (Meagher 1973). Testing in Wood Buffalo National Park from 1950 to 1974 showed an average tuberculosis infection rate of 40% (range 15 to 56%) (Broughton 1987). In the Slave River Lowlands, tuberculosis infection rates varied from 25 to 40% in tests done between 1964 and 1974 (Broughton 1987). Little is known about the effects of tuberculosis on bison populations. However, Broughton (1987) estimates that tuberculosis in the Slave River Lowlands probably causes at least a 15% loss of productive capacity in terms of factors such as feed efficiency, weight gain and milk production. In a 1952-56 study at Hay Camp, Wood Buffalo National Park, Fuller (1962) estimated that adult mortality caused by tuberculosis may have been 4 to 6%. The incidence of tuberculosis in the herd was 40% at that time. Later testing of the Claire Lake herd showed reduced incidence of tuberculosis (14.5%, 19.1%, and 13.5% incidence in 1957-59, respectively) (Choquette *et al.* 1961), but no estimates of the imp[illegible] mortality were made. Tuberculosis did not appear to affect the productivity o[illegible] infected herd at B[illegible]alo National Park, Wainwright, Alberta, and its overall importance as a [illegible] for free-ranging herds remains unclear (Reynolds *et al.* 1982, Meagher 1986).

Brucellosis is an infectious disease caused in bison by the bacteria *Brucella abortus*. It has been nearly eliminated from confined bison herds. However, it still persists in the free-ranging bison of northern Canada and Yellowstone National Park (Reynolds *et al.* 1982). Brucellosis testing of these free-ranging herds has shown infection rates from 6 to 62%, varying widely between years and between subpopulations (Meagher 1973, Choquette *et al.* 1978). Testing in Wood Buffalo National Park from 1950 to 1974 showed an average brucellosis infection rate of 30% (range 6 to 62%), while the average infection rate in the Slave River Lowlands between 1964 and 1974 was 38% (Broughton 1987).

Brucellosis is of particular importance as it is a serious disease of cattle. In cattle, brucellosis causes abortion, temporary sterility, frequent returns to service, metritis, and lowered milk production (Choquette *et al.* 1978). Recent research has shown that, under experimental conditions, brucellosis causes similar effects in bison (Bison Disease Task Force 1988). Slaughter studies conducted in Elk Island and Wood Buffalo National Parks in the 1950s identified a reduced productivity which authors indicated may have been attributable to brucellosis-caused abortions (Corner & Connell 1958, Fuller 1962). In the long term, brucellosis may have significantly reduced the reproductive capacity of the Wood Buffalo National Park and Slave River Lowlands herd (Broughton 1987). However, studies in Yellowstone National Park, where the incidence of brucellosis was over 50% in some subpopulations, concluded that brucellosis there had little effect, if any, on herd productivity (Meagher 1973). As bison seldom show clinical signs of brucellosis infection, it has been postulated that they may have acquired a natural immunity to the disease as an evolutionary response to the presence of *B. abortus* (Meagher 1973, McCorquodale & DiGiacomo 1985).

The most common mode of brucellosis transmission is through oral contact with aborted fetuses and placentas (Witter 1981, McCorquodale & DiGiacomo 1985). This occurs on wintering and calving grounds where feed and water may subsequently become contaminated. The disease can also be spread by venereal contact, bloodsucking parasites, and ingestion of edible tissues or contaminated milk. Brucellosis can be transmitted from bison to cattle (Bison Disease Task Force 1988), and the presence of brucellosis in the free-ranging bison herds of northern Canada and Yellowstone National Park has caused and continues to cause concern among livestock producers and various agricultural agencies. In the early 1970s, Yellowstone National Park was called upon to eradicate brucellosis from its bison, a task that would necessitate the elimination of almost the entire herd (Meagher 1974). In response to this concern, Yellowstone instituted a boundary control program to ensure no contact of bison and domestic stock. However, in recent years, bison have begun to return to their historic range, including a wintering area near Gardiner, Montana, north of the park. As a result, concern over the spread of brucellosis to domestic livestock has once again arisen (Meagher pers. comm.

1986). Likewise in Canada, a close look is currently being taken at the incidence of disease in northern bison herds and its implications for future management. In 1986, the Bison Disease Task Force was established to prepare an evaluation of the problem of brucellosis and tuberculosis in bison in northern Canada. Concerns included the possible spread of these diseases to livestock, other wildlife including the threatened wood bison, and man. A number of management options have been put forth by the Task Force for review and action by the Bison Disease Steering Committee and the various agencies involved (Bison Disease Task Force 1988).

For bison in Banff National Park, the maintenance and introduction of disease-free stock should ensure that the spread of disease does not become a problem. However, there are no guarantees, as diseases may be introduced to the bison by domestic stock, other wild ungulates, insects, predators and scavengers. If free-ranging bison were to be infected with a disease such as brucellosis, the control of herd movement outside park boundaries would become important.

7.3.3.4 Other diseases and parasites

Bison are host to many species of ectoparasites and endoparasites. The effects of parasitism can range from minimal irritation to acute or chronic disease resulting in death (Reynolds *et al.* 1982). While the effects on wild herds are minimal (Meagher 1986), confinement and on-ground feeding may enhance occurrence. Bison producers use a variety of livestock methods to treat bison for gastrointestinal nematodes, lungworms, and flukes (Jennings & Hebbring 1983). Fly problems can be reduced by feeding insecticides mixed in mineral supplements or by spreading insecticides in wallows.

Bison suffer from a range of other pathological conditions, but they are generally of incidental occurrence and do not seriously affect mortality rates in bison populations (Reynolds *et al.* 1982). Some bison producers vaccinate against diseases such as colostridium and leptospyrosis, and occasionally treat conditions such as pink-eye and hoofrot (Jennings & Hebbring 1983).

7.3.3.5 Accidents

A certain number of bison mortalities can be attributed to accidents. Accidental drowning can occur during the crossing of rotten ice, flooding rivers, or by being trapped during abnormal spring flooding (Reynolds *et al.* 1982). These occurrences can sometimes involve hundreds of animals and result in considerable mortality (Fuller 1962; Roe 1970). Forest fires in northern bison ranges rarely cause appreciable mortality (Soper 1941; Fuller 1962). However, prairie wildfires in the past have decimated [illegible] herds (Roe 1970).

An additional cause of mortality for free-ranging bison in Banff National Park could be bison-vehicle collisions along railways and roadways. A few bison fatalities resulting from vehicles have occurred in northern Canadian herds and Yellowstone National Park (Fuller 1962, Reynolds *et al.* 1982, Meagher pers. comm. 1986). In Yellowstone National Park, about two bison-vehicle accidents occur each year, caused largely by drivers familiar with the roads, driving at speeds too fast for good visibility (Meagher pers. comm. 1986). In Jasper National Park, two of the animals from the failed wood bison re-introduction in 1978 were killed by trains and one by a truck (Holroyd & Van Tighem 1983). Although fencing of the twinned Trans-Canada Highway in Banff National park has reduced wildlife-vehicle collisions, incidents still occur along unfenced roadways and the railway.

7.3.4 Population structure and growth

The age-sex class distributions of five bison herds are shown in Table 10. The population structures of the free-ranging herds only approximate those that would be found under natural population regulation, as at the time of studies, all four herds were influenced by either slaughter or hunting for population control and management. The population structure of the National Bison Range herd provides an example of a herd that is managed to maintain a healthy, vigorous population and provide a suitable age and sex class distribution for visitor viewing. In a stable population the proportion of calves in [illegible] herds may be 15

Table 10. Age-sex class distribution for five bison herds.

*Herd	(%) Calves	(%) Yearlings	(%) 2-3 Year Olds		(%) Adult Females	(%) Adult Males
WBNP	16	9	15		39	21
YNP	22	17	16		28	16
UTAH	21	13	no data		36	30
			(%) 2yr	(%) 3yr	(%) 4-10yr	(%) +10yr
NBR	25	15	10-15	10	25-30	<10
					(57 fem:43 male)	
			(%) Subad. Females	(%) Subad. Males	(%) Adult Females	(%) Adult Males
SRL	19.7	3.7	0.7	2.4	55.7	17.6

*Location of herd, management at time of study, and source.

W3NP: Wood Buffalo National Park
Free-ranging with annual slaughter (Fuller 1960)

YNP: Yellowstone National Park
Free-ranging with annual slaughter (Meagher 1973)

UTAH: Henry Mountains, Utah
Free-ranging with annual public hunt (van Vuren 1979)

NBR: National Bison Range
Pasture rotation with annual slaughter (Rutberg 1984)

SLR: Slave River Lowlands
Free-ranging with hunting (Van Camp & Calef 1987)

to 20%, with 25% indicating a population undergoing increase (Meagher 1973). In a 1964-65 study in Yellowstone National Park, Meagher (1973) observed calf mortality to be minimal, with overwinter mortalities of 19% for yearlings and 31% for one year olds. In contrast, Fuller (1962) and Oosenbrug & Carbyn (1985) in their studies in Wood Buffalo National Park observed just over 50% calf mortality.

When favorable conditions exist, bison herds can increase rapidly to carrying capacity levels. The wood bison herd introduced to the Mackenzie Bison Sanctuary, Northwest Territories, increased from 16 animals to over 1000 in the first twenty years, an average annual increase of 25% (Reynolds *et al.* 1985). The growth of the herd can be described by an exponential equation with a growth rate of 0.215 and $r^2 = 0.985$ (Wood Bison Recovery Team 1987). Similar rapid population expansion was seen with the Yellowstone National Park bison herd following the termination of herd reductions in 1966. The herd increased steadily from 400 animals until carrying capacity was reached at 2000 animals (Meagher pers. comm. 1986). The more intensively managed plains and wood bison herds of Elk Island National Park have increased at an average annual rate of 17% and 26%, respectively (Blyth pers. comm. 1986[19]). The growth of the Elk Island National Park wood bison herd from 31 animals in 1969 to 111 in 1977 can be described by an exponential equation with a growth rate of 0.188 and $r^2 = 0.992$ (Wood Bison Recovery Team 1987).

Management of bison as a free-ranging or confined herd in Banff National Park must consider the consequences of population growth. Maintenance of desired herd size and structure is relatively simple with a confined herd. The captive Banff herd is at present highly productive, with a 100% pregnancy rate and no mortality. Herd size is controlled through biannual removal of offspring, and replacement breeding stock can be obtained from Elk Island National Park. It would be difficult to control the size or structure of a free-ranging bison population, except perhaps through hunting outside park boundaries or the introduction of new stock. Population modeling should be carried out to predict the growth pattern to be expected for a free-ranging herd in Banff National Park.

[19] C. Blyth, Park Warden, Elk Island National Park.

7.3.5 Supplemental feed, nutrients, and water

Supplemental feeding may be required during the winter for a confined herd with limited range. Bison producers report success with various hays and concentrated cattle feeds (Jennings & Hebbring 1983). Winter feeding in a park setting should not be automatic, but rather based on forage carryover and range condition, or in response to the occurrence of severe winter weather conditions, such as snow crusting which prevents efficient grazing. Feeding increases domesticity, encourages spread of disease, can cause overuse of portions of range, and results in elevated intraspecific competition and, therefore, stress.

Mineral requirements not met in the bison diet can be provided through the use of mineral licks by free-ranging animals and through the provision of mineral supplements for captive herds (McHugh 1958, Jennings & Hebbring 1983). As there is some indication that native forages may be deficient in selenium (Shaw & Reynolds 1985), consideration should be given to analysing the nutrient content of forage available to a confined herd and/or providing selenium in a mineral supplement.

Bison must have access to ponds, streams, or artificial water sources. Artificial sources can include troughs or ponds filled by water truck, artesian well systems, or by mechanically or electrically powered pumps. Artificial sources should be located so as to encourage even use of the range. In winter bison can survive on snow, but if they are being artificially fed, water should also be provided. This may necessitate breaking ice in ponds or frozen streams, hauling water, or ensuring continuous or timed interval flow with artesian or pump well systems to prevent freezing.

7.3.6 Facilities and equipment

Facilities and equipment for handling bison continue to evolve as the bison industry develops. Equipment originally designed for cattle has been adapted over the years by ranchers, wildlife sanctuary and park managers, and finally by livestock equipment manufacturers. Information on the latest technologies can be obtained from organizations such as the Alberta Game Growers Association, Canadian Bison Association, the National

Buffalo Association, and the American Bison Association, and from managers of public herds and numerous bison producers across Canada and the United States.

The facilities and equipment required for the management of a confined herd in Banff National Park are limited. Fencing is a primary concern. Options for fencing range from the present fencing, 2.4 m heavy gauge paige wire, to four strand barbed wire which is used by some bison producers. The management objectives for a confined herd would dictate the type of fencing required. If the exclusion of other ungulates was desired, a fence similar to the one now in place would be necessary. The present fence eliminates most use by other ungulates, although elk occasionally gain access to the Buffalo Paddock, likely over sections of fence which are in need of repair. Alternatively, if access to other ungulates was to be allowed, or even encouraged, a number of other fence designs could be suitable.

Although some ranchers successfully pasture bison in 1.2 m barbed wire fences, and experience at Elk Island National Park has shown 1.2 m fences to deter the entrance of bison into elk traps (Olsen, pers. comm. 1986[40]), 1.5+ m fences are generally considered more suitable for bison. Bunnage (1985) recommends six strand, 1.5 m fences for young stock and for mature stock that are accustomed to the pasture. Barbed wire is not recommended as it appears to have no deterrent effect on bison, and can cause injury. High tensile, smooth wire is gaining favor, particularly in conjunction with an offset electrical wire, which seems to work well with bison. Stronger holding pastures are required for new stock and heavy gauge paige wire fences, at least 1.5 m high, are recommended. The bison herd at Rocky Mountain House National Historic Park is enclosed by similar fencing, 1.4 m paige wire topped by a single strand of barbed wire at 1.5 m (Gaudet, pers. comm. 1987[41]). This fence has successfully contained the herd, except for a calf which slipped under the fence in a low spot.

An example of fencing designed specifically to hold bison and allow other ungulates free passage exists on the National Bison Range. Two non-domesticated herds of plains bison are rotated through a series of eight internal pastures while elk, white-tailed deer, mule

[40]W. Olsen, Park Warden, Elk Island National Park.
[41]D. Gaudet, Rocky Mountain House National Historic Park.

deer, pronghorn antelope, bighorn sheep, and mountain goats are allowed free passage. To facilitate this, the internal fences are constructed with 1.2 m of heavy-gauge woven wire strung 30.5 to 40.5 cm up from the ground, for a total fence height of 1.5 m (Malcolm, pers. comm. 1986[42]). Some fences have a barb along the top of the woven wire, but it is not believed to be necessary. Steel posts are used for all line fences with wooden posts at corners and braces. The fences are generally effective in holding bison. Problems have arisen during herding or when bulls were pastured on opposite sides of a fence. The bison will go through the fence if pushed or will jump it, usually hitting it about three-quarters of the way up and then going over (Malcolm, pers. comm. 1986). However, under similar circumstances, bison have even managed to get through the heavy duty Watchman wire fences at Elk Island National Park (Bunnage 1985). The other ungulates of the National Bison Range move freely under or over the internal fences. Bull elk easily jump the fences flat-footed and cows either jump the fences or, quite often, go under spaces as small as 40.5 cm. Mr. Malcolm has observed mixed cow-calf groups of up to 15 elk pass under the fences in a matter of seconds. If one location is used frequently for this type of under fence passage, a depression results that could allow movement of bison under the fence. The National Bison Range is presently considering the installation of braces at key places such as these, constructed with wire from the ground up to the cross brace, forcing elk to cross in the empty space above the brace. It is possible that bison will also learn to use these crossings, and the necessary brace height to discourage this has unfortunately not yet been established. Bison calves can cross under the internal fences, but rarely wander far, and once past their first winter they are generally too large.

Cattle guards or Texas gates may also be required, although it is best to avoid them if possible as bison, especially mature bulls, appear to be adept at crossing or leaping them, easily spanning distances of at least three m. The previous bison bull at the Banff Buffalo Paddock was able to cross the Texas gate, and similar occurrences have been recorded at the National Bison Range (Lott 1974), and Wind Cave National and Custer State Parks

[42]J. Malcolm, Manager, National Bison Range, Moiese, Montana.

(Petersburg 1973). There are several designs of Texas gates being successfully used at various park and private facilities. However, it is difficult to identify the *best* gate, as a structure which has successfully contained a bison herd for years, may be immediately crossed by a particularly agile or adventuresome bison introduced to the facility. In the case of private herds, this problem can usually be solved by the removal of the individual. However, as this is not as easily done with park herds, it is likely better to install the most extreme Texas gate available.

Limited handling facilities would be required for a confined herd in Banff National Park. Such facilities are necessary for handling during herd culling, for treatment of or preventative measures against disease, and possibly in the future for mandatory disease testing. To increase the efficiency of bison handling, to minimize the stress to the animals, and to ensure the safety of bison and handlers, the present Banff National Park facilities should be expanded and adapted for bison, and new facilities built if the herd is relocated. Sorting pens, an alley divided by sliding gates, a bison squeeze, and loading ramp are required. A system similar to that of Waterton Lakes National Park, or patterned after those of a number of small bison producers would be sufficient. Corral systems must be sturdy, and are usually built of either heavy planking or steel pipe. Many bison handlers recommend that the sides of pens and alleys be covered with planking or plywood to limit the vision of bison and reduce disturbance during handling. The walls of the handling facilities should be at least two m in height. Alleys should be built with sliding cutoff gates, and corners should be 45 degrees or rounded, rather than square. A squeeze with a head gate is recommended. Squeezes designed specifically for bison are available and should be used.

7.4 Human Dimensions of Bison Management in Banff National Park

7.4.1 The wildlife viewing context

The provision and management of wildlife viewing opportunities has recently become identified as a goal for wildlife management. Over the last fifteen years it has become evident that a growing number of North Americans are interested in direct contact with and observation of wildlife, in particular, nonconsumptive uses of wildlife (Burger 1979, More 1979, Wilkins & Peterson 1979, Shaw & Cooper 1980, Jackson 1982, Lyons 1982, Filion *et al.* 1983, Boyle & Samson 1985, Kellert & Brown 1985, Shaw *et al.* 1985). A comprehensive survey conducted by Statistics Canada in 1982 identified wildlife related activities as one of the most prevalent forms of recreation undertaken by Canadians fifteen years of age and over (Filion *et al.* 1983). In 1981, 3.6 million Canadians, 19.4% of the survey population (Canadians 15 years of age and over), participated in primary nonconsumptive use of wildlife through trips or outings taken specifically for that purpose. A further 8.1 million Canadians (43.9%) participated in secondary nonconsumptive use of wildlife through enjoyment gained by encountering wildlife during trips or outings taken primarily for business or pleasure. Similar percentages were obtained in a 1980 survey conducted in the United States (Shaw & Mangun 1984). These numbers indicate a potentially large demand for nonconsumptive wildlife viewing opportunities and also a potentially large impact on resources. Agencies responsible for private, urban, municipal, provincial, state, and federal wildlife resources are beginning to incorporate the needs of nonconsumptive users into their management strategies. They are actively seeking ways to facilitate the wildlife viewing experience and yet protect other resource values and uses.

Researchers and managers are developing strategies for effective management of wildlife viewing. To provide the best wildlife viewing experience possible, the manager must be aware of the desired attributes of a wildlife viewing experience, the factors which affect user interaction with wildlife, and the subsequent satisfaction gained from the encounter. User groups may have preferences as to the species, age, gender, grouping, proximity, and behavior of animals observed, the physical, social, and managerial setting of the observation, and the type, degree, and duration of interaction with the animal. These preferences reflect the knowledge, attitudes, motivations, and value systems of the nonconsumptive user group, which in turn also affect interaction and satisfaction. Many researchers have identified the need for this sort of human dimensions information to enhance the understanding and management of nonconsumptive wildlife users (Hendee & Potter 1971, More 1979, Kellert 1980, Shaw & Cooper 1980, Lyons 1982, Boyle & Samson 1985, Driver 1985, Kellert & Brown 1985). To date only a limited number of studies has been conducted to specifically address the issues of nonconsumptive wildlife use. However, managers and researchers can draw from the results and methodologies of studies concerning the socio-psychological aspects of leisure and recreation in general, and research addressing the human dimensions of the consumptive wildlife activities of hunting and fishing. The methodologies of these studies can be adapted to conduct studies of the nonconsumptive wildlife user to delineate the attributes of the viewing experience which will result in viewer satisfaction.

The impacts of nonconsumptive wildlife use on resources must also be identified. A much larger body of information exists for this more biological component of the management issue. While the impacts may include damage to soil and vegetation, the impacts of primary concern are those on wildlife. Several recent reviews have outlined the effects of nonconsumptive recreation on wildlife (Cornish *et al.* 1980, Ream 1980, Vaske *et al.* 1983, Boyle & Samson 1985). As described in these reviews, the impacts of observers on wildlife can include harassment, loss of habitat, habituation, reduced productivity and even death. Researchers have identified a variety of factors that influence the response or vulnerability of wildlife to encounters with humans. The wildlife species and its feeding and breeding characteristics, the type, degree, and length of the encounter, the age and general health of the animals in question, the number of animals in the group, the availability of refuges from disturbance, the past experience of the animals with humans, and the season and weather conditions are all important factors. It is necessary for wildlife managers to recognize these factors and carefully assess the degree of vulnerability of wildlife species present in an area which receives or is to be managed to accommodate wildlife viewing pressures.

This study provides an opportunity to examine another facet of nonconsumptive wildlife use. While studies have been conducted to ide[illegible] the desired attributes of wildlife viewing, little work has been done to actually quantify the attributes provided by a given wildlife management scenario. The observation of bison in the Buffalo Paddock possesses many of the elements of a wildlife viewing experience, despite the confined nature of the herd. In fact, its confined nature eliminates a number of variables such as the presence of other wildlife species, the use of the area for other activities, and large variations in wildlife numbers or locations. The Buffalo Paddock, therefore, provides a somewhat controlled situation in which to describe the attributes of the bison viewing opportunity, to quantify visitor use, and to examine bison-visitor interaction. Information obtained can be used to evaluate the alternatives for bison management, to identify qualities for relocation sites, and to recommend design, interpretation, habitat, and management considerations for visitor viewing of captive and, to some extent, free-ranging bison. The methods developed can be adapted and expanded for evaluating wildlife viewing opportunities and predicting visitor use and interaction with wildlife in other situations.

7.4.2 Bison-human interaction

7.4.2.1 Bison handling

The reaction of bison to handling has been studied at Wood Buffalo (Hudson *et al.* 1976) and Elk Island National Parks (Blyth, pers. comm. 1986). Reactions to the stress imposed by handling can be both behavioral and physiological, with the effects ranging from temporary to fatal. The most obvious behavioral manifestations of handling stress are redirected aggression in the form of head butting, goring, pushing, and kicking, and frantic attempts at escape. Both can result in serious injury. Fear induced immobility is another behavioral response which slows the movement of animals through the facility, thereby increasing the stress imposed upon them. Milder behavioral responses indicating stress include running away, wallowing, tail lifting, urination, vocalizations, and pawing the ground. Physiological manifestations of handling stress include hyperthermia, neurogenic shock, and spontaneous abortion. Bison may also exhibit delayed reactions to stress for several weeks after handling. Some examples of delayed reaction are capture myopathy (white muscle stress syndrome), infection of wounds, and stress-induced diseases similar to the shipping-fever complex of domestic animals, all of which can be fatal. Although most aggression during handling is directed towards other bison, several horses and workers have been chased and some gored by bison during handling operations (McHugh 1972, Dary 1974, Reynolds *et al.* 1982).

Caution, skill, and adequate facilities are necessary to safely handle bison. Even with a small herd, such as exists at present in Banff National Park, some handling facilities, as described in Section 7.3.6, are required to reduce stress and prevent injuries to the bison and handlers. Measures which have been found to reduce handling stress and injury include conducting operations during cool weather or sprinkling animals with water, designing an efficient system to minimize the length of time spent by animals in the handling facilities, sorting animals by dominance or age-class, moving individual animals mainly by prodding rather than by excessive shouting so efforts stimulate the desired animal without increasing the emotional tension of the entire herd, and keeping animals visually separated from handlers when possible. Low-stress handling in Banff National Park would be simplified by the small size of a captive herd. However, some animals may remain several years, necessitating repeated handling. Ranchers have found that bison learn quickly, and in repeat handling situations, animals must be treated carefully so as to prevent the development of extremely panicky or aggressive reactions to handling.

7.4.2.2 Bison observation or chance encounters

The reaction of bison and bison herds to man in the observer or park visitor role, varies from shy timidity to stolid indifference, and from frantic flight to overt aggression. In a national park setting, the effects of bison-human interaction on both the animal and the park visitor are important. Resource protection and public safety concerns would have to be addressed for either a confined or free-ranging bison herd in Banff National Park.

As previously stated, the impacts of observers on wildlife can include harassment, habitat loss, habituation, and reduced productivity. Harassment, as defined by Ream

(1980) includes events that cause excitement and/or stress, disturbance of essential activities, severe exertion, displacement, and sometimes death. Harassment can be either intentional or unintentional. Several authors suggest that the major impacts of nonconsumptive use on wildlife result from observers who unknowingly produce stressful situations for wildlife. As reported by various researchers, bison are susceptible to harassment by human observers.

The most commonly reported reactions of bison to humans are flight and aggression. The degree of wariness and distance of flight seems to be variable. A hunted population of bison studied by Van Vuren (1979) in the Henry Mountains of Utah were extremely wary when humans were present. Detection by either sight or smell usually caused them to stampede for up to 5.0 km with an average flight distance of 1.8 km. These bison tolerated human presence to 400 m, but only if the bison were on a steep slope above the person. The Hayden herd of Yellowstone National Park studied by McHugh (1958) paid little attention to people walking 0.8 to 1.3 km away, if neither noise nor scent could be detected. However they became alarmed if people approached closer, and would stampede without hesitation at the scent of humans, even if they were not visible. Soper (1941) found that bison in open areas of Wood Buffalo National Park would allow people to get within 100 m and would then flee. In a study of nordic skier interaction with ungulates in Elk Island National Park, Ferguson (1980) noted that escape behavior by bison occurred more often when skiers stopped to watch than when they continued skiing. This variation in response by bison may be related to their degree of familiarity or previous experience with people, the nature of the interaction with people, whether or not the bison are hunted, and the type of escape terrain available to them.

Other variations in behavior exist between bull and cow groups. Bulls and bull groups are generally less wary than cow groups and their flight distances are shorter (Soper 1941, McHugh 1958, 1972, Petersburg 1973). McHugh (1958) observed flight distances of less than 90 m for bulls in Yellowstone National Park and from 60 to 300 m for cows. This trait means that bulls are often the primary display animals in parks. However, it also means that they are involved in more aggressive encounters with observers than are cows. Their seeming indifference tempts observers to get so close, that there is little chance of escape if a bull does decide to react aggressively. As well, aggressive behavior by bull bison towards both vehicles and people is elevated during the rut (Soper 1941, Herrig & Haugen 1969, Petersburg 1973). Cow groups are less approachable during and after calving, when they move away more quickly, and flee a greater distance (McHugh 1958, Engelhard 1970). However, cows will also behave aggressively towards people, particularly when they feel their calves are being threatened (McHugh 1958, Fuller 1960). As their calves mature, cow groups become more approachable, instances of aggression decrease, and flight distances lessen. McHugh (1958) observed the flight distance of the Hayden herd in Yellowstone National Park to decrease from 300 to 450 m in the summer, to 90 to 180 m in November, to as low as 60 m in December.

Bison likely exhibit other signs of harassment that are not reported by most observers because they are less obvious. These signs could include previously described indicators of stress such as wallowing, tail lifting, and vocalizations, or behavioral modifications such as altered feeding and herd movement patterns. If feeding patterns are altered to the point where bison avoid areas in which they are exposed to people, the loss of habitat can occur. The wariness of cow groups can be seen as a form of habitat loss. Areas near roads and/or frequented by people are rarely used by cow groups with young calves.

Habituation of wildlife to humans can have beneficial as well as detrimental effects. Habituated animals experience lower stress levels when in contact with humans. However, they also lose their fear of man and can become more aggressive. Increased mortality on roads, vulnerability to poaching, and nuisance problems can result. Similar to other wildlife species, bison become more easily habituated to vehicles than to humans on foot, and will neither flee as often nor as far from them (Fuller 1960, Engelhard

1979, Van Vuren 1979). Under domesticated circumstances, bison can become approachable, but never really become completely tame. There are several cases of "tame" bison eventually turning on and even killing their owners and handlers (Roe 1970, Dary 1974).

Harassment, habitat loss, and habituation can all lead to reduced productivity at the individual, or in severe cases, at the population level. Actions that produce extreme stress on pregnant cows or interfere with the breeding, birthing, or care of young calves, are likely to reduce productivity of a captive or free ranging bison.

Bison human interactions that affect the safety of visitors [illegible] of concern to park managers. One of the reactions of bison to harassment or stress is aggression. The degree of aggression bison display towards people can range from threat posturing (vocalizations, elevation of the tail, pawing, wallowing, side presentation, head nodding), to bluff charges, to full scale charges accompanied by hooking, goring, and trampling. Aggressive reactions by bison generally occur when people approach them "too closely". However, this critical distance seems to be extremely variable, and direct approach towards bison at any distance is risky without adequate means of escape. Many people have been only bluff-charged by bison, but others have been chased, butted, and gored resulting in injuries varying from minor cuts and bruises to severe lacerations and death (McHugh 1972, Dary 1974, Meagher pers. comm. 1986).

Although several encounters are believed to have occurred between bison and visitors in Canadian national park herds, few serious incidents have been recorded. On record are two gorings, one in Prince Albert National Park (Anions, pers. comm. 1987), and one in Waterton Lakes National Park in July 1984 (Tilson, pers. comm. 1986). In Elk Island National Park, reports of aggressive free-ranging bison are received about three to five times per year. These situations are normally managed by trail closures. However, one unusually aggressive bull was destroyed in 1983-84 (Graham, pers. comm. 1987)[41] Many less serious incidents in these and other parks go unrecorded because

---

[41]Mr. D. Graham, Park Warden, Elk Island National Park.

visitors are essentially unhurt or because they have disobeyed signage requesting that they remain in their vehicles and therefore do not wish to report the incident.

A number of serious bison-human encounters have occurred over the [illegible] Yellowstone National Park (Meagher pers. comm. 1986). In 1971, the park recorded its first bison caused fatality. However, in general the occurrence of aggressive encounters was still fairly low, with about one injury being recorded every three to four years. By the late 1970s, the injury rate had increased to one injury in every two years and in [illegible] there were twelve incidents, including one fatality. No incidents were recorded in [illegible], but in 1985 ten bison-human encounters had occurred by the end of July. The [illegible] issued a warning pamphlet in July of 1985 which seemed effective in preventing further encounters that summer. Dr. Mary Meagher, a research biologist at Yellowstone National Park, attributes the increase in bison-human interaction to increased visitor numbers combined with the presence of more bison close to roads, and more bulls frequenting the housing areas. The gradual expansion of bison habitat is a product of the niching-in process which has occurred as the population has increased to carrying capacity in the park. The pamphlet appears to be helping at present to reduce bison-human conflicts in Yellowstone National Park by warning visitors of the danger of wild bison and cautioning them to keep their distance. The distribution of a warning pamphlet has also been implemented at Elk Island National Park to inform visitors of the presence of free-ranging bison and the dangers of approaching the animals.

Bison-vehicle collisions could present a public safety concern if a free ranging herd were established in a high traffic area (see Section 7.3.3.5). Measures taken to reduce the incidence of vehicle-wildlife collisions, such as fence construction, improved visibility, and reduced speed limits, would likely be as effective for bison as for other large ungulates.

To effectively manage bison-human interactions in Banff National Park [illegible] information and awareness would be necessary. In a confined or free ranging situation harassment and public safety concerns could be addressed through information, interpretation, and facility design. However, as with any other large ungulate, some risk of harassment, vehicular accidents, and visitor encounters with aggressive animals would always remain.

8. RESULTS III. ANALYSIS OF BISON HABITAT

8.1 Ecosite and Winter Range Identification

As discussed in Section 7.1.3, studies have identified grasses and sedges as the primary foods of bison, with sedges being particularly important in winter. Therefore, in the first step of the Ecosite identification outlined in the methodology, vegetation types were identified which were comprised of at least 20% grass and grass-like species. The results of this broad selection procedure included all vegetation types that could contribute even marginally to the bison diet. The process identified 37 vegetation types, thirteen of which had grass or grass-like cover to at least 50% (Table 11). Of these 37 types, fifteen are closed forest, five open forest, five shrub, one low shrub-herb, and ten herb-dwarf shrub vegetation types. Based on these vegetation types, 52 Ecosites were then identified (Table 12). As these Ecosites range from marginal to primary bison forage habitat, each must be examined individually. While, for some Ecosites, all dominant vegetation types are suitable (*e.g.* BV1: C9, C18, C19), for other Ecosites, suitable vegetation types may comprise only one half (*e.g.* CA4: C19 C20) to two-thirds (*e.g.* AT1: C3, C6, C19) of the dominant vegetation types (see Tables 11 and 12 for explanation of codes). Other Ecosites with wet dry patterns, namely AZ1, BK6, CA1, CV1, MC1, and PL5, only have suitable vegetation types on the wet portions, representing only 30% of mapped units for all but MC1, where it is 80%. Another exception is found with Ecosite PR4 where suitable vegetation types exist only on southerly exposures. The habitat types represented by these 52 Ecosites also vary widely, including closed forests (24), open forests (2), shrub meadows (4), grasslands (4), wet herb meadows and sedge fens (3), and combination habitats composed of open and closed forest, shrub, and herb-dwarf shrub vegetation types (15).

Due to the opportunity for site manipulation and supplemental feeding, all of these Ecosites could be considered for the identification of paddock relocation sites. However, this level of Ecosite identification was not sufficiently precise for examining the availability of forage habitat for free-ranging bison. The forested Ecosites and forested portions of

Table 11. Vegetation types with at least 20% cover for grass and grass-like species.

Closed Forest Vegetation Types	
C1	Douglas fir/hairy wild rye
*C4	white spruce/prickly rose/horsetail
C6	lodgepole pine/buffaloberry/showy aster
C9	lodgepole pine/dwarf billberry
C16	aspen/hairy wild rye-peavine
C17	balsam poplar/buffaloberry
C18	lodgepole pine/buffaloberry/grouseberry
C19	lodgepole pine/buffaloberry/twinflower
*C22	aspen/hairy wild rye-showy aster
C26	white spruce/buffaloberry/fern moss
C27	white spruce/prickly rose/fern moss
*C28	balsam poplar/horsetail
*C32	Engelmann spruce/horsetail/feathermoss
C33	Engelmann spruce/hairy wild rye
C36	lodgepole pine-white spruce/willow/hairy wild rye
C37	white spruce/buffaloberry/feathermoss
Open Forest Vegetation Types	
O3	white spruce/shrubby cinquefoil/bearberry
O5	Douglas fir/juniper/bearberry
*O6	Engelmann spruce-subalpine fir/willow/ribbed bog moss
O11	spruce/labrador tea/brown moss
*O18	Engelmann spruce-subalpine fir/willow/hairy wild rye
Shrub Vegetation Types	
*S1	dwarf birch-shrubby cinquefoil-willow/brown moss
S7	willow/horsetail
S10	willow-dwarf birch-shrubby cinquefoil
S11	willow/timber oatgrass
S12	willow/hairy wild rye
Herb-Dwarf Shrub Vegetation Types	
*H2	black alpine sedge-everlasting
*H5	hairy wild rye-wild strawberry-fireweed
H6	junegrass-pasture sage-wild blue flax
*H7	wheatgrass-pasture sage
H9	mountain marigold-globeflower
*H11	water sedge-beaked sedge
H13	Richardson needlegrass-junegrass-everlasting
*H14	hairy wild rye-junegrass-bearberry
H15	mountain avens-curly sedge
*H19	bluebunch wheatgrass-hairy wild rye-showy aster
Low Herb-Shrub Types	
L1	shrubby cinquefoil/bearberry-northern bedstraw

*at least 50% cover

Table 12. Ecosites for which vegetation types with at least 20% cover for grass and grass-like species are dominant or codominant.

AL1	lodgepole pine forest (C19)
AT1	lodgepole pine forest (C3, C6, C19)
AZ1	Dry 70%:
	Engelmann spruce-subalpine fir open forest (O10)
	Wet 30%:
	wet shrub thicket (S8)
	wet herb meadow (H9)
BK1	Dry 70%:
	lodgepole pine forest (C18, C19)
	Wet 30%:
	wet spruce open forest (O11)
	wet shrubby meadow (S1)
	birch fen (S3)
BK4	Dry 70%:
	lodgepole pine forest (C18, C19)
	Wet 30%:
	wet spruce open forest (O11)
	wet shrubby meadow (S1)
	birch fen (S3)
BK6	Dry 70%:
	Engelmann spruce-subalpine fir forest (C13)
	Wet 30%:
	wet spruce open forest (O11)
	wet shrubby meadow (S1)
	birch fen (S3)
BV1	lodgepole pine forest (C9, C18, C19)
CA1	Dry 70%:
	Engelmann spruce-subalpine fir forest (C14,C13,C21)
	Wet 30%:
	wet spruce open forest (O11)
	wet Engelmann spruce-subalpine fir open forest (O14)
	w[illegible] shrubby meadow (S1)
	birch fen (S3)
CA4	lodgepole pine fores[illegible] C20)
CN1	dry shrub thicket (S[illegible]
	moist shrub thicket
CV1	Wet 80%:
	wet spruce open forest [illegible]11)
	wet Engelmann spruce-subalpine fir open forest (O14)
	>wet shrubby meadow (S1)
	birch fen (S3)
	Dry 20%:
	Engelmann spruce-subalpine forest (C13)
	lodgepole pine forest (C20, C29)
FR1	lodgepole pine forest (C6, C19)
GA1	lodgepole pine forest (C3, C6, C19)

(Cont.)

Table 12. (Continued)

GT2	Northerly:
	lodgepole pine forest (C6, C19)
	Southerly:
	dry grassland (H14)
	low shrub-herb meadow (L1)
HC1	moist Engelmann spruce forest (C32)
	wet Engelmann spruce-supalpine fir open forest (O6)
	>wet shrubby meadow (S1)
	birch fen (S3)
HC2	sedge fen (H11)
HC4	wet shrubby meadow (S1)
	birch fen (S3)
	wet shrub thicket (S11)
	sedge fen (H11)
HD1	aspen forest (C16)
HD2	spruce open forest (O3)
HD3	white spruce forest (C2, C26, C27)
	white spruce-Douglas fir forest (C5)
HD4	grassland (H6)
	>lodgepole pine forest (C3)
IB1	lodgepole pine forest (C18, C19, C29)
MC1	Wet 80%:
	spruce open forest (O11)
	birch fen (S3)
	Dry 20%:
	lodgepole pine forest (C29)
	Engelmann spruce-subalpine fir forest (C30)
ML2	lodgepole pine forest (C18, C20)
NT2	wet shrub thicket (S8)
	moist shrub thicket (S4, S11)
NT3	wet herb meadow (H9)
	cottongrass fen (H10)
	sedge fen (H11)
NY1	lodgepole pine forest (C6)
	Douglas fir forest (C1)
NY3	Northerly:
	white spruce-Douglas fir forest (C5)
	lodgepole pine forest (C19)
	Southerly:
	Douglas fir open and closed forest (O5, C1)
	low shrub-herb meadow (L1)
PL5	Dry 70%:
	Engelmann spruce-subalpine fir closed and open forest (C15, O10)
	subalpine larch-subalpine fir forest (C23)
	Wet 30%:
	wet shrub thicket (S8, S11)
PP1	lodgepole pine forest (C19, C3, C6)

(Cont.)

Table 12. (Continued)

PP6	Engelmann spruce-subalpine fir open forest (O18)
	white spruce open forest (O17)
PP7	shrubby meadow (S9)
	shrub thicket (S10)
PR2	lodgepole pine forest (C6, C18, C19)
PR3	lodgepole pine forest (C18, C19)
PR4	Northerly:
	Engelmann spruce-subalpine fir forest (C13, C14)
	Southerly:
	lodgepole pine forest (C3, C6, C19)
PR6	lodgepole pine forest (C11, C18, C19, C29)
PT1	lodgepole pine forest (C6, C19)
PT3	lodgepole pine forest (C3, C6, C19)
PT5	Dry 60%:
	lodgepole pine forest (C6, C11, C19)
	Wet 40%:
	black spruce-lodgepole pine forest (C8)
	spruce open forest (O11)
SB3	lodgepole pine forest (C3, C6, C19)
SB5	grassland (H14)
SP1	lodgepole pine forest (C18, C19)
TA3	white spruce forest (C2, C26, C27)
TR1	dry shrub thicket (S10)
	moist shrub thicket (S12)
	Engelmann spruce-subalpine fir open forest (O18)
TR2	grassy tundra (H4)
	dry grassland (H14)
VD2	lodgepole pine forest (C19, C20)
VL1	sedge fen (H11)
	>wet shrubby meadow (S1)
	wet shrub thicket (S7)
VL3	wet white spruce forest (C4)
	>shrubby meadow (S1)
	wet shrub thicket (S7)
VL4	wet white spruce forest (C4)
VL5	wet shrub thickey (S7)
WF4	Engelmann spruce forest (C33)
WF7	grassland (H14)
	shrub thicket (S10)
	grassy tundra (H4)

Ecosites would pro only minimal amounts of forage, and would used by bison largely a cover and travel r at. Primary bison forage habitat would be provided by the grassland and sedge fen Ecosite and portions of Ecosites. Therefore, the second stage of the Ecosite identification process was conducted to identify these Ecosites. Nine vegetation types that are grasslands and sedge fens were identified (H2, H5, H6, H7, H11, H13, H14, H15, H19), however, only three of these vegetation types (H6, H11, H14) occupied major portions of Ecosites. Ecosite selection based on these three vegetation types identified nine Ecosites capable of providing *primary* bison forage habitat (Table 13).

There are however, constraints found with each of these nine Ecosites that must be recognized and, as previously mentioned, could be evaluated by on-site study as required. For example, the sedge fens of the HC2, HC4, NT3, and VL1 Ecosites may be inaccessible during periods of high water and of limited winter use in the event of a high water freeze. The areal extent of some sedge fens in sedge fen +SC complex units may be limited since the SC area may have little or no vegetation cover, and may occupy 20 to 80% of a tract. As the HD4 grasslands are extremely restricted in area, and occur in heavily developed, high-use areas, their availability to bison is limited. The steepest slopes of the GT2 (South), SB5, TR2, and WF7 grassland Ecosites, that range to 42° (*i.e.* 90%), may not be fully utilized by bison even though bison are known to forage on slopes up to 40°(*i.e.* 84%). The forage value of the mixed sedge fen Ecosites (HC4, NT3), would depend on the site-specific proportion and productivity of the sedge component, and the location of the Ecosite in relation to other bison forage habitat types. In addition, the shrub components of the HC4, VL1 and WF7 Ecosites, willows in particular, may provide suitable bison forage in the absence of adequate grasses and sedges. Finally, there is a seasonal element d in Ecosite suitability, as some of the Ecosites would be inaccessible to bison in winte

For a free-ranging bison herd, the critical forage habitat component would be the presence of suitable winter range. Winter snow depth would generally confine bison to the Lower Subalpine and Montane in the winter. For the purpose of identifying possible winter range, Ecosites with maximum snow depths of less than one meter were deemed to be

Table 13. Matrix of open grassland and sedge fen vegetation types and corresponding Ecosites showing Ecosites with suitable winter snow depths.

Ecosite	Vegetation Type H6	H11	H14	Suitable Winter Snow Depth
GT2			X	X
HC2		X		X
HC4		X		X
HD4	X			X
NT3		X		
SB5			X	X
TR2			X	
VL1		X		X
WF7			X	

suitable. Of the nine *primary* forage habitat Ecosites, six have suitable snow depth characteristics for wintering bison (Table 13). It must be recognized that this Ecosite selection by snow depth only provides a rough guideline to identifying winter range. Subject to local crusting conditions, or in combination with severe winter weather or increased snow density, one meter of snow could be excessive for foraging and traveling bison.

Based on the distribution of these six Ecosites in Banff National Park, and considering the existence of other marginal habitat and the degree of present winter use by elk, three areas were identified to be suitable for wintering bison (Figure 10). The sedge fen-stream channel complex (VL1+SC) and grassy slopes (NY3) of the lower Howse and North Saskatchewan Rivers could provide adequate winter habitat for a small number of bison. Historical reports record bison wintering in the Howse valley as far west as "Kootenay Park" at Glacier River. The number of bison that the area could support depends upon the productivity and areal extent of sedge cover on the river flats. This would have to be determined by field survey. Suitable bison winter range also exists in the lower Red Deer River valley. The grassy slopes (GT2, SB5) combined with sedge fens and grasslands scattered in the open spruce forest (HC1) and shrub meadows (HC4, PP7), could provide bison forage. Although snow depths are greater here, they are not excessive, as elk winter successfully in the valley. Given favorable snow conditions, additional habitat would be provided by the shrubland portions of the BK4, BK6, and PP6 Ecosites of the valley bottom. The third possible winter range identified is the Bow River valley below Castle Mountain. Grassland and grassy slopes (HD4, NY3, SB5) and the sedge fens (VL1) and shrublands (HC4, VL1, VL5) of the Bow River floodplain would provide the major bison forage habitat. The grassland openings of the aspen forests (HC1) and shrubland component of the VL3 Ecosite would also be important. These three areas provide the largest continuous areas of suitable winter habitat. However, other areas such as the middle Cascade watershed and the Panther and Dormer River valleys could provide additional winter bison range.

All three of these valleys have been identified as historical bison range. However, it is not clear whether they were used in winter by cow-calf groups or only by bulls. Favorable

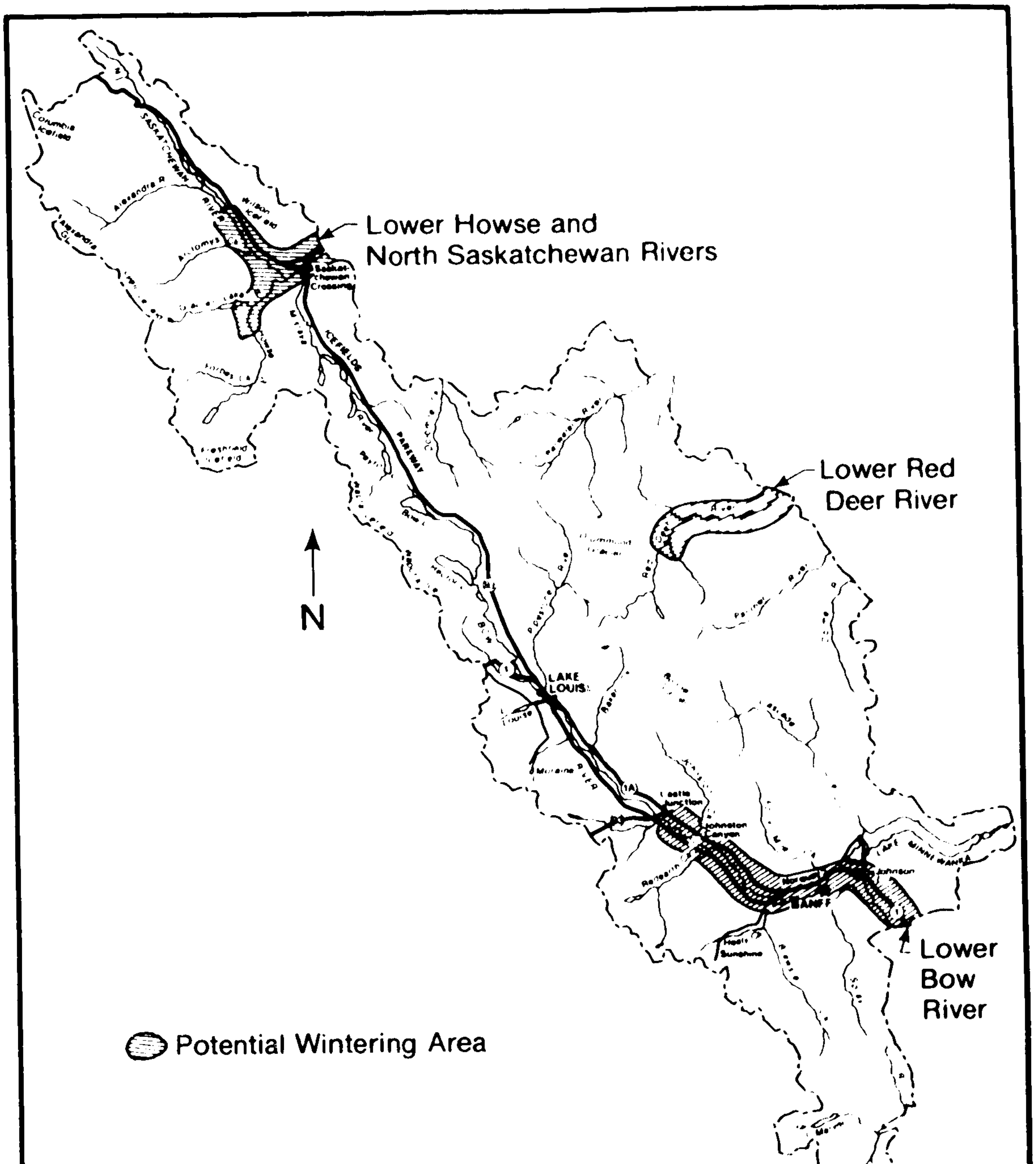


Figure 10. Location of potential wintering areas for free-ranging bison in Banff National Park.

winter habitat lies in the foothills outside each of these valleys, and a free-ranging bison herd would likely expand its winter range to include these areas. As discussed in Section 7.3.1, this range expansion outside the park would require that several issues of concern be addressed. The land which lies outside the park on the Red Deer River is somewhat of a special case, as it is federally controlled. Government horses for use in the local national parks are raised on the Ya Ha Tinda Ranch. Habitat here is suitable for bison, however, the ranch is already used by wintering horses and elk. The presence of free-ranging bison in the Bow or North Saskatchewan River valleys could present conflicts with present visitor use. It is also in these two valleys that bison could be involved in bison-vehicle collisions and opportunities for aggressive encounters with visitors would be most frequent.

As the ELC is not site-specific, the level of information and accuracy provided is obviously lower than that which could be achieved with an in-depth field habitat study. However, this interpretation of ELC data provides the background information required for the general review of alternatives, and provides a framework for preliminary evaluation of bison habitat that can be used by resource managers. Field studies could later be conducted on the most promising sites to provide site-specific information on plant species composition, site-productivity, and associated carrying capacity estimates, local snow conditions and their influence on seasonal forage availability, and the predicted degree of interspecific competition and conflicts with present land use as dictated by expected bison use patterns.

8.2 Paddock Relocation Site Selection and On-site Reconnaissance

To determine the feasibility of the fifth alternative, relocation of the Buffalo Paddock, a number of possible paddock sites were identified and described. The purpose of this exercise was not to select the best relocation site, but rather to provide background information for the review of alternatives regarding the nature of suitable sites available. Ten areas were identified as possible relocation sites (Table 14, Figure 11) and initial on-site reconnaissances were conducted as described in Section 5.2.2.

Table 14. Possible paddock relocation sites.

Carrot Creek
Cascade Pits
Hillsdale Meadows
*Indian Grounds
Johnson Lake
*Lower Bankhead
*Muleshoe
*Old Dump Site on Two Jack Road
*Second Vermilion Lake
*Upper Bankhead

*Eliminated after initial reconnaissance.

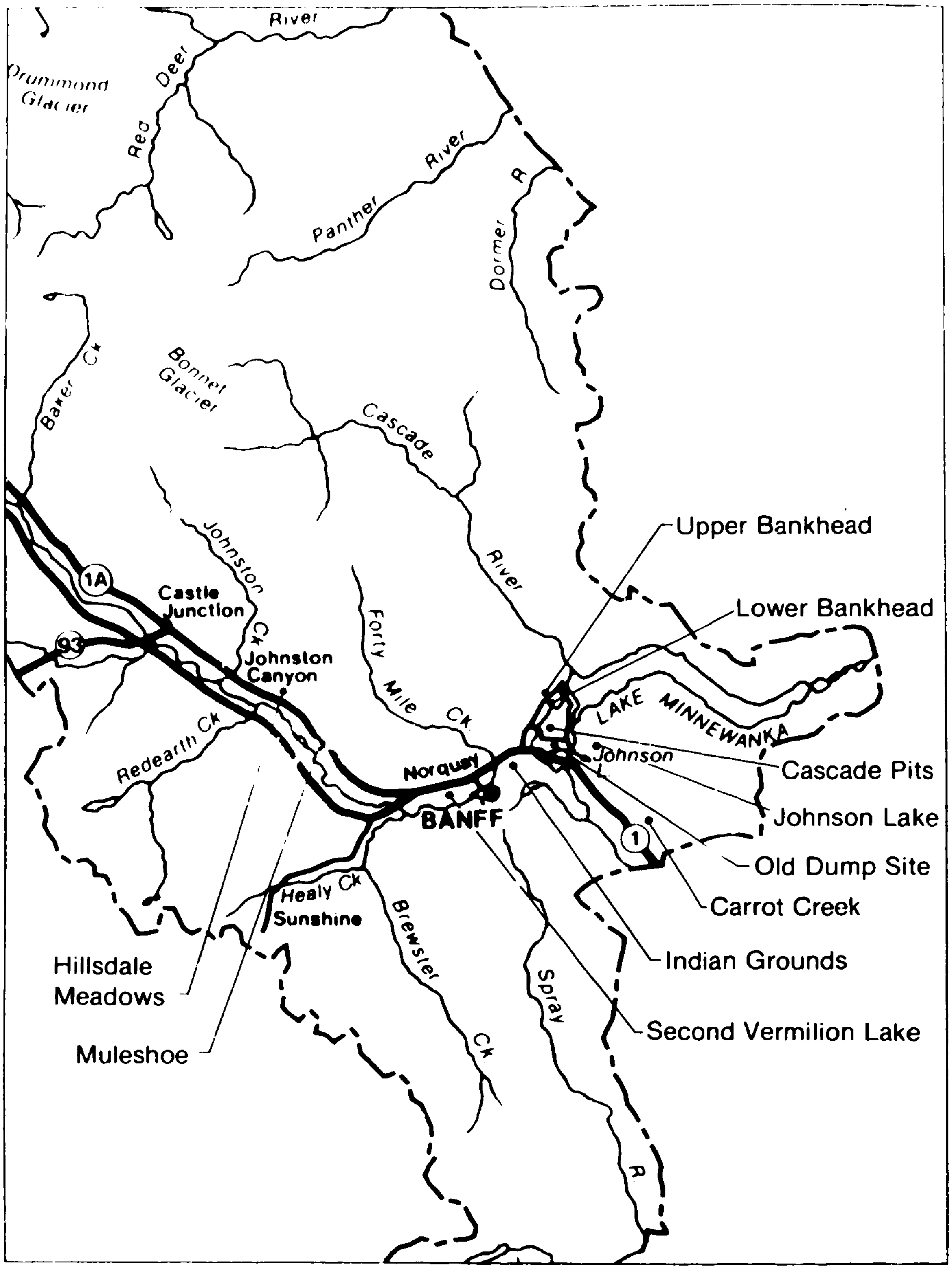


Figure 11. Location of possible paddock relocation sites in Banff National Park.

All ten locations could meet the forage and cover requirements of bison with varying degrees of site rehabilitation, clearing, thinning, and supplemental feeding. Improved water sources would be necessary for some of the sites, but installation is feasible in all. However, initial reconnaissance revealed that not all of the sites would fulfill the primary advantages of the relocation alternative, namely, eliminating the barrier to wildlife movement in the congested Banff Townsite area and providing a facility for visitors to view bison in a natural setting. Six sites were therefore eliminated as outlined below.

The historical coal mining sites of Upper and Lower Bankhead contain old building foundations, slag heaps, equipment, and interpretive exhibits. These physical structures and the present visitor use of the sites would be incompatible with bison viewing and interpretation. Therefore, the sites were eliminated from further consideration.

The Old Dump Site on Two Jack Road is the level, reclaimed surface of a garbage dump, intersected by the road. The area has obviously been mechanically cleared and has abrupt forest edges on all sides. The site is situated on a hillside with moderately steep forested slopes above and below. The downhill slope of the covered dump is extremely steep. These factors combine to limit the area available for paddock construction to the presently rehabilitated area. This would allow only a small paddock and present an artificial environment which would at best be a display-type paddock. As this would not provide a quality bison viewing experience, this site was eliminated

The construction of a paddock on the Indian Grounds would impact present wildlife use and create a barrier to wildlife movement. The area is small and relatively open and the fence would be highly visible, presenting a less natural setting for bison viewing. As this site makes no improvement in wildlife movement in the Banff Townsite area and does not provide as good a viewing opportunity as the present Buffalo Paddock, the site was eliminated.

The Muleshoe and Second Vermilion Lake sites include aspen forest and wet meadow habitat. The Muleshoe site is intersected or bordered by the Bow Valley Parkway, the Canadian Pacific Railway, and a power line right-of-way, and includes a picnic area. The Second Vermilion Lake site is intersected by the Vermilion Lakes Road which receives considerable pedestrian and cyclist traffic and lies between Second Vermilion Lake and the way. The wetland areas of both sites are subject to flooding, further n and construction of necessary facilities. The configuration of the and present development would make it impossible to design a paddocks ow visitors to view bison in a natural setting. Conflicts with other visitor uses would also arise. Therefore, these sites were eliminated.

A second reconnaissance was then conducted on the remaining four sites; the Carrot Creek, Cascade Pits, Hillsdale Meadows, and Johnson Lake sites[44]. For each site, the ability of the site to meet bison requirements, the degree of environmental compatibility expected with the introduction of a paddock, the way the site addressed visitor use concerns, and the cost effectiveness of the relocation were described. The general configuration of the four sites is described below and summary descriptions are provided in Tables 15 through 18.

The Carrot Creek site is located 14 km east of Banff on the Trans-Canada Highway. It is based on 75 ha of aspen forest (HD1) surrounding a recently abandoned trade waste pit. Lodgepole pine forest (PT1 and AT1) surrounds the core on the east, west and north sides and the Trans-Canada Highway forms the south boundary. Carrot Creek flows through the site. A summary description of this site is presented in Table 15.

The Cascade Pits site is located along the Two Jack Lake Road, five km east and north of Banff. The site is based upon a 10 ha abandoned gravel pit. The Cascade River flows through open spruce forest (HD2) to the north and west of the site. The site is bounded by an aspen forest (HD1) covered slope and the Minnewanka/Two Jack Lake Road to the west, a lodgepole pine-white spruce (NY3, AT1) covered slope to the east, and the Two Jack Lake Road to the south. A summary description of this site is presented in Table 16.

The Hillsdale Meadows site is located in the mouth of a small valley 18 km west of Banff along the Bow Valley Parkway (1A Highway). A 25 ha grassland (HD4) forms the

---

[44]The Johnson Lake and Hillsdale Meadows sites, and the present Buffalo Paddock were reviewed with Mr. H. Reynolds of the Canadian Wildlife Service (Edmonton, Alberta).

Table 15. Summary for second-round reconnaissance of Carrot Creek paddock relocation site.

Location of Site: Carrot Creek

1. Bison Requirements
   a) Forage medium; aspen forest with some open meadows beginning to infill with white spruce, lodgepole pine forest with little forage, some clearing/thinning required; open meadow following revegetation of old trade waste pit; likely will have to provide supplemental feed
   b) Cover high; aspen forest; some lodgepole pine forest along edge of site could be included
   c) Water high; Carrot Creek along the NW side of site could be included in paddock

2. Environmental Compatibility
   a) Wildlife medium; would eliminate moderate present use by ungulates; would be a barrier to local movement
   b) Vegetation/Soil medium; portions previously disturbed; clearing/thinning required for habitat and visibility; few problems with construction or erosion forseen; fence construction will impact creek
   c) Visual/Aesthetic high; not visible from TCH

3. Visitor Use
   a) Compatibility with Present/Planned Use low; Carrot Creek hiking/skiing trail passes through site; possible future site of Visitor Centre
   b) Predicted Visibility of Bison medium; periodic thinning of cover required
   c) Aesthetic Quality of Setting high; will provide a natural environment for bison viewing; design should seek to lessen visual impact of power line right-of-way
   d) Access low; approximately 14 km from Banff; not on regular scenic tour route

4. Cost Effectiveness
   a) Construction high; fencing, road, handling facilities, feed storage, interpretation, clearing/thinning, revegetation, special fencing needs to include creek for water source, reroute Carrot Creek trail
   b) Maintenance medium; distance from Banff increases cost; facility maintenance, supplemental feeding, periodic thinning

Table 16. Summary for second-round reconnaissance of Cascade Pits paddock relocation site.

Location of Site: Cascade Pits

1. Bison Requirements
  a) Forage medium; former gravel pit presently being revegetated so forage depends upon success and on species planted; white spruce forest with little forage; supplemental feed until vegetation established and likely after
  b) Cover low; white spruce forest surrounding site, but difficult to design so bison are not separated from escape cover by road; revegetation should include establishing some cover in centre of site
  c) Water high; Cascade River along N edge of site could be included in paddock; pond in center of site but winter reliability unknown; ice may have to be broken for bison

2. Environmental Compatibility
  a) Wildlife medium; would eliminate use by other ungulates which would occur after revegetation; would present partial barrier to movement up and down Cascade River
  b) Vegetation/Soil high; site previously disturbed; some recontouring may be required to maintain good visibility if Cascade River is included in paddock; few problems with construction or erosion forseen if revegetation successful; fence construction will impact river
  c) Visual/Aesthetic low; visible from Two Jack Lake Road

3. Visitor Use
  a) Compatibility with Present/Planned Use high; no present use except picnic area across the road; would eliminate opportunity for viewing other wildlife which would use area after revegetation
  b) Predicted Visibility of Bison high; however there would be conflict between providing sufficient cover and secure access to water and providing good visibility
  c) Aesthetic Quality of Setting low; lack of natural cover would lessen aesthetic appeal of site; fences visible
  d) Access high; approximately 5 km from Banff; on regular scenic tour route

4. Cost Effectiveness
  a) Construction medium; fencing, road, handling facilities, feed storage, interpretation, revegetation including establishment of cover: some recontouring and special fencing needs if include river for water source
  b) Maintenance high; facility maintenance, supplemental feeding

---

basis of the site along with 40 ha of aspen forest (HD1) to the southeast and some lodgepole pine forest on the valley floor (FR1, GA1, PT1). The site is bounded by lodgepole pine covered slopes to the northwest (GA1) and northeast (PT1) and the Bow Valley Parkway along the southwest side. An intermittent stream flows through the site. A summary description of this site is presented in Table 17.

The Johnson Lake site encompasses an area northeast of Johnson Lake, which is located 10 km east and north of Banff, off the Two Jack Lake Road. The site is based upon 40 ha of aspen forest (HD1) and 25 ha of sedge fen wet shrub meadow and open spruce forest habitat (PT5) located along a small creek which flows through the site. Lodgepole pine covered slopes rise gradually from the site on the north (PT5, NY1) and east (PT1, PT5) sides. The site is bounded by the access road to Johnson Lake on the west side and a lodgepole pine-Douglas fir covered ridge and Johnson Lake to the south. A summary description of this site is presented in Table 18.

Relative merit values were assigned for each variable and are indicated in the summary tables and illustrated in matrix form in Table 19. The matrix provides a systematic basis for comparing relocation sites. The best site could be identified by assigning number values to the merit rankings and weights to the various categories and/or variables within categories. The end result of such an exercise is dependent upon the weighting factors chosen. As these factors reflect management priorities, policy objectives, cost constraints, and resource (physical and manpower) limitations, this exercise was not carried out at this time. Rather, the brief description of the various sites and the relative merit matrix provide sufficient information for the review of alternatives in a form which could be later expanded if required. A subjective evaluation of Table 19 suggests that the present site is the best location for a paddock, particularly if the wildlife movement problem could be alleviated.

Table 17. Summary for second-round reconnaissance of Hillsdale Meadows paddock relocation site.

Location of Site: Hillsdale Meadows

1. Bison Requirements
 a) Forage high; productive natural grassland with moderate previous disturbance; aspen forest with few small meadows, logepole pine forest with little forage; supplemental feed may be required to maintain range quality
 b) Cover medium; aspen forest and lodgepole pine forest; design would have to insure bison are not isolated from escape cover by road
 c) Water low; small stream through site not reliable; ensured water source required

2. Environmental Compatibility
 a) Wildlife low; area is productive grassland and receives significant use by elk; would present a barrier to local movement and may decrease use of grasslands in immediate vicinity; may suffer predation by wolves
 b) Vegetation/Soil medium; limited thinning of forest cover may be required for visibility; few problems with construction or erosion forseen except for possibile wallowing on south-facing slopes along W side of site if included in paddock
 c) Visual/Aesthetic low; visible from Bow Valley Parkway

3. Visitor Use
 a) Compatibility with Present/Planned Use medium; hiking trail to Johnson Canyon passes through site; other ungulates can often be viewed in area; contains a range enclosure study plot
 b) Predicted Visibility of Bison high; periodic thinning of cover may be required
 c) Aesthetic Quality of Setting medium; will provide a natural environment for bison viewing however fence along Bow Valley Parkway will be visible
 d) Access medium; approximately 18 km from Banff; on regular scenic tour route

4. Cost Effectiveness
 a) Construction high; fencing, road, handling facilities, feed storage, interpretation, establish water source, some thinning, reroute trail
 b) Maintenance medium; distance from Banff increases costs; facility maintenance, supplemental feeding, periodic thinning

---

Table 18. Summary for second-round reconnaissance of Johnson Lake paddock relocation site.

Location of Site: Johnson Lake

1. Bison Requirements

a) Forage low; wetland with sedge and shrub, water regime uncertain, some wetland areas appear to be drying up and as succession occurs will loose sedge component, problems with inaccessability during flooding or high water freeze; aspen, lodgepole pine, and white spruce forests with little forage, possible clearing required; supplemental feed would likely be required

b) Cover high; aspen, lodgepole pine, and spruce forests

c) Water high; small stream through site; winter reliability unknown but likely ok; ice may have to be broken for bison

2. Environmental Compatibility

a) Wildlife medium; would eliminate moderate present use by ungulates; would create a barrier in combination with penstock and Two Jack Canal

b) Vegetation/Soil low; disturbance of aspen forest and wetland areas with little previous impact; clearing and thinning of forest cover; continuing impact on water regime; fence and road construction in wetland areas

c) Visual/Aesthetic medium; portion of facility visible from Johnson Lake Road

3. Visitor Use

a) Compatibility with Present/Planned Use medium; hiking/skiing trail passes through site; would eliminate some trails and area associated with Johnson Lake day use area

b) Predicted Visibility of Bison low; even with clearing and periodic thinning of forest cover, the configuration and varied topography of the site make good visibility unlikely

c) Aesthetic Quality of Setting medium; will provide a natural environment for bison viewing however clearing and construction will visually impact site

d) Access medium; approximately 10 km from Banff; on regular scenic tour route

4. Cost Effectiveness

a) Construction low; fencing, road, handling facilities, feed storage, interpretation, clearing/thinning, reroute trail, special materials and design needed for construction in varied terrain/wetland a:

b) Maintenance low; facil maintenance more expensive in varied terrain/wetland area, supplemental feeding, periodic thinning

Table 19. Matrix of relative merits for paddock relocation sites evaluated by second-round reconnaissance.

	Carrot Creek	Cascade Pits	Hillsd. Meadows	Johns. Lake	Present Paddock
Bison Requirements					
Forage	M	M	H	L	M
Cover	H	L	M	H	H
Water	H	H	L	H	H
Env. Compatibility					
Wildlife	M	M	L	M	L
Vegetation/Soil	M	H	M	L	H
Visual/Aesthetic	H	L	L	M	H
Visitor Use					
Use Compat.	L	H	M	M	H
Predicted Visib.	M	H	H	L	M
Setting Quality	H	L	M	M	H
Access	L	H	M	M	H
Cost Effectiveness					
Construction	H	M	H	L	H
Maintenance	M	H	M	L	H

*relative merit
L=low
M=medium
H=high

9. RESULTS IV. BUFFALO PADDOCK STUDY

9.1 Attributes of the Bison Viewing Opportunity

9.1.1 Bison observations conducted

During the 12 week study period, a total of 280 loops were conducted as specified by the schedule. Time for loop completion varied from 22 to 60 minutes with a mean loop time of 37.2 minutes (SD=6.82) (Table 20). Loop completion time depended primarily on the number and length of bison sightings conducted during the loop. Mean time for loops with no sightings was 32.6 minutes (SD=3.04, range 28 to 42 min.), compared to a mean loop time of 39.8 minutes (SD=6.99, range 22 to 60 min.) for loops with one or more sightings. In total, 10,390 minutes (173.2 hours) were spent conducting loops in the Buffalo Paddock over the study period.

Bison were observed on 64.3% of the 280 paddock loops conducted (95% CI 64.3±5.6). While only one sighting was recorded for most of the successful loops (156 loops or 86.7%), there were 22 loops (12.2%) with two sightings, and two loops (1.1%) with three sightings, for a total of 206 bison sightings. *Loop sighting success*, or the occurrence of one or more bison sightings on a loop, was found to be significantly related to *loop hour* (x^2=27.04 df=14 p<.05). The association was weak (Lambda=0.0900). However, as illustrated in Figure 12, the chance of sighting bison was generally greater in the morning hours. *Loop sighting success* was highest, 94.4%, at 0600 hours, and then decreased to 68.4% at 1200 hours (Figure 12). In the afternoon and evening *loop sighting success* was variable with the lowest chance of seeing bison occurring at 1600 and 1700 hours (42.1% loop sighting success). *Loop sighting success* was not significantly related to *observed sky conditions*, *observed precipitation conditions*, or to the *day of study* (p> .05).

The 206 bison sightings varied in length from two to ten minutes ($\bar{x}$=9.45 min., SD=1.67), with the target sighting length of ten minutes being achieved for 88.3% of all sightings. The average sighting time for the 180 *first sightings*, or those that occurred first

Table 20. Mean time for loop completion.

	Mean No. Minutes	Standard Deviation	Min.	Max.	Total Time Minutes\Hours
Loops with no sightings (n=100)	32.6	3.04	28	42	
Loops with 1,2,or3 sightings (n=180)	39.8	6.99	22	60	
All loops	37.2	6.82	22	60	10390\173.2

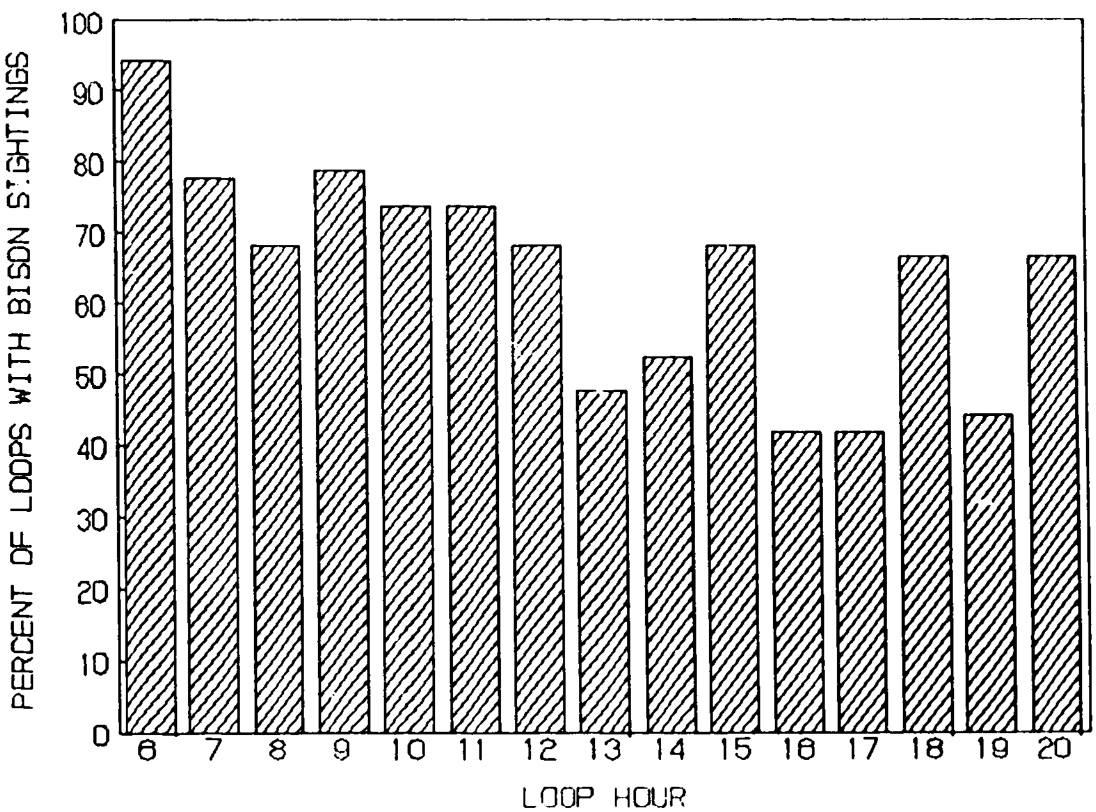


Figure 12. Sighting occurrence BY *loop hour*.

during successful loops, was slightly longer ($\bar{x}=9.52$ min., SD=1.53, range 2 to 10 min.), with ten-minute sightings being achieved for 89.4% of all *first sightings*. In total 1946 minutes (34.4 hours) were spent observing bison, with 1713 of these minutes occurring on *first sightings*. The number of bison seen per *first sighting* varied from one to eight, with the sighting of six (23.9%) or seven (22.2%) animals being most common and 84.4% of all *first sightings* having four or more animals (Figure 13)[4].

9.1.2 Characteristics of bison sightings

During each sighting, bison observations were recorded by *bison minute*; the observation of one bison for one minute. In this manner, observations were recorded for a total of 7457 *bison minutes*. The view of the bison for each *bison minute* was described by recording four categorical variables indicating how far away the bison was, what percent of the bison was visible, what screening if any interfered with visibility, and what major activity of the bison was observed.

Bison were rarely (1.5% of *bison minutes*) observed from a distance closer than 11 meters (Figure 14). The frequency of observations in the other distance categories decreased as distance increased, with observations at 11-50 meters being most common (44.4%), followed by the 51-100 meter category (32.9%), and the greater than 100 meters category (21.2%).

The views of bison were highly obstructed, with the animal observed being less than one-quarter visible in 51.1% of all *bison minutes* (Figure 15). The 25-49% visible category accounted for an additional 19.8%, for a total of 70.8% of all *bison minutes* spent observing less than one-half of a bison. Conversely then, bison were at least one-half visible for only 29.2% of all *bison minutes*, with complete views accounting for 4.3%, three-quarter to 99% views accounting for 15.4%, and 50-74% views accounting for 9.4% of all *bison minutes*.

---

[4] The number of bison in the Buffalo Paddock increased from five to eight over the study period. Two calves were born in May, and initial sightings occurred on days seven and thirteen. The adult male bison, which was absent from the paddock at the beginning of the study, returned on day 68.

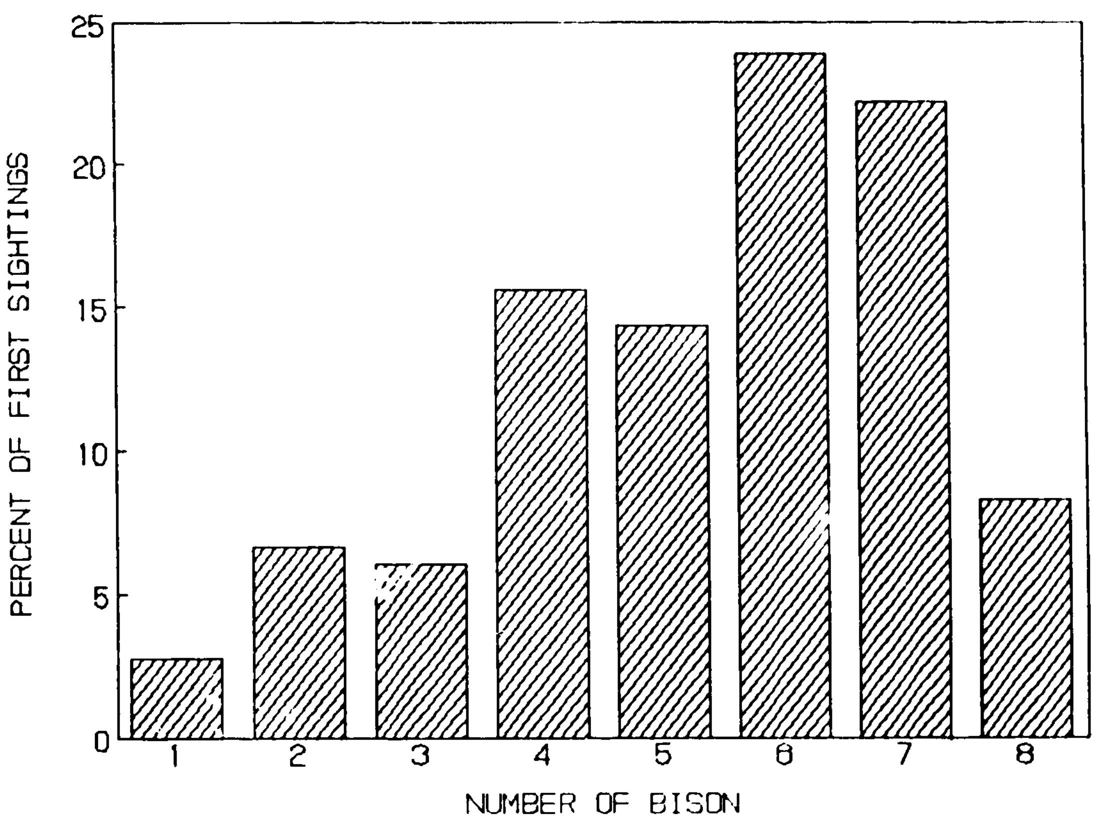


Figure 13. Number of bison observed per *first sighting*.

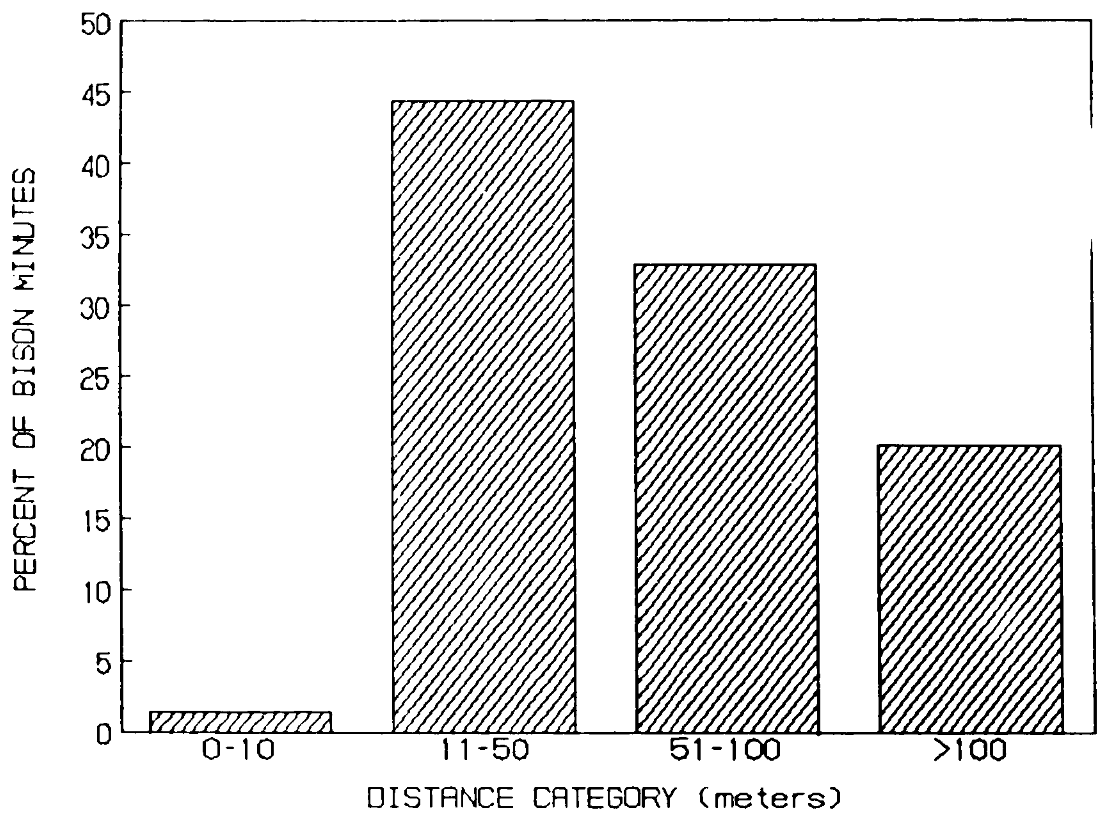


Figure 14. Percentage occurrence of *distance away* categories.

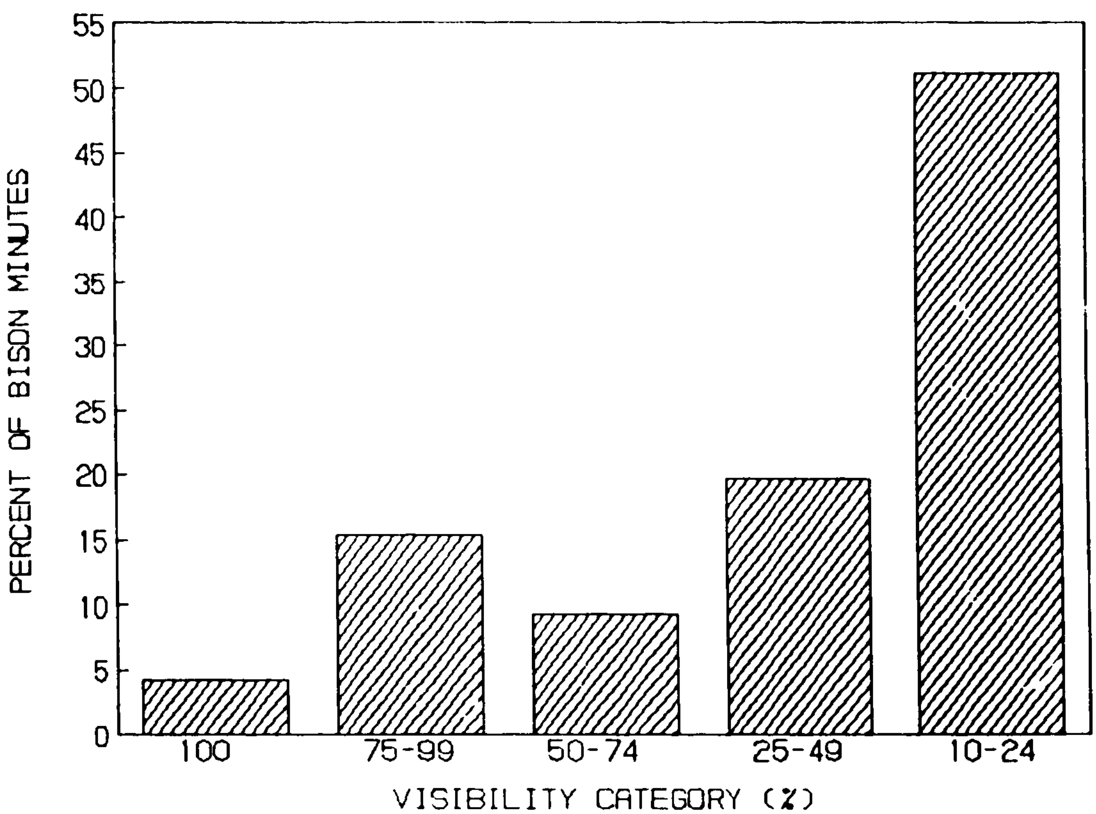


Figure 15. Percentage occurrence of *percent visible* categories.

The most common screening medium was vegetation. It was recorded as the only screening medium for 70.2% of all *bison minutes* and in combination with other screening mediums, namely topography (10.0%), bison (7.6%), and topography and bison (1.1%) for a further 18.7% of *bison minutes*. The remaining screening was identified as bison (4.2%), topography (2.4%), and cars (0.4%). Summarizing the combined screening medium categories by dividing cases equally among the separate screening components yields summary percentages of 79.3% for vegetation, 8.3% for bison, and 7.7% for topography (Figure 16). Only 4.2% of the *bison minutes* were witho screening of any kind.

Observed bison activities were recoded into seven major categories; *feed, walk, run, stand, lay down, groom* and *unknown* (due to poor visibility). The most common major activity category was *lay down*, recorded for 35.9%, of all *bison minutes* followed closely by *feed* at 34.4% (Figure 17). Together these two categories accounted for 70.3% of observed bison activity. *Stand* and *walk* represented 16.7% and 9.9% of observed activity respectively and *run, groom*, and *unknown* comprised the remaining 3.1%.

To further describe the bison viewing opportunity, the two ordinal bison observation variables, *distance away* and *percent visible*, were examined using Kendall's tau-b (τ-b) rank correlation. The associations between *distance away, percent visible, day of study, loop hour, observable sky condition*, and *observable precipitation condition* were explored. The correlation matrix is presented in Table 21. Significant τ-b coefficients ($p<.05$) were found for all variables tested with *distance away* and for all variables except *loop hour* tested with *percent visible*. The strongest association was found between *percent visible* and *distance away* (τ-b= .22). The relationship was moderately positive with the percent of the animal screened increasing as *distance away* increased. *Distance away* and *percent visible* were very weakly associated with observable weather. As cloud cover increased, bison were observed further away (τ-b= .03), but were less screened (τ-b= -.02). As rain intensity increased, bison were observed closer (τ-b= -.03), but were more screened (τ-b= .04). These relationships cannot be directly interpreted as they are confounded by the relationship of observable weather to the *day of study*, and they are a function of the physical characteristics

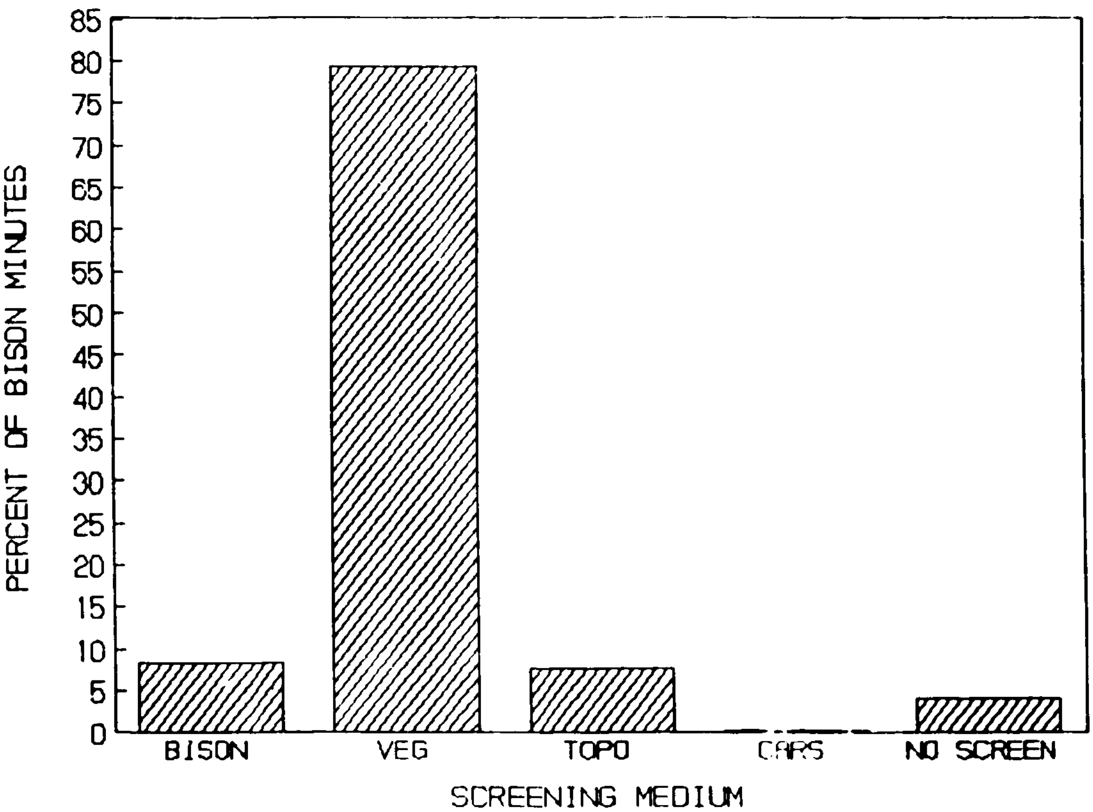


Figure 16. Percentage occurrence of screening mediums.

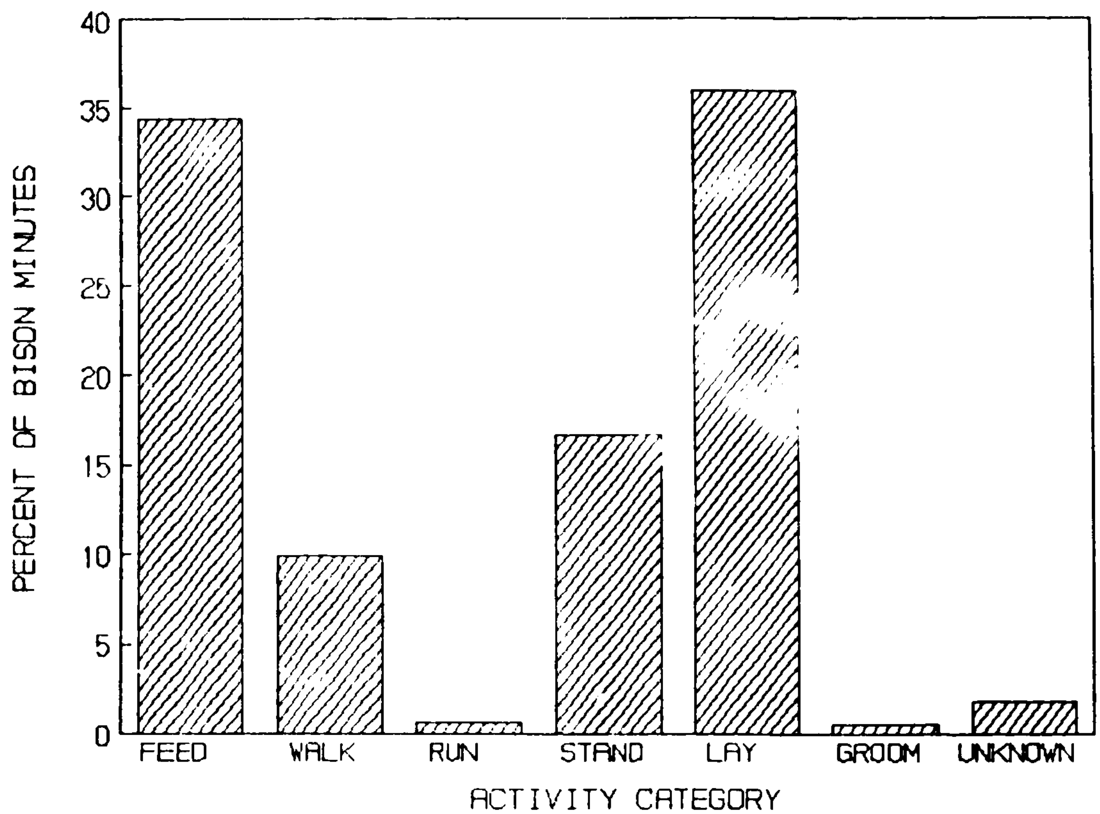


Figure 17. Percentage occurrence of major bison activities.

Table 21. Kendall's tau-b correlation matrix for bison observation variables *distance away* and *percent visible*.

	Loop Hour	Sky Condit.	Precip. Condit.	Distance Away	Percent Visible
Day of Study	.0321 (280)	.0718 (203)	.1008* (203)	-.1283* (7440)	-.0190* (7446)
Loop Hour		.0245 (203)	-.0213 (203)	.1652* (7440)	-.0032 (7446)
Sky Conditions			.4151* (202)	.0251* (7356)	-.0196* (7362)
Precip. Conditions				-.0319* (7347)	.0348* (7353)
Distance Away					.2240* (7430)

*Significant tau-b (p<.05)

Note: With increasing category values, the hour of the day gets later, sky gets cloudier, rain intensity increases, distance gets further away, and percent visibility decreases.

and location of the sites used by bison during different types of weather and the activities performed there. For example, during cool overcast weather, bison would feed in open meadows in the centre of the paddock resulting in further distances and less screening. During heavy rain, bison would bed down in an area of moderately heavy aspen close to the road, resulting in closer distances and more screening. *Distance away* and *percent visible* showed weak (τ-b = -.13) and very weak (τ-b = -.02) negative association with day of study, indicating closer observation distances and less screening as the study progressed. A weak positive association between *distance away* and *loop hour* (τ-b = .17) showed increasing observation distance throughout the day.

The overall trends of the relationships between *distance away* and *loop hour* and *distance away* and *day of study* are illustrated in Figures 18 and 19. The mean value of the ordinal *distance away* scale was calculated for each *loop hour* and for each *week of the study* and the relationship plotted. The *distance scale average* value is the least (bison are closest) at 0600 hours and gradually increases during the morning and early afternoon to a peak at 1600 and 1700 hours (Figure 18). The *distance scale average* then decreases again in the evening hours, but bison are still observed at a greater distance than in the morning hours. As illustrated in Figure 19, the *distance scale average* value increases from Week 1 to Week 2 and then gradually decreases to a minimum value in Week 9. The *distance scale average* then increases again over the last three weeks of the study.

9.2 Visitor Use of the Buffalo Paddock

9.2.1 Daily visitation

Daily visitation of the Buffalo Paddock was recorded as the number of vehicles that passed the paddock traffic counter between 0800 hours on that day and 0800 hours on the next day of the study. Traffic counter readings were adjusted daily to account for researcher entries and known non-visitor entries such as park warden, construction, and maintenance vehicles. For four periods when the traffic counter was not working properly, estimates of

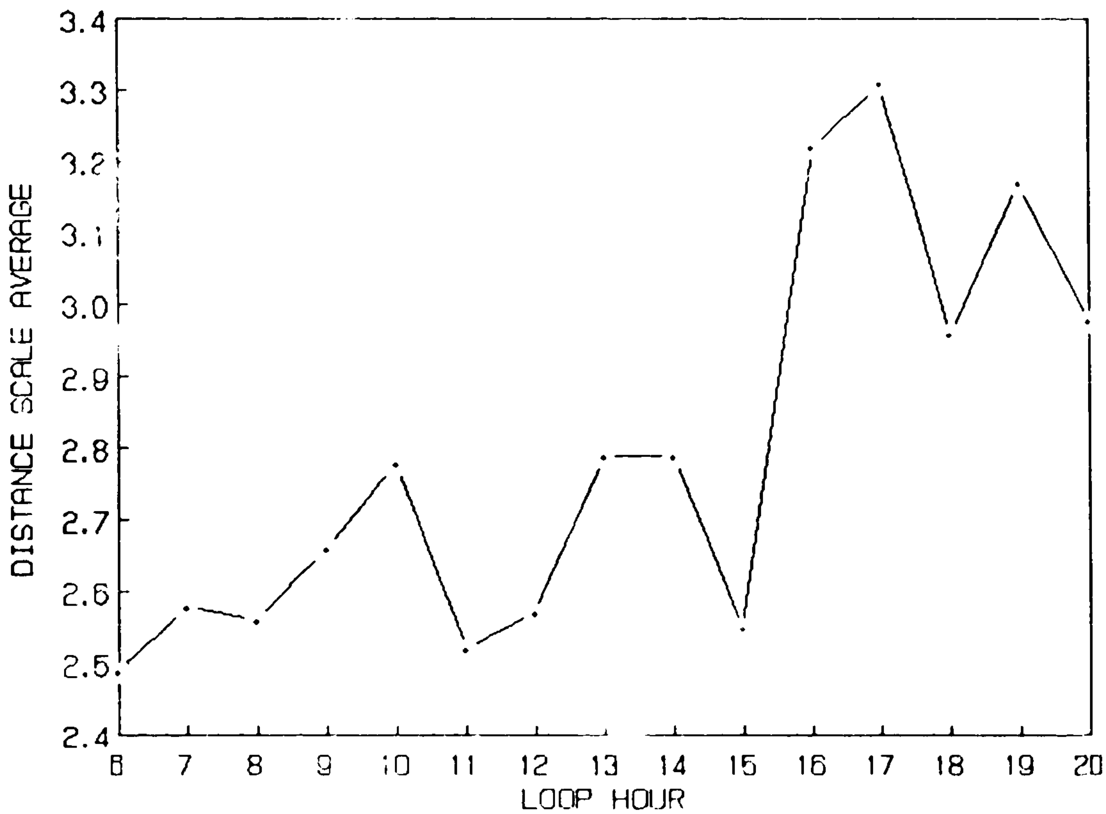


Figure 18. *Distance scale average* BY *loop hour.*

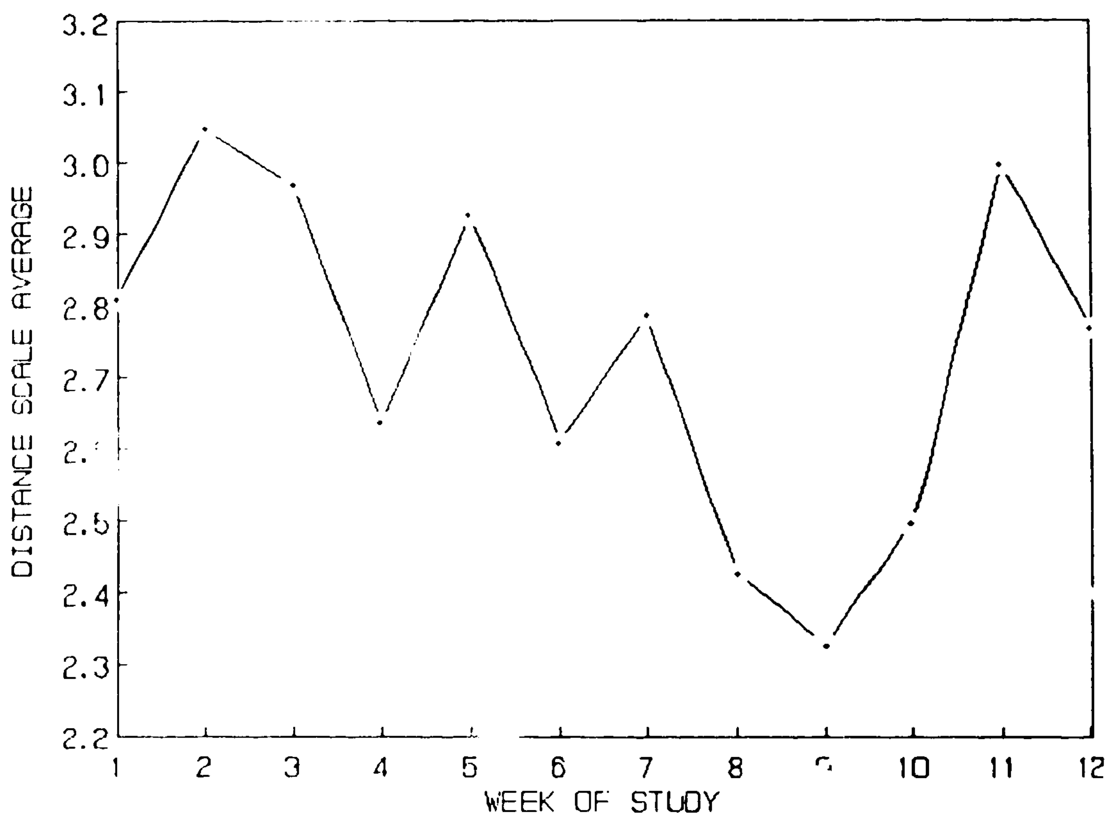


Figure 19. *Distance scale average* BY *week of study.*

visitor vehicle entries were made by averaging the visitor vehicle counts for the two identical time spans previous and the two following. Overall, the counter was 97% accurate when compared to visual counts. Differences can be attributed to factors such as extremely slow-moving vehicles pulling trailers being counted as two vehicles instead of one, bison or coyotes walking in front of the counter's electronic eye, and the occasional equipment malfu ction.

Total visitation estimated in this manner was 25,767 visitor vehicles (Table 22). This total visitation included four days when the Buffalo Paddock was closed to visitor traffic for most of the day due to construction on the access road. Visitation on these days was only 2, 4, 5, and 50 vehicles. Including these days when the Buffalo Paddock was closed, the mean *daily visitation* was 306.8 visitor vehicles (SD=140.22) with a minimum of 2 and a maximum of 525 visitor vehicles. If the four minimum values are excluded, the mean *daily visitation* is 321.3 (SD=126.97) with a range from 72 to 525 visitor vehicles.

The relationships of *daily visitation* with *day of study* and with *day of week* were tested using Kendall's tau-b correlation and the Chi-square test of independence respectively. *Daily visitation* and *day of study* showed a significant ($p<.05$), moderately strong positive association (τ-b=.65) while *daily visitation* and *day of week* were not significantly related ($p>.05$). *Daily visitation* generally increased over the study period to a maximum of 525 vehicles on Day 57 (Wednesday, July 9), after which *daily visitation* declined and remained steady to the end of the study period (Figure 20). Two *daily visitation* peaks occurred in conjunction with the long weekends of May and August. The maximum *daily visitation* associated with these weekends occurred on Day 5, Sunday, May 18 (257 vehicles), and Day 2, Sunday, August 3 (520 vehicles).

9.2.2 Traffic observation periods conducted

During the study period, 256 traffic observation periods (TOPs) were conducted. TOPs lasted from two to 60 minutes, with a mean TOP length of 23.90 minutes (SD=7.89). A total of 6118 minutes (102.0 hours) were spent observing traffic over the study period.

Table 22. Mean daily visitation recorded by traffic counter.

	Mean No. Vehicles Enter	Standard Deviation	Min.	Max.	Total Vehicles Enter
All days (n=84)	306.8	140.22	2	525	25767
Excluding days paddock closed (n=80)	321.3	126.97	72	525	---

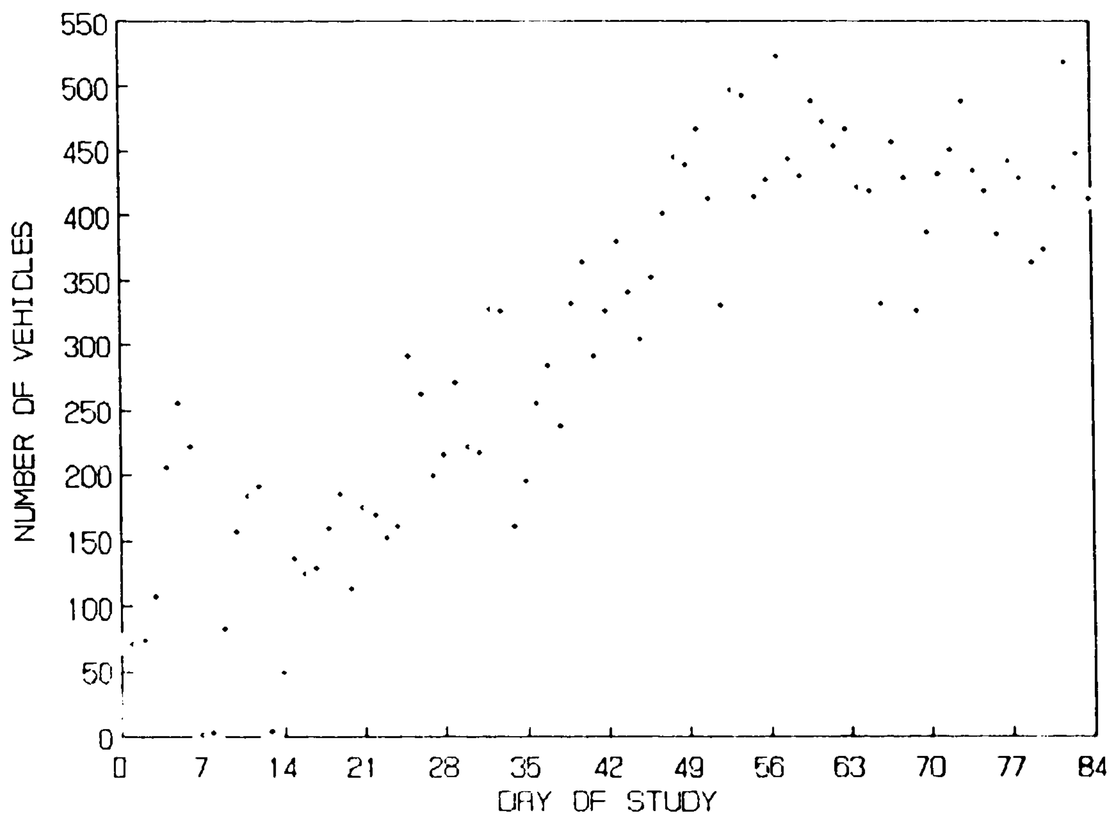


Figure 20. *Daily visitation* of the Buffalo Paddock.

The number of vehicle visits per traffic observation period varied from zero to 55 with a mean of 11.2 vehicle visits (SD= 8.64)(Table 23). Total vehicle visits recorded during the traffic observation periods was 2866.

Of vehicles observed during traffic observation periods, 93.0% were classified as private vehicles with 14.8% of these specified as being rentals from Alberta or British Columbia (Table 24). The remaining seven percent was comprised of bus tours (6.1%), other tours (0.2%), and motorcycles, cyclists, and non-visitor vehicles (0.7%). For all buses recorded, 70.4% were identified as belonging to one of three tour companies; Brewster Transportation and Tours (29.1%), Greyhound (24.4%), and Pacific Western Transportation (16.9%).

Vehicle license plates were recorded for 2741 vehicles. Of those plates recorded, 55.9% were from Alberta (13.3% Alberta Rentals) and 11.4% from British Columbia (0.8% British Columbia Rentals)(Table 25, Figure 21). The remaining Canadian provinces and territories, with the exception of Prince Edward Island which was not represented, made up a further 11.0%, for a total of 78.3% Canadian (14.1% Canadian Rentals) license plates. Plates from the United States comprised another 21.0% with the most common states being California (4.4%), Washington (3.3%), Florida (1.1%), Oregon (1.0%), and Minnesota (0.9%). The remaining 0.7% of plates were from Europe and Mexico, as well as buses with multiple plates.

For each vehicle visit, time of entry, time of loop one, time of loop two (if applicable), and time of exit was recorded. The length of time for completion of the first loop was obtained for 1263 (44.1%) vehicles (Table 26). The mean completion time for the first observed loop was 8.7 minutes (SD=2.71), with a range from 4 to 33 minutes (Table 27). Of the remaining vehicles, 766 (26.7%) were only observed beginning the first loop, 788 (27.5%) vehicles were only observed ending the first loop, and 49 (1.7%) vehicles were observed entering the gate and exiting by driving around the island or backing out of the paddock before beginning the first loop. The length of time for completion of the second loop was obtained for 79 (2.8%) vehicles. The time for second loop completion ranged from

Table 23. Mean vehicle visits observed during traffic observation periods, loops, and sightings.

	Mean No. Vehicles Observed	Standard Deviation	Min.	Max.	Total Vehicles Observed
Traffic Obs. Periods (n=256)	11.2	8.64	0	55	2866
Loops (n=280)	9.5	7.61	0	34	2650
Sightings (n=206)	3.2	3.18	0	18	651
Stop	2.4	2.96	0	18	489
Not Stop	0.8	1.45	0	8	162

Table 24. Percentage occurrence of vehicle types during traffic observation periods, loops, and sightings.

Type of Vehicle Observed	Traffic Observation Period	Loop	Sighting
Private	93.0 14.8 Rental 85.2 Non-Rental 100.0	92.6	93.1 74.4 Stop 25.6 Not-Stop 100.0
Bus Tour	6.0 29.1 Brewster 24.4 Greyhound 16.9 PWT 29.7 Other 100.0	6.7 32.6 Brewster 20.2 Greyhound 11.2 PWT 36.0 Other 100.0	5.8 92.1 Stop 7.9 Not-Stop 100.0
Other Tour	0.2	0.2	0.3 50.0 Stop 50.0 Not-Stop 100.0
Motor-cycle	0.2	0.2	0.3 50.0 Stop 50.0 Not-Stop 100.0
Bicycle	0.3	0.2	0.3 0.0 Stop 100.0 Not-Stop 100.0
Non-Visitor	0.2	0.2	0.2 100.0 Stop 0.0 Not-Stop 100.0
Total	100.0 (n=2866)	100.0 (n=2650)	100.0 (n=652)

Table 25. Vehicle licence plates recorded during traffic observation periods

Province or State of Issue and Vehicle Type	% of Vehicles Observed
Alberta	
Private	38.1
Private Rental	13.3
Other	4.5
Total Alberta	55.9
British Columbia	
Private	9.8
Private Rental	0.8
Other	0.8
Total B.C.	11.4
Ontario	[illegible].5
Saskatchewan	3.4
Manitoba	2.1
Quebec	1.[illegible]
Northwest Territories	0.[illegible]
New Brunswick	0.[illegible]
Nova Scotia	0.1
Newfoundland	0.0
Yukon	0.0
Total Canada	78.3
California	4.4
Washington	3.3
Florida	1.1
Oregon	1.0
Minnesota	0.9
Other U.S.	10.3
Total U.S.	21.0
Other (Mexico, Europe, Multiple Plates e.g. buses)	0.7
Total Recorded	10[illegible] (n=27[illegible])

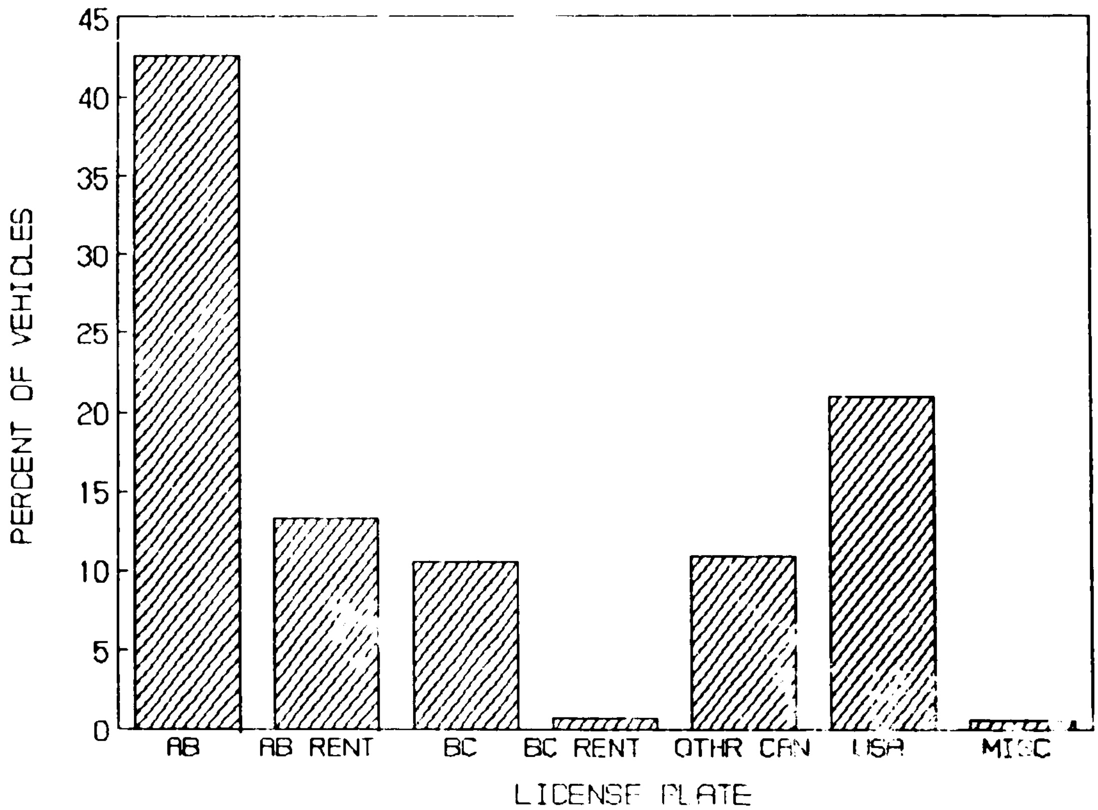


Figure 21. Percentage occurrence of vehicle licence plates recorded during traffic observation periods.

Table 26. Vehicle visits observed during traffic observation periods.

	% of Vehicle Visits Observed (n=2866)				
	Begin Only	End Only	Around Island or Back Out No Loop	No Second Loop	Complete Loop Observed
First Loop Observed	26.7	27.5	1.7	----	44.1
Second Loop Observed	2.0	----	0.1	95.2	2.8

Table 27. Mean loop completion times recorded during traffic observation periods.

	Completed Loop Times			
	Mean No. Minutes	Standard Deviation	Min.	Max.
First Loop Observed	8.7	2.71	4	33
Second Loop Observed	10.3	3.76	4	24

4 to 24 minutes with a mean time of 10.3 minutes (SD=3.76). An additional 56 (2.0%) vehicles were observed beginning the second loop, but 2727 (95.2%) vehicles were observed to exit before beginning a second loop, and 4 (0.1%) vehicles were observed passing the island as if to begin a second loop, but backing up and exiting instead.

9.2.3 Loop and sighting vehicle observations

In addition to vehicle observation during TOPs, 2650 vehicles were observed during loops with a mean of 9.5 vehicle visits per loop (SD=7.61) and a range of [illegible] to 34 vehicle visits (Table 23). These loop vehicle visit totals include vehicle visit totals recorded for all of the sightings conducted during the loop. Of these 92.6% were private vehicles, 6.7% were bus tours, 0.2% were other tours, 0.6% were motorcycles, cyclists, and non-visitor vehicles (Table 24, Figure 22). Of the observed bus tours, 64% were identified as Brewster Transportation and Tours (32.6%), Greyhound (20.2%), and Pacific Western Transportation (11.2%).

During the 206 sightings, 651 vehicles visits were observed and categorized as stopping or not stopping (Table 23). The mean number of vehicle visits observed per sighting was 3.2 (SD=3.18), with a range from zero to 18 vehicle visits. 93.1% of these vehicles were private, 5.8% were bus tours, 0.3% were other tours, and 0.8% were motorcycles, cyclists, and non-visitor vehicles (Table 24). Of these vehicles, 75.1% stopped at the sighting location and 24.9% did not. By vehicle type, 74.4% of the private vehicles (n=606), 92.1% of the bus tours (n=38), 50.0% of the other tours (n=2), 50.0% of the motorcycles (n=2), 0.0% cyclists (n=2), and 100.0% of the non-visitor vehicles (n=1) stopped.

9.2.4 Visitation rates

The rate of vehicle use (vehicles/minute) in the Buffalo Paddock was calculated for vehicles observed during loops and sightings and for vehicles entering the paddock as recorded by the traffic counter during the hour of each loop. The means and ranges of the three visitation rates, ***observed rate for loops***, ***observed rate for sightings***, and ***recorded rate of entrance*** are shown in Table 28. Mean observed visitation rates were 0.26 vehicles/min at

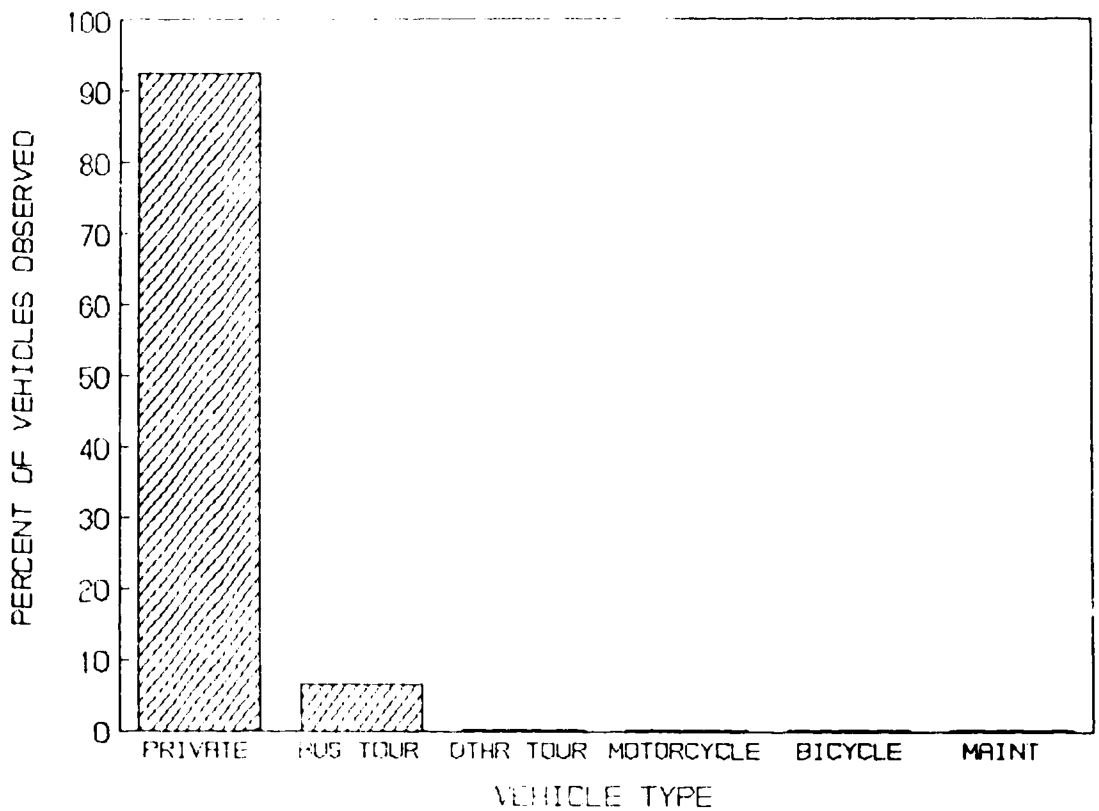


Figure 22. Percentage occurrence of vehicle types observed during loops.

Table 28. Mean visitation rates observed during loops and sightings and recorded by traffic counter.

	Mean Vehicles/Minute	Standard Deviation	Min.	Max.
Observed Rate for Loops (n=2650)	0.3	0.20	0.0	0.9
Observed Rate for Sightings (n=654)	0.3	0.35	0.0	2.0
Recorded Rate of Entrance (n=5315)	0.3	0.25	0.0	1.2

(SD=0.20) for loops and 0.34 vehicles/minute (SD=0.35) for sightings. The mean visitation rate recorded by the traffic counter was 0.33 vehicles/minute (SD=0.25). Overall, the paddock visitation rate was approximately one vehicle every three minutes.

To further describe visitation rates, the three rates were examined using Kendall's tau b rank correlation. The associations between *observed rate for loops*, *observed rate for sightings*, and *recorded rate of entrance* and *day of study*, *loop hour*, *observable sky condition*, and *observable precipitation condition* were explored. The correlation matrix is presented in Table 29.

The visitation rates showed strong positive association with each other. The *observed rate for loops* showed a slightly stronger association with *recorded rate of entrance* (τ-b=.79) than did the *observed rate for sightings* (τ-b=.64).

Significant τ-b coefficients ($p<.05$) were found for all three visitation rate variables tested with *day of study* and *loop hour*. The τ-b coefficients all indicated moderate, positive relationships with visitation rates increasing with *day of study* and *loop hour*. The associations with *day of study* (τ-b=.32 to .40) were stronger than those with *loop hour* (τ-b=.24 to .29).

The shape of the relationships between *recorded rate of entrance* and *day of study* and *recorded rate of entrance* and *loop hour* are illustrated in Figures 23 and 24. The average rates of vehicles entering the paddock were calculated for each *week of the study* and for each *loop hour*, and the relationships were plotted. The relationship between *average entrance rate and week of study* (Figure 23) closely reflects the relationship of *daily visitation* with *day of study* seen previously in Figure 20. After an initial decline from the May long weekend peak, the *average entrance rate* steadily increases to Week 9 (July 9 to 15), dips sharply in Week 10, and then levels off. Figure 24 illustrates the relationship between *average entrance rate* and *loop hour*. Visitation rate increases from a low of 0.01 vehicles/minute at 0600 hours to a peak of 0.56 vehicles/minute, or approximately one vehicle every two minutes at 1100 hours. The *average entrance rate* then declines and levels off at approximately 0.47 vehicles/minute from 1200 to 1500 hours, after which rates decline to 1900 hours. A small increase in

Table 29. Kendall's tau-b correlation matrix for visitation rate variables, *observed rate for loops*, *observed rate for sightings*, and *recorded rate of entrance*

	Loop Hour	Sky Condit.	Precip. Condit.	Obs. Rate Loops	Obs. Rate Sights.	Rec. Rate Entr.
Day of Study	.0321 (280)	.1290* (278)	.1103* (277)	.3582* (280)	.3233* (206)	.3969* (267)
Loop Hour		.0571 (278)	.0407 (27[illegible])	.2782* (280)	.2920* (206)	.2346* (267)
Sky Condit.			.4908* (277)	.1484* (278)	.0214 (203)	.1513* (265)
Precip. Condit.				.0469 (277)	.0223 (203)	.0485 (264)
Obs. Rate Loops					.6925* (180)	.7883* (267)
Obs. Rate Sightings						.6397* (172)

*Significant tau-b (p<.05)
Note: With increasing category values, the hour of the day gets later, sky gets cloudier, rain intensity increases, and visitation rates increase.

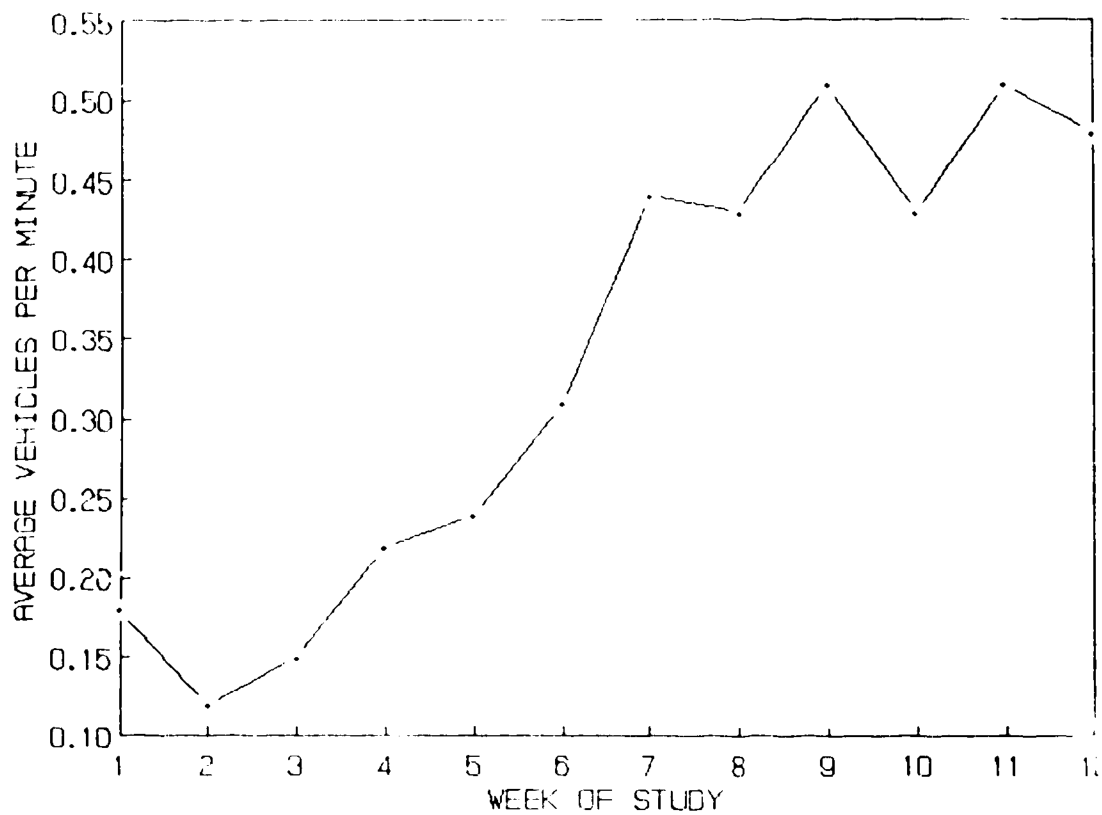


Figure 23. *Recorded rate of entrance* BY *week of study.*

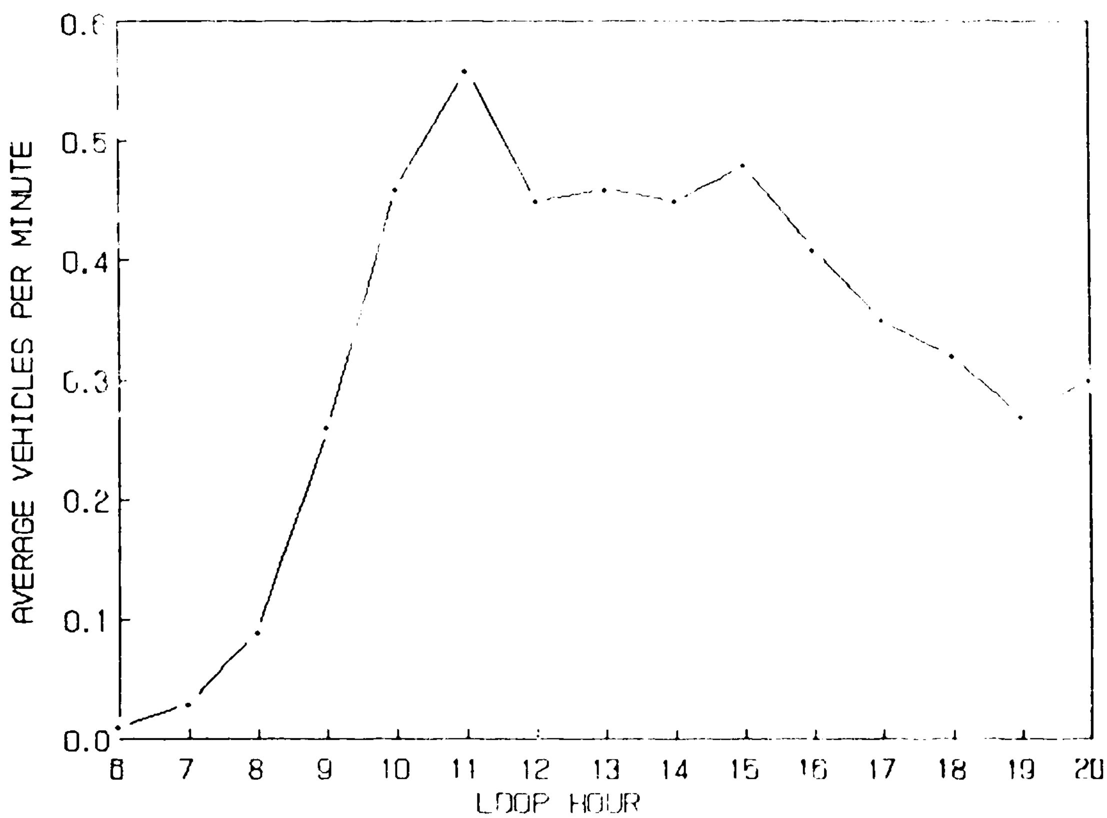


Figure 24. *Recorded rate of entrance* BY *loop hour.*

average entrance rate then occurs at 2000 hours.

Observed rate for loops and *recorded rate of entrance* were also significantly ($p<.05$) associated with *observable sky condition*. The relationships were weakly positive (τ-b=.15) with visitation rates increasing as cloud cover increased. However, these relationships cannot be directly interpreted due to the similar positive relationships of observable weather to *day of study*. Visitation rates were not significantly associated with *observable precipitation condition*($p>.05$).

9.2.5 Tour agency [illegible]

The drivers and guides of Mountain Park Tours (MPT) and Brewster Transportation and Tours (BTT) completed 49 and 26 *Buffalo Paddock Tours* forms respectively, describing their tours through the paddock during the study period. Due to incomplete participation by tour staff, forms were not completed for every trip through the paddock. Therefore, only general inferences can be made, based on the forms received.

Both of the tour agencies conducted the majority of their reported tours through the paddock between 0900 and 1200 hours, with only a few mid-afternoon tours and one early evening tour. MPT conducted 55% of its tours at 0900 hours and another 18% at 1000 hours, whereas BTT tours were spread more evenly between 0900(21%), 1000 (25%), 1100 (25%), and 1200 (21%). The completed forms represented the visits of 1666 passengers with MPT and 674 passengers with BTT. The mean number passengers/tour was 37.0 (SD=6.95, range 21 to 60 passengers) for MPT and 27.0 (SD=10.89, range 8 to 48 passengers) for BTT. BTT drivers reported a 83.3% bison sighting success rate, while MPT guides reported bison observed on 69.4% of all recorded tours. The success rate of MPT guides is similar to the average rate for researchers of 64.3%. The BTT drivers success rate is high, even when compared to the researcher's success rate between 0900 and 1200 hours, which averaged 73.7%. The reason for the high BTT success rate is unknown. Perhaps drivers were more inclined to return observation forms when bison were seen, thereby inflating the success rate. Or, perhaps the higher vantage point from bus windows combined with several observers in the vehicle may have in fact resulted in a higher success rate for the BTT bus tours.

Sightings for which bison were described as close or clearly visible represented only 35.2% of all sightings (26.0% of all tours). Reported visitor reactions to close or clear bison sightings were positive, with visitors interested and excited about seeing bison. When sightings were far away or visibility was poor, reactions were still generally positive although many visitors expressed the wish for a better view. On the occasions when bison were not visible, the reported visitor reactions varied from "very disappointed" and "very [illegible]" to "mildly disappointed" and "no reaction".

The tour agencies provided estimates of their use of the Buffalo Paddock throughout the entire 1986 summer season. MPT guides conducted approximately [illegible] which included the Buffalo Paddock, serving 12,500 passengers (Anderson, C., pers. comm. 1987)[46]. Approximately 70% of these tours took place during July and August. BTT took approximately 6885 passengers through the Buffalo Paddock on its Banff General Drive tour (Sandford, pers. comm. 1987)[47]. In addition BTT provided a rough estimate taken from a representative sample of over 3000 of their charter customers, which indicated that perhaps as many as 28,000 charter passengers visited the Buffalo Paddock in the summer of 1986.

The tour agency drivers and guides generally commented that the Buffalo Paddock was a positive experience for visitors, but expressed the view that the chances of sighting bison should somehow be improved. Ms. Anderson indicated that MPT staff and management support the continued operation of the present Buffalo Paddock, as tour guides enjoy interpreting bison history in the Buffalo Paddock, and visitor response to the visits is most often favorable. Mr. Sandford of BTT described the Buffalo Paddock as as "important part of the Banff experience for most visitors" and recommended that any changes to the paddock enhance the natural habitat through visual separation of buildings and fences, and increase bison sighting success to 100%.

---

[46] Ms. C. Anderson, President, Mountain Park Tours, Banff, Alberta.
[47] Mr. R. W. Sandford, Corporate Secretary, Brewster Transportation and Tours Banff, Alberta.

9.3 Interaction of Visitors and Bison

During each loop and bison sighting, observations were made of visitor compliance with posted warnings and of the interaction of visitors and bison. Although the sign at the entrance to the Buffalo Paddock states that cycles are prohibited, two bicycles (one at a sighting) and four motorcycles (two at sightings) were observed in the paddock during loops. Signage also warns visitors to remain in their vehicles. However, people were observed out of their vehicles on forty loops (14.3%). Twenty of these occasions took place at bison sightings (see below), but the remainder appeared to be for a variety of other reasons; feeding ground squirrels (3), picking flowers (2), taking pictures (-), walking (4), and standing by vehicles (5).

During each bison sighting, observations were made of the interaction of visitors and bison. Bison generally did not react strongly[43] to the presence of the researcher or visitors provided that people remained inside their vehicles. Bison attempting to cross the loop road were blocked by vehicles on four occasions, and were forced to wait or walk around the vehicles. This caused some confusion for calves, resulting in apparent concern by the bison cows. The bison did not generally react to slow-moving or stopped vehicles with alarm or aggression. However, on two sightings bison were startled into flight by the sudden approach of vehicles: on one occasion a single motorcycle and on the other a group of five vehicles. In addition, bison reacted strongly by rapidly walking away when approached by a vehicle which was driven off the loop road and into the paddock towards them.

During twenty (9.7%) sightings, one or more visitors were recorded as being out of their vehicles. Visitors left the loop road and approached the bison on 10 of these occasions, or 4.9% of all bison sightings. The strongest reaction shown by the bison during each of the twenty sightings is shown in Table 30. As long as visitors remained near their vehicles, bison generally did not show a strong reaction. However, on two occasions, bison walked quickly away from the visitors and on one occasion, a cow bison bluff charged a visitor who stepped

[43]"Strong reaction" was defined as obvious movement away from or towards the source of disturbance. Due to poor visibility, less obvious responses, such as standing alert, were not consistently recorded and so are not reported.

Table 30. Strongest recorded reaction of bison to visitors out of their vehicles during twenty sightings.

	No Visible Reaction	Stand Up	Walk Away	Run Away	Charge	Bluff Charge
Visitors out of vehicles (n=10)	7		2			1
Visitors approach bison (n=10)	1	1	2	3	3	

out of his vehicle only five meters from her.

Bison [illegible] were consistently stronger when visitors directly approached them. Only on one occasion, when [illegible] quietly approached resting bison, did the bison show no strong response. Resting bison on a second occasion were observed to stand and remain alert as the visitors approached to take pictures. Bison moved away from approaching visitors on five occasions, twice at a fast walking pace, and three times running out of sight into forest cover. On three sightings, visitors approaching to within 15, 30, and 50 m of bison were charged by a cow bison. Two of the visitors were charged all of the way back to their vehicles, approximately 80 m, and in the third charging, the bison chased the visitor for only 20 m, half way back to his car.

On two additional occasions, not on scheduled loops, visitors were observed actively chasing bison. In one incident, a man and teenage girl followed the bison, which left at a rapid walk, through the trees and well into the centre of the paddock. In the second incident observed, a man with a video camera chased the bison out of the trees and down the road towards the research vehicle. A passing cyclist was able to hide behind the research vehicle and then requested a ride out of the paddock.

9.3.1 Summary

The opportunity for viewing bison in the Buffalo Paddock is limited. Sighting success by researchers, who travelled approximately four times slower than visitors, was only 64%. The best sighting opportunities were in the early morning when visitation was lowest. Bison at this time were closer to the loop road than later in the day. Whether this is a factor of bison avoiding the road area during hours when traffic volumes are higher is unknown. Most sightings (84%) were of four or more bison and lasted at least ten minutes (88%). On average, bison were seen at a distance of 50 meters or less on only 50% of bison sightings. The aspen forest cover greatly reduced bison visibility. Vegetation screening, which accounted for 80% of all screening, was extensive enough that the opportunity to see at least one-half of the animal being observed occurred on only 29% of bison sightings. Bison were observed from closer distances and were less screened as the study period progressed. This may be a result of less secretive behavior by cow bison as their calves mature. Bison were most commonly observed lying down or feeding.

The Buffalo Paddock was visited by 25,767 vehicles [illegible] study period, approximately 6.7% of which were bus tours. Assuming an average [illegible] passengers per bus and 2.5 persons per private and other vehicles, total visitation can be estimated at [illegible] visitors; 60,424 bus tour passengers and 60,102 other visitors. By way of comparison, [illegible] the same time period, 181,400 people visited the Cave and Basin, 131,111 people [illegible] Upper Hot Springs Pool and Bath, 72,626 people visited the Banff Museum, and [illegible] people were served at the Banff Townsite Information Centre[49]. Daily visitation in the Buffalo Paddock increased over the study period, generally reflecting park use trends. Most of the paddock visitors drove vehicles with Canadian licence plates (78%), again reflecting park visitation trends. Buses carried a significant number of passengers through the paddock, with Brewster Transportation and Tours, Greyhound, and Pacific Western Transportation being the major identifiable carriers. Visitors spent an average of nine minutes in the paddock with only 5% making a second loop. Their speed was almost four times faster than the research vehicle and so the number of visitors who saw bison is likely somewhat less than the 64% success rate found by the researcher would indicate. On average, approximately three-quarters of the vehicles which were seen during sightings would stop to observe the bison. The people who did not stop likely could not see the bison because of poor visibility. Visitation in the Buffalo Paddock averaged one vehicle every three minutes. However, there was considerable variation, from zero vehicles to two vehicles per minute. Vehicles often ended up travelling in groups which would greatly increase the passage rate experienced at any one point. This inconvenienced visitors who wanted to drive slower and so were continually forced to pull off to the side of the road. It also disturbed bison who were unable to cross the road at will. Visitation rates were highest at mid-day, and an increase in rates was seen as the study progressed and daily visitation totals increased. Use

[49]Banff National Park Visitor Services and Interpretation files.

of the paddock by the two cooperating tour agencies was high, with over 47,000 passengers being conducted through the paddock over the summer season.

Visitors do not fully comply with the posted warnings of the Buffalo Paddock. Cycles were observed in the paddock, although the incidence was low, and not all visitors remained in their vehicles. People were observed out of their vehicles on 14% of the loops and at approximately 10% of the bison sightings. In most cases, people being out of their vehicl did not create a dangerous situation for the visitors, nor did it appear to affect the bison. However, on the occasions when visitors approached bison, bison reacted strongly 90% of the time, with 45% of these reactions being aggressive. There is therefore some concern for both visitor safety and bison harassment in the Buffalo Paddock.

10. SUMMARY AND REVIEW OF ALTERNATIVES

10.1 Summary of Sub-Study Results

The completion of the four sub-studies provided information necessary for a review of the alternatives for bison management in Banff National Park. The major factors are summarized below.

1. Prehistory and History of Bison in Banff National Park
   a. Bison, most likely plains bison, were indigenous to the park area until *circa* [illegible]
   b. Summer bison distribution included most major valleys and many smaller [illegible] valleys, and extended to upper subalpine and alpine habitat.
   c. Historic winter bison distribution is unknown.
   d. Plains bison were reintroduced in 1897 as a captive herd. The herd was maintained until 1981, when the plains bison were replaced with the present herd.
2. Review of Bison Management Factors
   a. Climatic conditions are favorable for bison, although snow conditions limit winter range.
   b. Suitable forage, cover, and water resources exist in the park.
   c. Bison would compete with other ungulates for space and common resources, with the most severe competition occurring between elk and bison for winter range.
   d. Seasonal movement patterns, that would develop as a free ranging bison herd became established, would eventually involve movement out of the park. This would raise several issues of concern including protection and/or hunting of bison, monitoring of livestock diseases, mitigation of bison competition with elk and horses for winter range, and provision of compensation for bison damage to adjacent agricultural lands, crops, or facilities.
   e. Severe winter weather would likely be the primary source of bison mortality. However, wolf and grizzly predation, disease, and bison-vehicle collisions could be contributing factors.

f. A captive herd would require the provision of supplemental feed, nutrients, and water, and the installation of handling facilities and special fencing.

g. Public information, interpretation, and appropriate facility design are necessary enhance visitor experience and minimize public safety hazards and harassment of bison.

3. Analysis of Bison Habitat

a. The interpretation of the ELC data provided a framework for the identification of potentially suitable bison habitat in Banff National Park through use of the ELC maps.

b. There are nine ELC Ecosites potentially capable of providing *primary* forage habitat. Six of these have suitable winter snow depths. A more detailed survey would be needed to estimate carrying capacity.

c. The lower Howse/North Saskatchewan, Red Deer, and Bow River valleys are potential wintering areas for free-ranging bison.

d. Sites located near Carrot Creek, Cascade Pits, Hillsdale Meadows, and Johnson Lake were assessed as potential paddock relocation sites.

4. Buffalo Paddock Study

a. The opportunity for viewing bison is limited, largely due to vegetation screening, and the fact that the best sighting opportunities occur in early morning when visitation is lowest.

b. The Buffalo Paddock receives significant use. There were about 26,000 vehicles or 120,000 visitors during the twelve week study period.

c. About [illegible]% of the vehicles using the Buffalo Paddock are buses, representing at least 50% of the visitors.

d. Improved interpretation and facility design are required to address bison harassment and public safety concerns, and to improve the visitor experience in the Buffalo Paddock.

10.2 Review of Alternatives

The five alternatives are reviewed in this section. The principal strengths and limitations of each alternative are summarized in Table 31.

10.2.1 Alternative 1. Paddock removal and elimination of bison from Banff National Park

The first alternative proposes the removal of the Buffalo Paddock and complete elimination of bison from Banff National Park. The present wood bison herd would be relocated outside the park, the paddock facility dismantled, and site rehabilitation carried out as necessary.

The elimination of the Buffalo Paddock would improve movement of ungulates through the area and allow wildlife access to previously enclosed habitat. The management of bison would have no further impact on park resources. However, the remaining structures associated with the public and government horse corrals would still provide barriers to movement and exclude ungulates from usable range.

As this alternative completely eliminates bison from the park, the role of Banff National Park in preserving bison as a species must be addressed. Immediate consideration of this issue is complicated by the distinction that must be made between the plains bison and the currently threatened wood bison. The captive wood bison herd was introduced to and is maintained in Banff National Park in cooperation with the Canadian Wildlife Service as part of the Wood Bison Rehabilitation Program. It provides an isolated breeding herd that contributes to preservation of the wood bison gene pool and produces stock for reintroduction projects. However, as this study addresses the long-term management of bison, it assumes successful completion of the Wood Bison Rehabilitation Program and removal of wood bison from the endangered species list. This will decrease the need to maintain captive wood bison breeding herds and fulfill the commitment of Banff National Park to the Wood Bison Rehabilitation Program. Subsequently, the need to further consider this responsibility is eliminated and the role of Banff National Park in the preservation of bison can be examined on a broader scale.

Table 31. Summary of alternatives: principal strengths and limitations.

#1 PADDOCK REMOVAL AND ELIMINATION OF BISON FROM BANFF NATIONAL PARK.

Strengths:
- remove paddock barrier to wildlife movement
- return paddock habitat to wildlife
- eliminate public safety and bison harassment concerns

Limitations:
- eliminate isolated bison gene pool herd
- remove indigenous species from park
- allow bison no role in park ecosystem
- eliminate viewing and interpretation opportunit..
- eliminate visitor attraction

#2 PADDOCK REMOVAL AND ESTABLISHMENT OF A FREE-RANGING BISON HERD IN BANFF NATIONAL PARK.

Strengths:
- remove paddock barrier to wildlife movement
- return paddock habitat to wildlife
- create unique viewing and interpretation opportunity
- allow bison to reassume role in park ecosystem
- maintain isolated bison gene pool
- maintain indigenous species in park

Limitations:
- eliminate visitor attraction
- reduce viewing frequency
- introduce different public safety concerns
- introduce bison impact to park ecosystem (soil, vegetation, wildlife)
- need to develop co-operative agreements with adjacent lar wners
- possible need .o control herd movements and numbers
- reduce certaint population survival and growth

#3 RETEN.ION OF PRESENT BUFFALO PADDOCK.

Strengths:
- maintain visitor attraction
- m intain viewing and interpretation opportunity
- allow bison to assume role on confined ecosystem scale
- maintain isolated bison gene pool
- maint.in in.igenous spec'es in park

Limitations:
- not remove paddock barrier to wildlife movement
- not return paddock habitat to wildlife
- mair ain bison in captive situation
- continued public safety and bison harassment concerns

(Con'.)

Table 31. (Continued)

#4 STRUCTURAL MODIFICATION OF PRESENT BUFFALO PADDOCK.

Strengths:
- maintain visitor attraction
- maintain viewing and interp. opportunity
- improve wildlife movememt through area
- opportunity to allow some wildlife access to paddock habitat
- depending on design: may improve viewing opportunity, and decrease public safety concerns and bison harassment
- allow bison to assume role on confined ecosystem scale
- maintain isolated bison gene pool
- maintain indigenous species in park

Limitations:
- provide some barrier to wildlife movement
- not allow wildlife complete access to paddock habitat
- maintain bison in captive situation
- depending on design: may decrease viewing opportunity, and increase/maintain public safety concerns and bison harassment

#5 RELOCATION OF THE BUFFALO PADDOCK.

Strengths:
- remove paddock barrier to wildlife movement
- return paddock habitat to wildlife
- substitute visitor attraction
- allow viewing and interpretation
- maintain isolated bison gene pool
- maintain indigen[illegible] [illegible] in park
- allow bison to as[illegible] on confined ecosystem scale

Limitations:
- [illegible] on wildlife movement and habitat, [illegible]ation, and soils elsewhere
- [illegible] on visual and aesthetic environment [illegible]where
- [illegible] safety and bison harassment concerns
- m[illegible]ain bison in captive situation
- provide lower quality viewing experience than present location
- unlikely to replace visitor attraction attributes of present location

The Canadian Parks Service was a major force in the initial preservation of bison in Canada, and in fact the world. The role of the Canadian Parks Service has lessened over the last century as plains bison, and soon wood bison, have become reestablished in both captive and free ranging herds across North America. The bison herds of Elk Island and Wood Buffalo National Parks still contribute significantly to the preservation of bison. In terms of international species preservation, the ecological value of the captive herds of Riding Mountain, Prince Albert, Waterton Lakes, and Banff National Parks is relatively low. However, they do continue to provide bison gene pools which are federally controlled and so can be protected from disease and hybridization. The ecological value of a herd in Banff National Park to the preservation of the bison species has, therefore, decreased from what it once was, but cannot be entirely discounted.

However, through its commitment to protect and maintain representative natural ecosystems, and its policy of reintroducing formerly indigenous species, the Canadian Parks Service must consider the value of bison as part of the ecosystems of Banff National Park. Bison were indigenous to the park prior to 1860. Although the stronghold of the species was obviously the prairies and foothills, evidence is sufficient to indicate that bison were once a significant presence in the park. The elimination of a large ungulate such as the bison would have had considerable impacts on associated vegetation, other ungulates and predator species. The continued absence of bison precludes participation of the species in the naturally evolving ecosystems that park management strives to preserve. Although neither historical population size, nor winter distribution can be firmly established, these factors would affect the magnitude and location, rather that the fundamental nature of the ecosystem impacts of bison. It would, therefore, be desirable to reintroduce bison to at least a portion of Banff National Park, rather than eliminate them as proposed by alternative

Removal of bison from the park would eliminate a valuable opportunity for bison viewing and related education and interpretation. The bison story has high educational and interpretive value. Early North American human history is strongly tied to the bison and the story of the near extermination and subsequent recovery of the species is a powerful illustration of the need for and methods of wildlife conservation. There are other locations where bison can be viewed and the bison story related. However, the opportunity in Banff National Park is of high value because of the intrinsic interest provided by the role which the park played in bison conservation, the existence of an established bison viewing facility in the park, the naturalness of the [illegible] ing environ[illegible] nd the large audience served by the park. The removal of the Buffalo Paddock would also eliminate a popular visitor att[illegible] [illegible] [illegible] both private [illegible] [illegible] interest in viewing bison.

10.2.2 Alternative 2. Paddock removal and establishment of a free-ranging bison he[illegible] in Banff National Park

The second alternative is to remove the Buffalo Paddock and establish a free [illegible] herd of bison in the park. The removal of the paddock wo[illegible] be accomplished [illegible] previously. The establishment of a free ranging herd would require on site evaluation [illegible] determine range carrying capacity, winter forage availability, and expected inters[illegible] competition and environmental impacts. The construction of a temporary paddock [illegible] and maintenance of a breeding herd for a few years would be necessary. Recent exp[illegible] gained through the establishment of herds within the Wood Bison Rehabilit[illegible] on Program could be appl[illegible] to improve th[illegible] hances of a successful reintroduction.

While this alternative would eliminate the visitor attract[illegible] provided by the Buffalo Paddock, the establishment of a free ranging herd would provide additional opportun[illegible] for [illegible] g and interpretation of bison. Bison would not be as visible as in a confined [illegible] but the sighting of free-ranging bison in the park would be a unique exp[illegible] Interpretation of free-ranging bison management in Banff National Park has the pot[illegible] reach a wide audience [illegible] vide high-profile education relat[illegible] to the preservation of [illegible] in Canada.

The presence of free-ranging bison in Banff National Park would pres[illegible] safety concerns related to the possible occurrence of vehicle-bison collisions and [illegible] encounters with aggres[illegible]ve bison. [illegible] information and awareness could be used to minimize the harassment of bison and [illegible] occurrence of [illegible]ssive encounters. However, some incidents would undoubtedly occur as bison became established in the park, with the frequency being dependent upon the size and [illegible]ibution of the herd.

The establishment of a free ranging herd would allow bison to reassume a natural role [illegible] evolving ecosystems of the park. Free ranging bison would impact soil and vegetation [illegible] impacts on [illegible] and vegetation would generally be [illegible]spersed and in any case would be similar to those of the original free ranging bison population. Bison [illegible]d compete for space and common resources with other ungulates, alth[illegible] differences in habitat use and food habits would minimize this co[illegible]petition. Some [illegible] grassland carrying capacity for other ungulates, particularly elk, would likely occur. Bison would provide a poten[illegible] food source [illegible] wolves, gr[illegible] bears, and other predators and scavengers. The ultimate environmental impacts of free ranging bison would depend on the numbers of bison introduced and the [illegible]ation of the herd.

Suitable habitat [illegible] wintering bison exists within the park, but the habitat boundaries [illegible] areas of provincial land. It is therefore likely that free ranging [illegible] eventually, [illegible] immediately, expand their wintering ranges to include habitat [illegible] park boundaries, in a manner similar to that of park elk. Once bison became familiar with this habitat, they might also spend some time there in summer. This likelihood of bison movement onto provincial lands would require that cooperative agreements be made [illegible] adjacent landowners regarding the managem[illegible] bison.

The uncertainty of population survival and growth is a disadvantage of the free ra[illegible] alternative. The reproductive success of a free ranging herd, the impacts of winter weather on the population, and the importance of wolf predation cannot be accurately predicted. If the population does expand successfully, impacts on park resources would increase. Of primary concern would be the competition of bison with elk for winter range. The acceptability of this increased competition with elk depends [illegible] management goals for the two species. The eventual spread of bison into high visitor use areas as home range expansion occurs, is also a concern. Habituation and increased opportunity for visitor encounters with bison will allow for improved viewing of bison but will also increase the likelihood of bison harassment, bison-vehicle collisions, and aggressive [illegible] visitor interaction. Control of bison numbers within the park would be difficult and likely unacceptable. However, the likelihood of bison straying onto provincial [illegible] [illegible] advantageous if control of [illegible] numbers by hunting becomes [illegible].

10.2.3 Alternative 3. Retention of present Buffalo Paddock

The third alternative proposes the retention of the present Buffalo Paddock [illegible] limited thinning of forest cover to improve bison visibility. Bison handling facilities should also be improved to reduce stress and prevent injury to bison and handlers.

This alternative would not alleviate the wildlife migration problem, nor restore [illegible] habitat to other wildlife. However, the severity of the barrier that the paddock presents to wildlife movement has not been firmly established. The reactions of elk using the corridor between the Buffalo Paddock fence and the Trans-Canada Highway fence is variable. Some elk have been observed displaying signs of stress and panic in the corridor, while others have been observed calmly feeding and proceeding without hesitation to use the underpass.

This alternative would maintain the Buffalo Paddock as a visitor attraction and [illegible] viewing of bison could continue. Bison viewing could be improved by thinning tree cover. However, thinning would have to be carefully conducted in order to preserve [illegible] the aesthetic quality of the bison viewing setting, and maintain sufficient and appropriately located escape cover to improve public safety and minimize bison harassment. Interpretation [illegible] in the Buffalo Paddock could be expanded to more fully realize the education potential provided by bison management in Banff National Park and to more effectively provide information which would enhance public safety and decrease harassment of bison.

The retention of the Buffalo Paddock requires that the acceptability of maintaining a captive bison herd within Banff National Park be addressed. From a policy standpoint, the decision to allow the degree of natural process and habitat manipulation that is required to maintain a captive bison herd, must be based upon recognition of the inability to maintain the species by natural means. This study suggests that the physical resources of Banff National Park are sufficient to maintain bison by natural means. It is therefore the perceived incompatibility of free ranging bison management with present resource conservation and visitor use goals, and the cost of solving bison management problems, which would prevent [illegible]

From an ecological standpoint, ca[illegible] reintroduction does not allow bison to assume a natural role in the ecosystems of the park. However, depending on the natural area encompassed by the facility and the opportunity for interaction with other wildlife, naturally evolving relationships may occur on a confined ecosystem scale. The ecological value of these relationships is low relative to free-ranging reintroduction. However, it is high relative to complete elimination of bison from the park. As this particular alternative for captive reintroduction does not allow paddock access to other ungulates, only limited interaction of bison with their environment can occur. Still, bison can exist in a relatively natural setting, with vegetation and climatic conditions representative of a small portion of Banff National Park.

Finally, the human dimensions of retaining a captive bison herd must be considered. Some visitors may perceive the ma[illegible]nce of captive wildlife as being in conflict with the modern philosophy of national park [illegible]agement. [illegible]ever, if the decision were made that the only way to maintain bison in Banff Nation[illegible]as through captive representation, interpretation and education could be used to inform visitors of the reason for the presence of captive [illegible]life. Most park visitors could recognize and appreciate the special management problems associated with maintaining a large ungulate species which has been absent from the park ecosystem for over a hundred years. As previously mentioned, the provision of an opportunity for bison viewing and interpretation in Banff National Park is worthwhile. The fact that this viewing and interpretation occurs in a captive situation may decrease, but does not eliminate, the value to be realized. Although bison visibility in the present Buffalo

Paddock is limited, the aesthetic quality of the actual bison viewing experience is high. Despite the captive nature of the herd, the Buffalo Paddock provides an opportunity for observing bison in a natural setting which is unequalled by most park, zoo, and private facilities in southern Canada. In fact, due to the high degree of development in adjacent areas, the Buffalo Paddock presents a comparatively natural setting in the Banff Townsite area in which to view several wildlife species.

10.2.4 Alternative 4. Structural modification of the present Buffalo Paddock

The primary objective of the fourth alternative, structural modification of the present Buffalo Paddock, is to improve ungulate movement through the area. This could be accomplished by changing the size and shape of the paddock, by altering the paddock fence to allow ungulates to pass through the paddock, or by a combination of the two methods. The change in paddock size and shape would, in general terms, be conducted by widening the corridor between the Buffalo Paddock fence and the Trans-Canada Highway fence. The resultant paddock could be designed to retain the areal extent of the old paddock by expanding towards the airport or reduced in area to the degree that the paddock becomes a display facility. Paddock modification by installing a fence that would allow ungulate passage could be combined with slight adjustments in paddock shape to ensure maximum passage of ungulates. This would decrease the degree of the barrier presented by the paddock and allow ungulates access to paddock range, without creating a small display paddock or an extremely narrow paddock.

The impacts of paddock modification could range from the exclusion of ungulates from the same amount of habitat as the present facility to impacting little area and allowing ungulates access to a significant amount of previously enclosed habitat. Similarly, the habitat available to bison would range from being equivalent to that of the present paddock to a feedlot situation. In a paddock which allowed access to ungulates, range condition would have to be monitored to determine any changes in carrying capacity for bison. Supplemental feeding of bison would have to be conducted in such a way as to avoid aggressive interspecific encounters and prevent consumption of excess feed by other ungulates.

This alternative possesses the advantages and disadvantages of captive herd management discussed for alternative three. The degree of interaction of bison with their environment varies with the design. A facility similar in size to the present paddock with a fence which allowed access to other ungulates would provide the most opportunity for bison to interact with their environment and other wildlife. Conversely, bison in a small display paddock would have no opportunity for natural interaction.

As with retention of the present Buffalo Paddock, this alternative would allow for viewing and interpretation of bison. However, the opportunity and quality of bison viewing would be affected by the size and design of the paddock. Paddock designs would differ in the way and extent to which they made provisions for the visibility of bison, the safety of visitors, the security of bison from harassment, and the aesthetic appeal of the paddock. A paddock which was considerably smaller than the present facility (or, a display-type paddock) would provide an artificial setting for bison viewing. This would greatly decrease the value of the facility as a visitor attraction and as a location for viewing and interpretation of bison. A narrow paddock could raise concerns for visitor safety and bison harassment. Road and fence location would affect the visibility of bison and the aesthetic appeal of the setting. The presence of other wildlife species in the paddock could enhance the wildlife viewing opportunity.

10.2.5 Alternative 5. Relocation of the Buffalo Paddock

The fifth alternative involves the relocation of the Buffalo Paddock. Four sites, Carrot Creek, Cascade Pits, Hillsdale Meadows, and Johnson Lake, have been identified as suitable for relocation. As described in Section 8.2, these sites differ based on their ability to meet bison requirements, the environmental impacts associated with the introduction of a paddock, the way the sites address visitor use concerns, and the relative costs for the relocation.

Relocation would remove the present Buffalo Paddock, thereby improving the movement of ungulates through the area and allowing wildlife access to previously enclosed habitat as described for the first alternative. However, paddock relocation to any of the sites would involve some impact on the local wildlife, vegetation, soil, and visual and aesthetic resources. Relatively high impacts would occur on wildlife at the Hillsdale Meadows site, on vegetation and soils at the Johnson Lake site, and on the visual environment at both [illegible] Pits and Hillsdale Meadows.

Paddock relocation would still require maintenance of a captive bison herd, and would thereby provide opportunities for bison viewing and interpretation. However, based on [illegible] compatibility with present and planned visitor use, the predicted visibility of bison, the aesthetic quality of the setting, and degree of access, none of the sites could replace the visitor attraction provided by the present Buffalo Paddock or provide an equivalent bison viewing opportunity.

11. RECOMMENDATIONS

This study has provided the framework required to analyze the alternatives for bison management in Banff National Park. Four sub-studies examined the historical presence of bison in the park, the management factors associated with the various alternatives, the availability of bison habitat in the park, and the concerns related to visitor use. The results of these sub-studies were applied to a review of the bison management alternatives, and the two best alternatives were identified as the introduction of a free-ranging bison herd or the modification of the present Buffalo Paddock.

The remaining alternatives were eliminated due to the disadvantages outlined below. Maintenance of the present Buffalo Paddock would not allow any improvement in wildlife movement through the area. Relocation of the Buffalo Paddock, while there are sites which would be suitable, would be expensive, would negatively impact wildlife habitat and natural environment elsewhere, and would provide a less desirable visitor experience than a modified paddock. Elimination of bison from the park is not judged acceptable as bison are indigenous to the area, and therefore attempts should be made to maintain them in the park. Their removal would also eliminate the opportunity for bison viewing and interpretation. Two major recommendations are therefore presented

1. The introduction of a free-ranging bison herd is recommended as the best alternative from a resource management perspective. This would eliminate wildlife conflicts associated with the paddock. A free-ranging herd would allow bison, an indigenous species, to reassume their role in the park ecosystem. It would also provide a unique opportunity for free-ranging bison management and interpretation in southern Canada. However, there are various implementation difficulties associated with this alternative. While habitat is available for summering bison, winter range is more limited and movement outside of the park would likely occur. A free ranging herd would have impacts on other ungulate species, and control of bison herd movement and numbers would be difficult. Free ranging bison would not be highly visible to visitors, depending on the location and size of the herd, and some visitor safety concerns may arise

2. Modification of the present Buffalo Paddock is the next best alternative, given the implementation difficulties of free-ranging bison. The maintenance of a captive bison population in the park would protect an isolated gene pool herd and prevent the complete elimination of an indigenous species from the park. Modification would require changes in fence design, paddock configuration, road location, and forest cover density (and, possibly, extent). A narrower paddock and/or lowered fence would facilitate ungulate movement and may allow some wildlife access to habitat now enclosed by the paddock. The bison viewing experience could be improved by elimination of some forest cover and relocation of the loop road. It would be necessary to balance good bison visibility with sufficient escape cover for bison, as the bison are sometimes harassed by visitors.

12. LITERATURE CITED

Achuff, P. L. 1982. Vegetation: introduction and methods. p. 71-75. *in* Ch. III Vegetation. W. D. Holland and G. M. Coen. (general eds.). 1982. Ecological (biophysical) land classification of Banff and Jasper National Parks. Volume II: Soil and vegetation resources. Alberta Inst of Pedology. Pub. No. SS-82-44. 540 p.

Achuff, P. L. and I. G. W. Corns. 1983. Vegetation. p. 42-92. *in* Ch. II. Description of the study area. W. D. Holland, and G. M. Coen. (general eds.). 1983. Ecological (biophysical) land classification of Banff and Jasper National Parks. Volume I: summary. Alberta Inst. of Pedology. Pub. No. M-83-2. 193 p.

Achuff, P., I. Pengelly, and C. White. 1986. Special resources of Banff National Park. Report prepared for Parks Canada, Banff National Park. 141 p.

Agresti, A. and B. F. Agresti. 1979. Statistical methods for the social sciences. Dellen Publishing Co., San Francisco. 554 p.

Baird, D. M. 1977. Banff National Park. How nature carved its splendour. Hurtig Pub., Edmonton. 237 p.

Banfield, A. W. F. 1958. The mammals of Banff National Park, Alberta. Natl. Mus. of Canada Bull. No. 159. The Queen's Printer, Ottawa. 53 p.

Banfield, A. W. F. 1974. The mammals of Canada. Univ. of Toronto Press, Toronto. 438 p.

Billyard, K. 1979. History of the buffalo in Banff National Park. Report prepared for Parks Canada, Banff National Park. 16 p.

Bison Disease Task Force. 1988. Evaluation of brucellosis and tuberculosis in bison in northern Canada. R. Coupland (co-chairman), Ag. Can., Grande Prairie, Alta., and B. Redhead (co-chairman), Can. Parks Serv., Fort Smith N. W. T. Rep. prepared for Bison Disease Steering Committee. 213 p.

Bostock, H. S. 1976. Ch. II: Physiographic subdivisions of Canada. p. 9-30 *in* R. J. W. Douglas (ed.). Geology and economic minerals of Canada. 5th edition. Geol. Surv. of Canada. Economic Geology Rep. No. 1. 838 p.

Boyle, S. A. and F. B. Samson. 1985. Effects of nonconsumptive recreation on wildlife: a review. Wildl. Soc. Bull. 13:110-116.

Broughton, E. 1987. Diseases affecting bison. p. 34-38 *in* H. W. Reynolds and A. W. L. Hawley (eds.). Bison ecology in relation to agricultural development in the Slave River Lowlands, NWT. Can. Wildl. Serv. Occas. Pap. No. 63. Minister of Supply and Services, Canada. 74 p.

Bunnage, J. (ed.). 1985. The Game Grower. 1(1):1-25. Edmonton.

Burger, G. V. 1979. Principles of wildlife management. p. 89-97 *in* R. D. Teague and E. Decker (eds.). Wildlife conservation. The Wildl. Soc. Washington, D. C. 280 p.

Cairns, A. L. 1976. Distribution and food habits of moose, wapiti, deer, bison and snowshoe hare in Elk Island National Park, Alberta. M. S. Thesis. Univ. of Calgary, Calgary. 169 p.

Cairns, A. L. and E. S. Telfer. 1980. Habitat use by four sympatric ungulates in boreal mixedwood forest. J. Wildl. Manage. 44:849-857.

Choquette, L. P. E., E. Broughton, E. Cousineau and N. S. Novakowski. 1978. Parasites and diseases of bison in Canada Part IV: Serologic survey for brucellosis in bison in Canada. J. Wildl. Dis. 14:329-332.

Choquette, L. P. E., E. Broughton, A. A. Currier, J. G. Cousineau and N. S. Novakowski. 1972. Parasites and diseases of bison in Canada Part III: Anthrax outbreaks in the last decade in northern Canada and control measures. Can. Field Nat. 86:127-132.

Choquette, L. P. E., J.F. Gallivan, J. L. Byrne, and J. Pilipavicius. 1961. Parasites and diseases of bison in Canada. Part I: Tuberculosis and some other pathological conditions in bison at Wood Buffalo and Elk Island National Parks in the fall and winter of 1959-60. Can. Vet. Jour. 2:168-174.

Christensen, O. A. 1971. Banff prehistory: prehistoric settlement and subsistence technology in Banff National Park. Natl. and Historic Parks Br. Manuscript Rep. No. 67. 323 p.

Christopherson, R. J., R. J. Hudson, and M. K. Christopherson. 1979. Seasonal energy expenditures and thermoregulatory responses of bison and cattle. Can. J. Anim. Sci. 59:611-617.

Cochran, W. G. 1963. Sampling techniques. 2nd edition. John Wiley & Sons, Inc. New York. 413 p.

Coder, G. D. 1975. The national movement to preserve the American buffalo in the United States and Canada between 1880 and 1920. Ph. D. Diss. Ohio State Univ. 348 p.

Corner, A. H. and R. Connell. 1958. Brucellosis in bison, elk and moose in Elk Island National Park, Alberta, Canada. Can. J. Anim. Sci. 59:611-617.

Cornish, B., J. van Camp, and M. McNicholl. 1980. The impacts of recreation on fish and wildlife with emphasis on Kananaskis Country: A literature review and partial bibliography. Kananaskis Country Planning Document # 4. Alberta Energy and Nat. Res., Fish and Wildl. Div. 116 p.

Damp, J. E., C. E. Connolly, and T. V. Smith. 1980. Conservation archaeological studies EhPw-2 and EhPw-4, Banff National Park. Manuscript on file, Archaeological Research Services Unit, Canadian Parks Service, Western Region, Calgary.

Dary, D. 1974. The buffalo book: the saga of an American symbol. Avon Books, New York. 374 p.

Davidson, T. and D. Norcross. 1978. Bison re-introduction, Jasper National Park. Interim report Nov. 1978. Unpubl. rep., Warden Service, Jasper National Park. 25 p.

Driver, B. L. 1985. Specifying what is produced by management of wildlife by public agencies. Leisure Sciences. 7:281-295.

Eastcott, D. 1984. Directions for wildlife management: a summary. Parks Canada, Western Region, Calgary. 140 p.

Egerton, P. J. M. 1962. The cow-calf relationship and rutting behavior in the American bison. M. S. Thesis. Univ. of Alberta. Edmonton, Alberta. 155 p.

Engelhard, J. G. 1970. Behavior patterns of American bison calves at the National Bison Range, Moiese, Montana. M. S. Thesis. Central Michigan Univ. Mt. Pleasant, Michigan. 150 p.

Environment Canada - Parks. 1986a. Background report, Banff National Park management planning program. Nov. 1986. Environment Canada - Parks. Western Region, Calgary. 94 p.

Environment Canada - Parks. 1986b. Banff core concept, Banff National Park management planning program. Dec. 1986. Environment Canada - Parks. Western Region, Calgary. 142 p.

Environment Canada - Parks. 1986c. Banff townsite peripheral land use initial environmental evaluation. Summary. Dec. 1986. Prepared by B. F. Leeson and G. Harrison, Nat. Hist. Res. Div., Environment Canada - Parks. Western Region, Calgary. 27 p.

Fedje, D. W. 1982. Preliminary excavations at the Whiskey Creek Site: EhPv 24, Banff National Park. Manuscript on file, Archaeological Research Services Unit, Canadian Parks Service, Western Region, Calgary.

Fedje, D. W. 1986a. The Second Lake site: archaeological mitigation in Banff National Park. Microfiche Rep. Series. No. 234. Environment Canada, Parks, Ottawa.

Fedje, D. W. 1986b. Banff archaeology 1983-1985. p. 25-62 *in* Archaeological Survey of Alberta Occas. Pap. No. 30. Alberta Culture, Edmonton.

Fedje, D. W. 1987a. The Norquay and Eclipse sites: Trans-Canada Highway twinning mitigation in Banff National Park. Manuscript on file, Archaeological Research Services Unit, Canadian Parks Service, Western Region, Calgary.

Fedje, D. W. 1987b. Banff resource description reconnaissance 1986. Manuscript on file, Archaeological Research Services Unit, Canadian Parks Service, Western Region, Calgary.

Fedje, D. W. and A. J. Landals. 1987. Archaeological resource impact assessment, Banff Springs Hotel golf course and staff housing expansion. Manuscript on file, Archaeological Research Services Unit, Canadian P rks Service, Western Region, Calgary

Fedje, D. W. and J. M. White. 1984. Vermillion Lakes archaeology and palaeoecology, Trans-Canada Highway mitigation in Banff National Park. Manuscript on file, Archaeological Research Services Unit, Canadian Parks Service, Western Region, Calgary.

Ferguson, M. 1980. Ungulates and cross-country skiing, Elk Island National Park, Alberta. M. S. Thesis. Univ. of Wisconsin. Madison, Wisconsin. 57 p.

Filion, F. L. S. W. James, J. Ducharme, W. Pepper, R. Reid, P. Boxall, and D. Teillet. 1983. The importance of wildlife to Canadians: highlights of the 1981 national survey. Report published by Can. Wildl. Serv., Env. Canada for the 47th FederalProvincial Wildl. Conf. 40 p.

Foster, J. 1978. Working for wildlife: the beginnings of preservation in Canada. Univ. of Toronto Press, Toronto. 283 p.

Fuller, W. A. 1959. The horns and teeth as indicators of age in bison. J. Wildl. Manage. 23: 342-344.

Fuller, W. A. 1960. Behavior and social organization of the wild bison of Wood Buffalo National Park, Canada. Arctic 13(1):1-19.

Fuller, W. A. 1962. The biology and management of the bison of Wood Buffalo National Park. Can. Wildl. Serv. Wildl. Manage. Bull., Ser. 1, No. 16. 52 p.

Geist, V. and P. Karsten. 1977. The wood bison (*Bison bison athabascae* Rhoads) in relation to hypotheses on the origin of the American bison (*Bison bison bison* Linnaeus). Z. Saugetierk. 42(2):119-127.

Guthrie, R. D. 1980. Bison and man in North America. Can. J. Anthropol. 1(1):55-73.

Haines, F. 1970. The buffalo. Thomas Y. Crowell. Co. New York. 242 p.

Halloran, A. F. 1968. Bison (Bovidae) productivity on the Wichita Mountains Wildlife Refuge, Oklahoma. Southwestern Nat. 13:23-26.

Harington, C. R. 1984. Mammoths, bison and time in North America. p. 299-309 *in* W. C. Mahaney (ed.). Quaternary dating methods. Elsevier Science Pub. B. V. Amsterdam. 431 p.

Haugen, A. O. 1974. Reproduction in the plains bison. Iowa State J. Res. 49:1-8.

Hawley, A. W. L., D. G. Peden, and W. R. Stricklin. 1981a. Bison and hereford steer digestion of sedge hay. Can. J. Anim. Sci. 61:165-174.

Hawley, A. W. L., D. G. Peden, and H. W. Reynolds. 1981b. Bison and cattle digestion of forages from the Slave River Lowlands, Northwest Territories. Can. J. Range Manage. 34:126-130.

Head, T. H. and S. Van Dyke. 1986. Archaeological resources site survey and assessment, Banff peripheral land use study area, Phase II, Phase III, and overview areas. Manuscript on file, Archaeological Research Services Unit, Canadian Parks Service, Western Region, Calgary.

Hendee, J. C. and D. R. Potter. 1971. Human behavior and wildlife management: needed research. Trans. N. Am. Wildl. Nat. Resour. Conf. 36:383-395.

Herrig, D. M. and A. D. Haugen. 1969. Bull bison behavior traits. Iowa Acad. Sci. 76:245-262.

Heusser, C. J. 1956. Postglacial environments in the Canadian Rocky Mountains. Ecol. Monogr. 26(3): 263-302.

Holland, W. D. and G. M. Coen. (general eds.). 1982. Ecological (biophysical) land classification of Banff and Jasper National Parks. Volume II: Soil and vegetation resources. Alberta Inst. of Pedology. Pub. No. SS-82-44. 540 p.

Holland, W. D., P. L. Achuff, and B. D. Walker. 1982. Climate. p. 4-12. *in* Ch. I. Physical environment. W. D. Holland and G. M. Coen. (general eds.). 1982. Ecological (biophysical) land classification of Banff and Jasper National Parks. Volume II: Soil and vegetation resources. Alberta Inst. of Pedology. Pub. No. SS-82-44. 540 p.

Holland, W. D., G. R. Hillman, and D. T. Allan. 1982. Physiography. p. 12-17. *in* Ch. I. Physical environment. W. D. Holland and G. M. Coen. (general eds.). 1982. Ecological (biophysical) land classification of Banff and Jasper National Parks. Volume

II: Soil and vegetation resources. Alberta Inst. of Pedology. Pub. No. SS-82-44. 540 p.

Holland, W. D. and G. M. Coen. (general eds.). 1983. Ecological (biophysical) land classification of Banff and Jasper National Parks. Volume I: summary. Alberta Inst of Pedology. Pub. No. M-83-2. 193 p.

Holroyd, G. L. and K. J. vanTighem. 1983. Ecological (biophysical) land classification of Banff and Jasper National Parks. Volume III. the wildlife inventory. Parts A and B. Can. Wildl. Serv., Edmonton. 691 p.

Holsworth, W. N. 1960a. Buffalo range and food habits of buffalo in Wood Buffalo Park. Report prepared for Can. Wildl. Serv., Edmonton. 15 p.

Holsworth, W. N. 1960b. Interactions between moose, elk, and buffalo in Elk Island National Park, Alberta. M. S. Thesis. Univ. of British Columbia, Victoria. 92 p.

Hornaday, W. T. 1889. The extermination of the american bison with a sketch of its discovery and life history. p. 367-548 *in* Part 2 (1889) Rep. U. S. Natl. Mus. 1886-1887.

Houston, D. B. 1982. The northern Yellowstone elk: ecology and management. Macmillan Pub. Co., Inc., New York. 474 p.

Hudson, R. J., T. Tennessen, and A. Sturko. 1976. Behavioral and physiological reactions of bison to handling during an anthrax vaccination program in Wood Buffalo National Park. p. 120-145. *in* Wildlife productivity-annual report 1976. Dept. Anim. Sci., Faculty of Agric. and For. Univ. of Alberta. Edmonton, Alberta.

I. R. Wilson Consultants, Ltd. 1985. Banff townsite peripheral land use study, heritage resources. Microfiche Rep. Series. No. 180. Parks Canada, Ottawa.

Jackson, J. J. 1982. Public support for nongame and endangered wildlife management: which way is it going? Trans. N. Am. Wildl. Nat. Resour. Conf. 47:432-440.

Janz, B. and D. Storr. 1977. The climate of the contiguous mountain parks: Banff, Jasper, Yoho, and Kootenay. Atm. Env. Serv. Proj. Rep. No. 30. Toronto. 324 p.

Jennings, D. C. and J. Hebbring. 1983. Buffalo management and marketing. Natl. Buffalo Assoc., Custer. 370 p.

Kellert, S. R. 1980. Needed research on people-animal interactions in national parks. Proc. 2nd Conf. on Sci. Res. in National Parks, Vol. 6 Sociology:165-167.

Kellert, S. R. and P. J. Brown. 1985. Human dimensions information in wildlife management, policy, and planning. Leisure Sciences. 7:269-280.

Ledwidge, M. 1982. Bison exhibit in Banff National Park. Report prepared for Parks Canada, Banff National Park. 3 p.

Lothian, W. F. 1981. A history of Canada's national parks. Vol. IV. Minister of Supply and Services, Canada. 154 p.

Lott, D. F. 1974. Sexual and aggressive behavior of adult male American bison (*Bison bison*) p. 382-394. *in* V. Geist and F. Walther (eds.). The behavior of ungulates and its relation to management. Internatl. Union Cons. Nature, New Series No 24. Morges, Switzerland. 940 p.

Lott, D. F. and S. C. Minta. 1983. Home ranges of American bison cows on Santa Catalina Island, Ca. J. Mamm. 64:161-162.

Luxton, F. G. 1975. Banff - Canada's first national park. Summerthought, Banff. 157 p.

Lyons, J. R. 1982. Non-consumptive wildlife associated recreation in the United States: identifying the other constituency. Trans. N. Am. Wildl. Nat. Resour. Conf. 47:677-685.

McCorquodale, S. M. and R. F. DiGiacomo. 1985. The role of wild North American ungulates in the epidemiology of bovine brucellosis: a review. J. Wildl. Dis. 21:351-357.

McCullough, Y. B. 1980. Niche separation of seven North American ungulates on the National Bison Range, Montana. Ph. D. Diss. Univ. of Michigan. Ann Arbor. 239 p.

Mc[illegible] J. N. 1981. N[illegible] bison: their classification and evolution. Univ. of California Press, Berke[illegible].

McHugh, T. 1958. Social behavior of the American bison. Zoologica 43(1):1-40.

McHugh, T. 1972. The time of the buffalo. Univ. of Nebraska Press, Lincoln. 339 p.

McIntyre, M. L. and B. O. K. Reeves. 1985. Archaeological investigations: Lake Minnewanka site (EhPu-1). Manuscript on file, Archaeological Research Services Unit, Canadian Parks Service, Western Region, Calgary.

Meagher, M. M. 1973. The bison of Yellowstone National Park. Natl. Park Serv. Sci. Monogr. No. 1. 161 p.

Meagher, M. M. 1974. Yellowstone's bison: a unique wild heritage. Natl. Parks and Conserv. Mag. May:9-14.

Meagher, M. M. 1976. Winter weather as a population regulating influence on free-ranging bison in Yellowstone National Park. p. 29-38 *in* Research in the parks. Trans. Natl. Park Centennial Symp. Amer. Assoc. Advancement Sci. Dec. 28-29, 1971. Ser. No. 1. U. S. Govt. Print. Office, Washington. 232 p.

Meagher, M. M. 1978. Bison. p. 123-133 *in* J. L. Schmidt and D. L. Gilbert (eds.). Big game of North America: ecology and management. Stackpole Books, Harrisburg. 494 p.

Meagher, M. M. 1986. *Bison bison.* Mammalian Species. No. 266. Amer. Soc. Mammalogists. 8 p.

Minion, P. F. and G. T. Schmidt. 1984. Status review of free-ranging bison in Prince Albert National Park. Jan. 1969 - Dec. 1983. Report prepared for Parks Canada, Prince Albert National Park. 58 p.

More, T. A. 1979. The demand for non-consumptive wildlife uses: a review of the literature. U. S. Dept. of Agric., For. Serv. Gen. Tech. Rep. NE-52. Northeastern For. Exper. Sta. Broomall, Pennsylvania.

National Research Council. 1984. Nutrient requirements of beef cattle. 6th revised edition. Natl. Acad. Press. Washington, D. C. 90 p.

Norland, J. E. 1984. Habitat use and distribution of bison in Theodore Roosevelt National Park. M. S. Thesis. Montana State Univ., Bozeman, Montana. 131 p.

Norland, J. E., L. R. Irby, and C.B. Marlow. 1985. Determination of optimum bison stocking rate in Theodore Roosevelt National Park, North Dakota. J. Env. Manage 21:225-239.

North-West Territories. 1877. Journals of the council of the North-West Territories of Canada. Session of 1877. Regina. 27 p.

Novakowski, N. S. 1978. Status report on wood bison (*Bison bison athabascae*) in Canada. Committee on the Status of Endangered Wildlife in Canada. 19 p.

Novakowski, N.S., J. G. Cousineau, G. B. Kolenosky, G. S. Wilton, and L. P. E. Choquette. 1963. Parasites and diseases of bison in Canada Part II: Anthrax epizootic in the Northwest Territories. Trans. N. Am. Wildl. Nat. Resour. Conf. 28:233-239.

Ogilvie, S. C. 1979. The park buffalo. Natl. and Prov. Parks Assoc. of Canada, Calgary. 68 p.

Olsen, W. 1982. Banff townsite peripheral land use wildlife component, initial environmental evaluation (interim report) Oct. 1982. Nat. Hist. Res. Div., Parks Canada, Calgary. 137 p.

Olsen, W. 1984. Banff townsite peripheral land use, wildlife component, initial environmental evaluation (final report) Jan. 1984. Nat. Hist. Res. Div., Parks Canada, Calgary. 210 p.

Oosenbrug, S. M. and L. N. Carbyn. 1985. Wolf predation on bison in Wood Buffalo National Park. Report prepared for Can. Wildl. Serv., Edmonton. 264 p.

Parks Canada. 1981. Manual on application of the Environmental Assessment and Review Process within Parks Canada. Nat. Resources Div., National Parks Branch, Parks Canada.

Parks Canada. 1983. Parks Canada Policy. Minister of Supply and Services, Canada. 47 p.

Parks Canada 1984. Banff townsite peripheral land use initial environmental evaluation (interim report) May, 1984. Nat. Hist. Res. Div., Parks Canada, Calgary. 35 p.

Peden, D. G. and G. J. Kraay. 1979. Comparison of blood characteristics in plains bison, wood bison, and their hybrids. Can. J. Zool. 57(9):1778-1784.

Peden, D. G., G. M. van Dyne, R. W. Rice, and R. M. Hansen. 1974. The trophic ecology of *Bison bison* L. on shortgrass plains. J. Appl. Ecol. 11:489-498.

Peters, H.F. and S.B. Slen. 1964. Hair coat characteristics of bison, domestic X bison hybrids, cattalo, and certain domentic breeds of cattle. Can. J. Anim. Sci. 44:48-57.

Petersburg, S. J. 1973. Bull bison behavior at Wind Cave National Park. M. S. Thesis. Iowa State Univ. Ames, Iowa. 302 p.

Popp, J. K. 1981. Range ecology of bison on mixed grass prairie at Wind Cave National Park. M. S. Thesis. Iowa State Univ. Ames, Iowa. 59 p.

Price, R. A. and E. W. Mountjoy. 1970. Geologic structure of the Canadian Rocky

Mountains between Bow and Athabasca Rivers - a progress report. p. 7-26 *in* J. O. Wheeler (ed.). Structure of the southern Canadian Cordiliera. Geological Assoc. of Canada. Special Paper No. 6. 166 p.

Ream, C. H. 1980. Impact of backcountry recreationists on wildlife: an annotated bibliography. U. S. Dept. of Agric., For. Serv. Gen. Tech. Rep. INT-84. Intermountain For. and Range Exper. Sta. Ogden, Utah. 62 p.

Reynolds, H. W. 1976. Bison diets of Slave River Lowlands, Canada. M. S. Thesis. Colorado State Univ. Ft. Collins. 66p.

Reynolds, H. W. 1980. Wood bison: past, present and future. Can. Wildl. Admin. Vol. VI: 75-78. Ontario Ministry of Nat. Resources.

Reynolds, H. W., R. D. Glaholt, and A. W. L. Hawley. 1982. Chapter 49: Bison. p. 972-1007 *in* J. A. Chapman and G. A. Feldhamer (eds.). Wild mammals of North America: biology/management/economics. John Hopkins Univ. Press, Baltimore. 1147 p.

Reynolds, H. W., R. M. Hansen, and D. G. Peden. 1978. Diets of the Slave River Lowland bison herd, Northwest Territories, Canada. J. Wildl. Manage. 42(3):581-590.

Reynolds, H. W. and A. W. L. Hawley. (eds.). 1987. Bison ecology in relation to agricultural development in the Slave River Lowlands, NWT. Can. Wildl. Serv. Occas. Pap. No. 63. Minister of Supply and Services, Canada. 74 p.

Reynolds, H. W., R. McFetridge, and F. Didzena. 1985. A management plan for wood bison in Alberta. Report prepared for Alberta Fish and Wildl. Div. and Can. Wildl. Serv., 26 p.

Richmond, R. J., R. J. Hudson, and R. J. Christopherson. 1977. Comparison of forage intake and digestibility by American bison, yak, and cattle. Acta. Theriol. 22:225-230.

Robinson, S. 1980. A report on the natural and human history of Banff National Park (The Book of Banff). Revised edition. Prepared for Parks Canada. 67 p.

Roe, R. G. 1957. Western penetration of the historic buffalo in the Upper Bow River Valley. Alberta Hist. Rev. 5(1): 21-24.

Roe, R. G. 1970. The North American buffalo: a critical study of the species in its wild state. (2nd edition). Univ. of Toronto Press, Toronto. 991 p.

Rorabacher, J. A. 1970. The American buffalo in transition. North Star Press, St. Cloud. 142 p.

Rutberg, A. T. 1984. Birth synchrony in American bison (*Bison bison*): response to predation or season? J. Mamm. 65:418-423.

Rutter, N. W. 1972. Geomorphology and multiple glaciation in the area of Banff, Alberta. Geol. Surv. of Canada. Bull. 206. Ottawa. 54 p.

Schulz, R. A. 1985. User profile study, Alberta Rocky Mountain National Parks. Report prepared for the Govt. of Canada, Dept. of Regional Industrial Expansion. PCM Construction Control Consultants. 84 p.

Scotter, G. W. 1972. Carrying capacity of the summer and winter bison paddocks, Banff

National Park. Report prepared for Can. Wildl. Serv., Edmonton. 9 p.

Shackleton, D. M. 1968. Comparative aspects of the social organization of American bison. M. S. Thesis. Univ. of Western Ontario, London. 67 p.

Shaw, G. G. and H. W. Reynolds. 1985. Selenium concentrations in forages of a northern herbivore. Arctic 36:61-64.

Shaw, W. W. and T. Cooper. 1980. Managing wildlife in national parks for human benefit. Proc. 2nd Conf. on Sci. Res. in National Parks. Vol. 6 Sociology 189-198.

Shaw, W. W. and W. R. Mangun. 1984. Nonconsumptive use of wildlife in the United States: An analysis of data from the 1980 national survey of fishing, hunting and wildlife associated recreation. U. S. Dept. of the Interior. Fish and Wildl. Serv. Resource Pub. 154. Washington, D.C. 20 p.

Shaw, W. W., W. R. Mangun, and J. R. Lyons. 1985. Residential enjoyment of wildlife resources by Americans. Leisure Sciences 7:361-375.

Skinner, M. F. and O. C. Kaisen. 1947. The fossil bison of Alaska and preliminary revision of the genus. Bull. Amer. Mus. Nat. Hist. 89:123-256.

Soper, D. J. 1941. History, range and home life of the northern bison. Ecol. Monogr. 11(4):347-412.

Soper, D. J. 1942. Mammals of Wood Buffalo Park, northern Alberta and District of Mackenzie. J. Mamm. 23:119-145.

Soper, D. J. 1964. The mammals of Alberta. The Queen's Printer, Edmonton. 402 p.

Spry, I. M. 1963. The Palliser Expedition. Macmillan Co., Toronto. 310 p.

Telfer, E. S. and A. Cairns. 1979. Bison-wapiti interrelationships in Elk Island National Park, Alberta. p. 114-121 *in* M. S. Boyce and L. D. Hayden-Wing (eds.). North American elk: ecology, behavior and management. Univ. of Wyoming, Laramie. 294 p.

Telfer, E. S. and J. P. Kelsall. 1979. Studies of morphological parameters affecting ungulate locomotion in snow. Can. J. Zool. 57:2153-2159.

Van Camp, J. 1975. Snow conditions and the winter feeding behavior of *Bison bison* in Elk Island National Park. Report prepared for Can. Wildl. Serv., Edmonton. 91 p.

Van Camp, J. 1987. Predation on bison. p. 25-33 *in* H. W. Reynolds and A. W. L. Hawley (eds.). Bison ecology in relation to agricultural development in the Slave River Lowlands, NWT. Can. Wildl. Serv. Occas. Pap. No. 63. Minister of Supply and Services, Canada. 74 p.

Van Camp, J. and G. W. Calef. 1987. Population dynamics of bison. p. 21-24 *in* H. W. Reynolds and A. W. L. Hawley (eds.). Bison ecology in relation to agricultural development in the Slave River Lowlands, NWT. Can. Wildl. Serv. Occas. Pap. No. 63. Minister of Supply and Services, Canada. 74 p.

Van Dyke, S. 1987. Final report: archaeological survey and assessment, upper Red Deer River valley, Banff National Park, 1987. Manuscript on file, Archaeological Research Services Unit, Canadian Parks Service, Western Region, Calgary.

Van Vuren, D. 1979. Ecology and behavior of bison in the Henry Mountains, Utah. M. S. Thesis. Oregon State Univ., Corvallis. 39 p.

Van Vuren, D. 1983. Group dynamics and summer home range of bison in southern Utah. J. Mamm. 64:329-332.

van Zyll de Jong, C. G. 1986. A systematic study of recent bison with particular consideration of the wood bison (*Bison bison athabascae* Rhoads 1898). Natl. Mus. of Nat. Sci., Pub. in Nat. Sci. No. 6, Ottawa. 69 p.

Vaske, J.J., A.R. Graefe, and F. R. Kuss. 1983. Recreation impacts: a synthesis of ecological and social research. Trans. N. Am. Wildl. Nat. Resour. Conf. 48:96-107.

Waggoner, V. and M. Hinkes. 1986. Summer and fall browse utilization by an Alaskan bison herd. J. Wildl. Manage. 50(2):322-324.

White, C. 1985. Wildland fires in Banff National Park 1880-1980. Natl. Parks Br., Parks Canada, Env. Canada. Occas. Pap. No. 3. 106 p.

Wilkins, B. J. and S. R. Peterson. 1979. Nongame wildlife. p. 178-183 *in* R. D. Teague and E. Decker (eds.). Wildlife conservation. The Wildl. Soc. Washington, D. C. 280 p.

Wilson, M. 1971. Banff National Park archaeological survey 1969: faunal remains. Manuscript on file, Dept. of Archaeology, Univ. of Calgary, Calgary.

Witter, J. F. 1981. Brucellosis. Ch. 24. p. 280-287 *in* Davis, J. W., L. J. Karstad, D. D. Trainer. (eds.). Infectious diseases of wild mammals. 2nd edition. Iowa State Univ. Press. Ames, Iowa. 446 p.

Wood Bison Recovery Team. 1987. Status report on wood bison (*Bison bison athabascae*) in Canada, 1987. C. Gates (chairman), Northwest Territories Wildl. Serv., Fort Smith, N. W. T. 87 p.

Yamane, T. 1967. Elementary sampling theory. Prentice-Hall Inc., Englewood Cliffs, New Jersey. 405 p.

Ying, K. L. and D. G. Peden. 1977. Chromosomal homology of wood bison and plains bison. Can. J. Zool. 55:1759-1762.

13. APPENDIX

13.1 Observation Loop Schedule

	THURSDAY	FRIDAY	SATURDAY	SUNDAY	MONDAY	TUESDAY	WEEK TOTAL
WEEK 1	May 15 0600 0700 1300 1500	May 16 1000 1100 1600 1700	May 17 0800 0900 1400 1500	May 18 0600 1600 1900 2000	May 19 1100 1200 1700 1800	May 20 0600 0700 0800 1300	24
WEEK 2	May 22 1300 1400 1900 2000	May 23 0900 1000 1500 1600	May 24 0600 0700 1200 1300	May 25 1000 1100 1600 1700	May 26 0800 0900 1400 1500	May 27 0700 0800 1800 1900 2000	25
WEEK 3	May 29 1100 1200 1700 1800	May 30 0600 0700 0800 1400	May 31 1300 1400 1900 2000	June 1 0900 1000 1500 1600	June 2 0600 0700 1200 1300	June 3 1000 1100 1600 1700	24
WEEK 4	June 5	June 6 0800 0900 1400 1500	June 7 0600 1800 1900 2000	June 8 1100 1200 1700 1800	June 9 0600 0700 0800 1500	June 10 1300 1400 1900 2000	20
WEEK 5	June 12 0900 1000 1500 1600	June 13 0600 0700 1200 1300	June 14 1000 1100 1600 1700	June 15 0800 0900 1400 1500	June 16 0900 1000 1900 2000	June 17 1100 1200 1700 1800	24
WEEK 6	June 19 0600 0700 0800 1600 1700	June 20 1300 1400 1900 2000	June 21 0900 1000 1500 1600	June 22 0600 0700 1200 1300	June 23 1000 1100 1600 1700	June 24	21
WEEK 7	June 26 0800 0900 1400 1500	June 27 1000 1800 1900 2000	June 28 1100 1200 1700 1800	June 29 0600 0700 0800 1700	June 30 1300 1400 1900 2000	July 1 0900 1000 1600 1800	24
WEEK 8	July 3 0600 0700 1200 1300	July 4 1000 1100 1600 1700	July 5 0800 0900 1400 1500	July 6 1100 1600 1900 2000	July 7 1100 1200 1700 1800	July 8 0600 0700 0800 1800	24
WEEK 9	July 10 1300 1400 1900 2000	July 11 0900 1000 1500 1600	July 12 0600 0700 1200 1300	July 13 1000 1100 1600 1700	July 14 0800 0900 1400 1500	July 15 1200 1800 1900 2000	24
WEEK 10	July 17	July 18 1100 1200 1700 1800	July 19 0600 0700 0800 1000	July 20 1300 1400 1900 2000	July 21 0800 1000 1500 1600	July 22 0600 0700 1200 1300	20
WEEK 11	July 24 1000 1100 1600 1700	July 25 0600 0900 1400 1500	July 26 1300 1400 1800 1900 2000	July 27 1100 1200 1700 1800	July 28 0600 0700 0800 2000	July 29 1300 1400 1900 2000	25
WEEK 12	July 31 0900 1000 1500 1600	August 1 0600 0700 1200 1300	August 2 1000 1100 1600 1700	August 3 0600 0900 1400 1500	August 4 1100 1200 1800 1900 2000	August 5 0900 1000 1500 1600	25
						TOTAL	280

13.2 Field Instructions and Forms for Conducting Observation Loops, Bison Sightings, and Traffic Observation Periods

13.2.1 Observation loop, bison sighting, and traffic observation period procedures

1. Five minutes before loop start time, park outside Buffalo Paddock entrance, well on edge of road
2. Record **Loop #**, **Day of Study**, **Date**, **Observer**, and **Loop Start Time** on *Paddock Observation Loop Form*
3. Record **Loop #** and **Sighting #** on *Bison Sighting Form*
4. Record **Day of Study**, **Date**, and **Observer** on *Bison Location Form*
5. Record **Day of Study**, **Date**, and **Observer** on *Paddock Traffic Observation Form I*
6. At loop start time begin a loop (*Paddock Observation Loop Form*)
7. Enter Buffalo Paddock and drive slowly to paddock traffic counter while looking for bison
8. Record any traffic observed under **Vehicles Observed** as described in 14. c. below
9. Stop before passing through paddock traffic counter beam (well on the edge of the road)
10. Walk over to counter, being careful not to disrupt beam, read paddock traffic counter and return to car
11. Record number under **Paddock Counter, Counter Reading (Start)** for both **Loop** and **Hour**
12. If there were vehicles recorded under **Vehicles Observed** since loop start time, adjust the paddock traffic counter reading to what it would have been at the start of the loop
13. Observe **Sky Condition** and **Precipitation** and complete codes
14. Proceed with loop
    a. Drive slowly, average less than 10 km/h
    b. Look carefully for bison, using binoculars and stopping when necessary
    c. Record all traffic observed during the loop (including any sightings - see 14. g. 9) below) under **Vehicles Observed**
        1) **Private** includes all vehicles except buses, rented or privately owned which are

operated by non-commercial ivers (cars, trucks, vans, campers, motorhomes)

2) **Bus Tour** includes all commercial tour buses and school buses, specify name of company using numbered 'X' codes defined under **Other Observations**

3) **Other Tour** includes all commercial tour vehicles other than buses (vans, taxi cabs), specify name of comp using numbered 'X'codes defined under **Other Observations**

4) **Other** includes all non- sitor vehicles such Warden Service, co ruction, and maintenance vehi specify pe non-visitor where p ble using numbered 'X' codes defined under **Othe Observations**

5) Also note the presence of motorcycles and cyclists using numbered 'X' codes defined under **Other Observations**

d. Move over if necessary to allow vehicles to pass

e. Note changes in **Sky Condition** and **Precipitation** as they occur

f. If you sight the bison, stop when you have the best view possible from that location

g. Begin a bison sighting (*Bison Sighting Form*)

1) Record the **Time of Sighting (Start)**, **Sky Condition** and **Precipitation** codes and begin the tape (ten minute recording of thirty second audio prompts)

2) Record the type of bison being observed across the top of the columns (eg. adult female, caif, calf, adult female, etc.)

3) Observe each animal for each one minute interval and complete distance, percent visible and screening codes under **View, D, P, and S**, and activity codes under **Act** for each animal. Specify any other screening or activity codes by using numbered 'X' codes, defined under **Other Observations**. More than one code can be given for each animal if the distance, percent visible, screening, or activity changes during the one minute interval.

4) Record for each minute if binoculars were used to observe the bison by placing a check under **Binocs**

5) Move the research vehicle to maintain the best possible sighting or to allow

vehicles to pass as necessary. Record any such movement for each minute by placing directional arrows under **Vehicle Move**. Specify if the movement was to allow a vehicle to pass by using a numbered 'X' code defined under **Other Observations**

6) When the recording signals that one minute has passed move to the row for the next minute and record observations for each animal, binocular use and vehicle movement again

7) Record unusual visitor behavior under **Other Observation** with as much detail as possible

8) Note changes in **Sky Condition** and **Precipitation** as they occur

9) Tally traffic observed during the sighting under **Vehicles Observed, Sighting #1, Stop and Do Not Stop** on the *Paddock Observation Loop Form*

10) Repeat the bison observations for a maximum of ten minutes or until all bison move out of sight and cannot be seen for more than one minute even by moving the research vehicle

11) Terminate the bison sighting

12) Record the **Time of Sighting (End)**, **Total Sighting Time** and **Sighting Form __of__**

13) Indicate location of bison during sighting on *Bison Location Form* map, and record **Legend** information

14) As soon as possible complete any additional **Other Observations** for sighting

h. Resume loop, continuing to look for bison in a new location

i. If bison are sighted again, repeat above process from 14. g.

j. The loop is complete upon reaching the island opposite the Buffalo Paddock entrance

15. Record the time under **Loop End Time** on the *Paddock Observation Loop Form* and in the **first space** under **Time of Observation** on the *Paddock Traffic Observation Form I*

16. Begin recording information on the *Paddock Traffic Observation Form I* as described in 23 below

17. Proceed to the paddock traffic counter, stop and read the counter as before

18. Record number under **Paddock Counter, Counter Reading (End)** for **Loop** on the *Paddock Observation Loop Form* and in the **first space** under **Paddock Counter** on the *Paddock Traffic Observation Form I*

19. Adjust reading for any vehicles which have passed the counter since the loop end time

20. Back up to the Buffalo Paddock entrance and leave paddock

21. Turn around and park on the edge of the road facing the entrance

22. As soon as possible tally **Vehicles Observed**, record **Total Loop Time**, **Total Number of Sightings**, and **Total Number of Bison Seen** and complete any additional **Other Observations** on the *Paddock Observation Loop Form*

23. Conduct a traffic observation period until the end of the hour as follows

    a. Begin the traffic observation period at loop time end (*Paddock Traffic Observation Forms I & II*)

    b. Record the paddock traffic counter reading as described above in the **first space** under **Paddock Counter**

    c. Observe **Sky Condition** and **Precipitation** and record codes

    d. For each vehicle observed during the traffic observation period

        1) Record the vehicle type code (specifying private rentals, bus tour and other tour companies, and the identity of non-visitors) under **Vehicle Type**

        2) Record the liscence plate under **Liscence Plate**

        3) Record a description of the vehicle to enable you to identify it if seen it again under **Vehicle Description**

    e. For vehicles entering the paddock record the time to the nearest minute (round up or down as appropriate) under **Time, Enter**

    f. For vehicles passing the island and beginning a second loop, record the time to the nearest minute under **Time, 2nd Loop**

    g. For vehicles leaving the paddock record the time to the nearest minute under **Time, Exit**

h. Note changes in **Sky Condition** and **Precipitation** as they occur

i. Use *Paddock Traffic Observation Form II* as required being sure to record the **Day of Study**, **Date**, **Observer**, and **Page __of__**

j. At the end of the hour, terminate the traffic observation period and begin the next loop if appropriate (see 6. above)

k. Record the time in the **second space** under **Time of Observation** and the total traffic observation period time in the **third space**

l. As soon as possible calculate the total times and averages under **Minutes**, **1st Loop**, **2nd Loop**, and **Total** for each vehicle and complete summary statistics for **Vehicle Type**

24. Proceed into the Buffalo Paddock to the paddock traffic counter, stop and read the counter as before

25. Record number under **Paddock Counter, Counter Reading (End)** for **Hour** on the *Paddock Observation Loop Form*, in the **second space** under **Paddock Counter** on the *Paddock Traffic Observation Form I*, and under **Paddock Counter, Counter Reading (Start)** for **Loop** if beginning another loop

26. Adjust reading for any vehicles which have passed the counter since end of the hour

27. Backup and leave the Buffalo Paddock or proceed with the next loop as appropriate

28. As soon as possible calculate the total paddock traffic count in the **third space** under **Paddock Counter** and the **Observed Paddock Counts** on the *Paddock Traffic Observation Form I* and compare the two to determine any counter error

29. Ensure all forms are completed fully and place in appropriate binders

13.2.2 Examples of field forms used

PADDOCK OBSERVATION LOOP FORM

Loop # __ __ __

Day of study: __ __

Date: __ __ (day) __ __ (01- May, 02- Jun, 03- Jul, 04- Aug) __ __ (01- Sun, 02- Mon, 03- Tue, 04- Wed, 05- Thu, 06- Fri, 07- Sat)

Observer: ____________________

Loop start time: __ __ __ __
Loop end time: __ __ __ __
Total loop time: __ __ minutes.

Total number of sightings: __ __
Total number of bison seen: __ __

	Gate Counter		Paddock Counter	
	loop	hour	loop	hour
Counter reading (start)				
Counter reading (end)				
Total Vehicles				
Researchers went through				
Non-visitor vehicles				
Total visitor vehicles				

Sky conditions: __ __
- 01- Sunny (scattered clouds) 0-5/10 cloud cover
- 02- Cloudy (Broken cover) 6/10- 9/10 cloud cover
- 03- Overcast, high clouds
- 04- Overcast, low clouds

Precipitation: __ __
- 01- No precipitation
- 02- Intermittent rain
- 03- Light, steady rain
- 04- Heavy steady rain
- 05- Intermittent snow
- 06- Light, steady snow
- 07- Heavy steady snow

	Vehicles Observed	Private	Bus Tour	Other Tour	Non-Visitor
	Total During Loop				
sighting #1.	Stop				
	Do not stop				
sighting #2.	Stop				
	Do not stop				
sighting #3.	Stop				
	Do not stop				

Other observations:

BISON SIGHTING FORM

Loop # _ _ _
Sighting form _ of _
Sighting # _ _ _

Time of sighting (start): _ _ _ _
Time of sighting (end): _ _ _ _
Total sighting time: _ _ minutes.

Sky condition: _ _
Precipitation: _ _

Minutes	[illegible]	View DPS	Act.	View DPS	Act.	View DPS	Act.	View DPS	Act.	View DPS	Act.	View DPS	Act.	View DPS	Act.	View DPS	Act.	View DPS	Act.	[illegible]
0																				
1																				
2																				
3																				
4																				
5																				
6																				
7																				
8																				
9																				
10																				

View codes:

Distance
1 - 0-10m
2 - 11-50m
3 - 51-100m
4 - 100+m

Percent visible
1 - 100%
2 - 75-99%
3 - 50-74%
4 - 25-49%
5 - 0-24%

Screening
B - other bison
V - vegetation
T - topography
X - other (specify)

Activity Codes
F - feeding
W - Walking
S - Standing
L - Laying down.
R - Running
X - Other (SPECIFY: charging, threatening, vocalization, etc.)

Other observations:

PADDOCK TRAFFIC OBSERVATION FORM I — page 21 of — —

Day of study: — —   Date: — — (date) — — (month) — — (day)   Observer: ____________

Time of observation: — — — — to — — — — = — — minutes

Gate counter: — — — — — to — — — — — = — — — counts ÷ — — — — counts/minute
Paddock counter: — — — — — to — — — — — = — — — counts ÷ — — — — counts/minute

Observed gate counts (Totals A + C) = — — — counts
Observed paddock counts (Totals A + B) = — — — counts

Gate counter error: — — counts
Paddock counter error: — — counts

Vehicle codes:
P - private
B - bus tour
OT - other tour
R - researcher
N - other non-visitor

Weather Changes			Vehicle	Liscence	Vehicle	Time			Minutes		
Time	Sky	Percip	Type	Plate	Description	Enter	2nd Loop	Exit	1st loop	2nd loop	Total
Totals/Sub Ts.			vehicles			A counts	B counts	C counts	min.	min.	min.
								Averages:	min/lp	min/lp	min. in padk.

PADDOCK TRAFFIC OBSERVATION FORM II

page __ __ of __ __

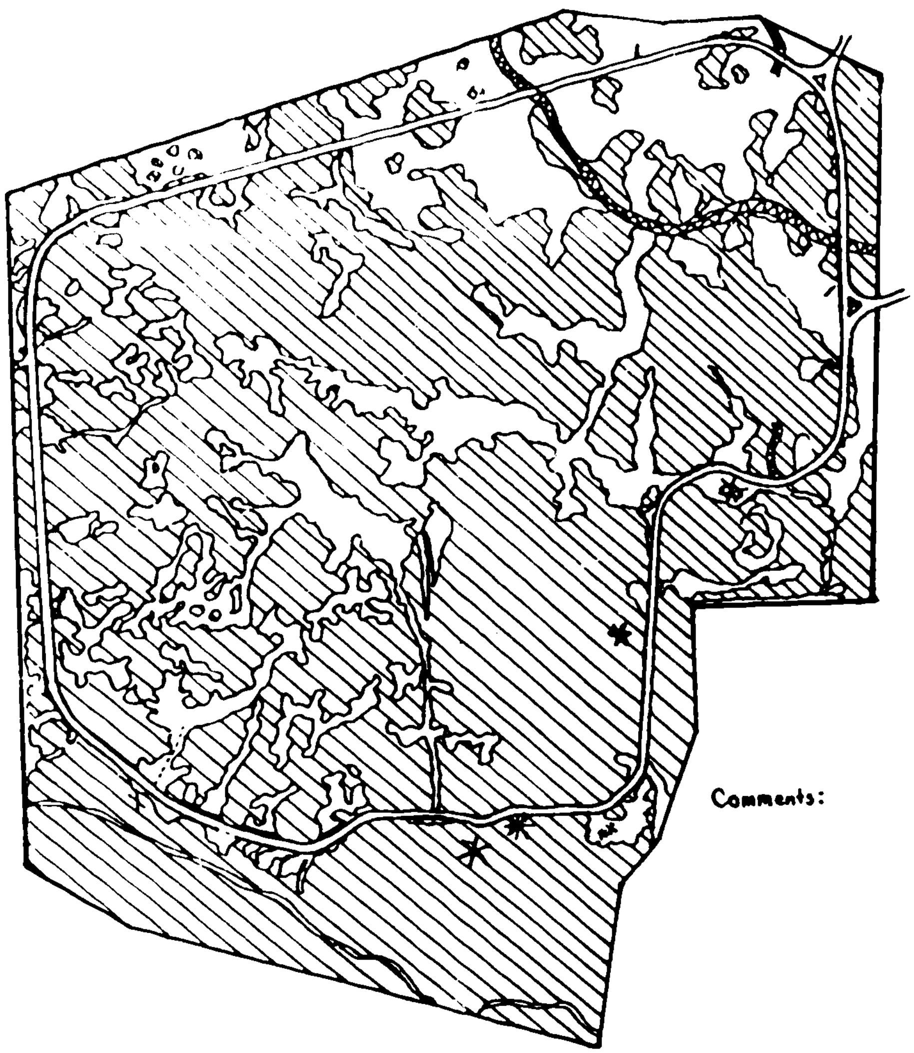
Day of study __ __ Date __ __ / __ __ / __ __ (date, month, day) Observer: ____________________

Vehicle Observations (cont'd)

Weather Changes			Vehicle	Licence	Vehicle	Time			Minutes		
Time	Sky	Percip	Type	Plate	Description	Enter	2nd loop	Exit	1st loop	2nd loop	Total
Subtotals:			vehicles			counts	counts	counts	min.	min.	min.
Totals from previous page:			vehicles			counts	counts	counts	min.	min.	min.
Totals:			vehicles			A counts	B counts	C counts	min.	min.	min.
					Averages:				min/[illegible]	min/[illegible]	min in paddock

CATION FORM

Day of study   Date ___ ___ ___ date month day   Observer ____________



Comments:

LEGEND:

__ __ = Loop __ __ __ Sighting __ __ __

__ __ __ __ __ __ __ __

__ __ __ __ __ __ __ __

__ __ __ __ __ __ __ __

__ __ __ __ __ __ __ __

__ __ __ __ __ __ __ __

__ __ __ __ __ __ __ __

__ __ __ __ __ __ __ __

__ __ __ __ __ __ __ __

________ = 100m. (approx.)

13.3 Tour Agency Form for Buffalo Paddock Tours

BUFFALO PADDOCK TOURS - SUMMER 1986

Dear Driver/Guide:

Hi!! Welcome to the Buffalo Paddock Study Research Team. We are conducting a study of the Buffalo Paddock this summer to gather information about the amount and quality of visitor use.

Please fill out this form for each tour that you take through the Buffalo Paddock this summer. Any details and comments you may care to add are welcome.

I will be collecting these forms from your company office every two weeks. If you have any questions about the forms, the Buffalo Paddock, or the bison, please feel free to leave me a note with your forms and I'll get back to you.

Your assistance with my study is greatly appreciated!! THANKS!!

Sincerely yours,

Nora Kopjar

Date of Tour: ____ ____ (Month Day) Time of Arrival at Paddock: __________ Number of Passengers: __________

Weather (Sunny, Cloudy, Rainy, Hot, Cool, Windy, etc.) ______________________________

____

Description of Tour Through Buffalo Paddock:
(Include brief notes on how many bison (if any) you saw, what they were doing (feeding, laying down, walking), the comments/reactions/actions of your passengers, and any other observations of other visitors, wildlife, etc.)

____

____

____

____

____

____

____

____

____

Any Other Comments: ______________________________

____

Your Initials: __________

11. RECOMMENDATIONS

This study has provided the framework required to analyze the alternatives for bison management in Banff National Park. Four sub-studies examined the historical presence of bison in the park, the management factors associated with the various alternatives, the availability of bison habitat in the park, and the concerns related to visitor use. The results of these sub-studies were applied to a review of the bison management alternatives, and the two best alternatives were identified as the introduction of a free-ranging bison herd or the modification of the present Buffalo Paddock.

The remaining alternatives were eliminated due to the disadvantages outlined below. Maintenance of the present Buffalo Paddock would not allow any improvement in wildlife movement through the area. Relocation of the Buffalo Paddock, while there are sites which would be suitable, would be expensive, would negatively impact wildlife habitat and natural environment elsewhere, and would provide a less desirable visitor experience than a modified paddock. Elimination of bison from the park is not judged acceptable as bison are indigenous to the area, and therefore attempts should be made to maintain them in the park. Their removal would also eliminate the opportunity for bison viewing and interpretation. Two major recommendations are therefore presented

1. The introduction of a free-ranging bison herd is recommended as the best alternative from a resource management perspective. This would eliminate wildlife conflicts associated with the paddock. A free-ranging herd would allow bison, an indigenous species, to reassume their role in the park ecosystem. It would also provide a unique opportunity for free-ranging bison management and interpretation in southern Canada. However, there are various implementation difficulties associated with this alternative. While habitat is available for summering bison, winter range is more limited and movement outside of the park would likely occur. A free ranging herd would have impacts on other ungulate species, and control of bison herd movement and numbers would be difficult. Free ranging bison would not be highly visible to visitors, depending on the location and size of the herd, and some visitor safety concerns may arise

2. Modification of the present Buffalo Paddock is the next best alternative, given the implementation difficulties of free-ranging bison. The maintenance of a captive bison population in the park would protect an isolated gene pool herd and prevent the complete elimination of an indigenous species from the park. Modification would require changes in fence design, paddock configuration, road location, and forest cover density (and, possibly, extent). A narrower paddock and/or lowered fence would facilitate ungulate movement and may allow some wildlife access to habitat now enclosed by the paddock. The bison viewing experience could be improved by elimination of some forest cover and relocation of the loop road. It would be necessary to balance good bison visibility with sufficient escape cover for bison, as the bison are sometimes harassed by visitors.

12. LITERATURE CITED

Achuff, P. L. 1982. Vegetation: introduction and methods. p. 71-75. *in* Ch. III Vegetation. W. D. Holland and G. M. Coen. (general eds.). 1982. Ecological (biophysical) land classification of Banff and Jasper National Parks. Volume II: Soil and vegetation resources. Alberta Inst. of Pedology. Pub. No. SS-82-44. 540 p.

Achuff, P. L. and I. G. W. Corns. 1983. Vegetation. p. 42-92. *in* Ch. II. Description of the study area. W. D. Holland, and G. M. Coen. (general eds.). 1983. Ecological (biophysical) land classification of Banff and Jasper National Parks. Volume I: summary. Alberta Inst. of Pedology. Pub. No. M-83-2. 193 p.

Achuff, P., I. Pengelly, and C. White. 1986. Special resources of Banff National Park. Report prepared for Parks Canada, Banff National Park. 141 p.

Agresti, A. and B. F. Agresti. 1979. Statistical methods for the social sciences. Dellen Publishing Co., San Francisco. 554 p.

Baird, D. M. 1977. Banff National Park. How nature carved its splendour. Hurtig Pub., Edmonton. 237 p.

Banfield, A. W. F. 1958. The mammals of Banff National Park, Alberta. Natl. Mus. of Canada Bull. No. 159. The Queen's Printer, Ottawa. 53 p.

Banfield, A. W. F. 1974. The mammals of Canada. Univ. of Toronto Press, Toronto. 438 p.

Billyard, K. 1979. History of the buffalo in Banff National Park. Report prepared for Parks Canada, Banff National Park. 16 p.

Bison Disease Task Force. 1988. Evaluation of brucellosis and tuberculosis in bison in northern Canada. R. Coupland (co-chairman), Ag. Can., Grande Prairie, Alta., and B. Redhead (co-chairman), Can. Parks Serv., Fort Smith N. W. T. Rep. prepared for Bison Disease Steering Committee. 213 p.

Bostock, H. S. 1976. Ch. II: Physiographic subdivisions of Canada. p. 9-30 *in* R. J. W. Douglas (ed.). Geology and economic minerals of Canada. 5th edition. Geol. Surv. of Canada. Economic Geology Rep. No. 1. 838 p.

Boyle, S. A. and F. B. Samson. 1985. Effects of nonconsumptive recreation on wildlife: a review. Wildl. Soc. Bull. 13:110-116.

Broughton, E. 1987. Diseases affecting bison. p. 34-38 *in* H. W. Reynolds and A. W. L. Hawley (eds.). Bison ecology in relation to agricultural development in the Slave River Lowlands, NWT. Can. Wildl. Serv. Occas. Pap. No. 63. Minister of Supply and Services, Canada. 74 p.

Bunnage, J. (ed.). 1985. The Game Grower. 1(1):1-25. Edmonton.

Burger, G. V. 1979. Principles of wildlife management. p. 89-97 *in* R. D. Teague and E. Decker (eds.). Wildlife conservation. The Wildl. Soc. Washington, D. C. 280 p.

Cairns, A. L. 1976. Distribution and food habits of moose, wapiti, deer, bison and snowshoe hare in Elk Island National Park, Alberta. M. S. Thesis. Univ. of Calgary, Calgary. 169 p.

Cairns, A. L. and E. S. Telfer. 1980. Habitat use by four sympatric ungulates in boreal mixedwood forest. J. Wildl. Manage. 44:849-857.

Choquette, L. P. E., E. Broughton, E. Cousineau and N. S. Novakowski. 1978. Parasites and diseases of bison in Canada Part IV: Serologic survey for brucellosis in bison in Canada. J. Wildl. Dis. 14:329-332.

Choquette, L. P. E., E. Broughton, A. A. Currier, J. G. Cousineau and N. S. Novakowski. 1972. Parasites and diseases of bison in Canada Part III: Anthrax outbreaks in the last decade in northern Canada and control measures. Can. Field Nat. 86:127-132.

Choquette, L. P. E., J.F. Gallivan, J. L. Byrne, and J. Pilipavicius. 1961. Parasites and diseases of bison in Canada. Part I: Tuberculosis and some other pathological conditions in bison at Wood Buffalo and Elk Island National Parks in the fall and winter of 1959-60. Can. Vet. Jour. 2:168-174.

Christensen, O. A. 1971. Banff prehistory: prehistoric settlement and subsistence technology in Banff National Park. Natl. and Historic Parks Br. Manuscript Rep. No. 67. 323 p.

Christopherson, R. J., R. J. Hudson, and M. K. Christopherson. 1979. Seasonal energy expenditures and thermoregulatory responses of bison and cattle. Can. J. Anim. Sci. 59:611-617.

Cochran, W. G. 1963. Sampling techniques. 2nd edition. John Wiley & Sons, Inc. New York. 413 p.

Coder, G. D. 1975. The national movement to preserve the American buffalo in the United States and Canada between 1880 and 1920. Ph. D. Diss. Ohio State Univ. 348 p.

Corner, A. H. and R. Connell. 1958. Brucellosis in bison, elk and moose in Elk Island National Park, Alberta, Canada. Can. J. Anim. Sci. 59:611-617.

Cornish, B., J. van Camp, and M. McNicholl. 1980. The impacts of recreation on fish and wildlife with emphasis on Kananaskis Country: A literature review and partial bibliography. Kananaskis Country Planning Document # 4. Alberta Energy and Nat. Res., Fish and Wildl. Div. 116 p.

Damp, J. E., C. E. Connolly, and T. V. Smith. 1980. Conservation archaeological studies EhPw-2 and EhPw-4, Banff National Park. Manuscript on file, Archaeological Research Services Unit, Canadian Parks Service, Western Region, Calgary.

Dary, D. 1974. The buffalo book: the saga of an American symbol. Avon Books, New York. 374 p.

Davidson, T. and D. Norcross. 1978. Bison re-introduction, Jasper National Park. Interim report Nov. 1978. Unpubl. rep., Warden Service, Jasper National Park. 25 p.

Driver, B. L. 1985. Specifying what is produced by management of wildlife by public agencies. Leisure Sciences. 7:281-295.

Eastcott, D. 1984. Directions for wildlife management: a summary. Parks Canada, Western Region, Calgary. 140 p.

Egerton, P. J. M. 1962. The cow-calf relationship and rutting behavior in the American bison. M. S. Thesis. Univ. of Alberta. Edmonton, Alberta. 155 p.

Engelhard, J. G. 1970. Behavior patterns of American bison calves at the National Bison Range, Moiese, Montana. M. S. Thesis. Central Michigan Univ. Mt. Pleasant, Michigan. 150 p.

Environment Canada - Parks. 1986a. Background report, Banff National Park management planning program. Nov. 1986. Environment Canada - Parks. Western Region, Calgary. 94 p.

Environment Canada - Parks. 1986b. Banff core concept, Banff National Park management planning program. Dec. 1986. Environment Canada - Parks. Western Region, Calgary. 142 p.

Environment Canada - Parks. 1986c. Banff townsite peripheral land use initial environmental evaluation. Summary. Dec. 1986. Prepared by B. F. Leeson and G. Harrison, Nat. Hist. Res. Div., Environment Canada - Parks. Western Region, Calgary. 27 p.

Fedje, D. W. 1982. Preliminary excavations at the Whiskey Creek Site: EhPv 24, Banff National Park. Manuscript on file, Archaeological Research Services Unit, Canadian Parks Service, Western Region, Calgary.

Fedje, D. W. 1986a. The Second Lake site: archaeological mitigation in Banff National Park. Microfiche Rep. Series. No. 234. Environment Canada, Parks, Ottawa.

Fedje, D. W. 1986b. Banff archaeology 1983-1985. p. 25-62 *in* Archaeological Survey of Alberta Occas. Pap. No. 30. Alberta Culture, Edmonton.

Fedje, D. W. 1987a. The Norquay and Eclipse sites: Trans-Canada Highway twinning mitigation in Banff National Park. Manuscript on file, Archaeological Research Services Unit, Canadian Parks Service, Western Region, Calgary.

Fedje, D. W. 1987b. Banff resource description reconnaissance 1986. Manuscript on file, Archaeological Research Services Unit, Canadian Parks Service, Western Region, Calgary.

Fedje, D. W. and A. J. Landals. 1987. Archaeological resource impact assessment, Banff Springs Hotel golf course and staff housing expansion. Manuscript on file, Archaeological Research Services Unit, Canadian P rks Service, Western Region, Calgary

Fedje, D. W. and J. M. White. 1984. Vermillion Lakes archaeology and palaeoecology, Trans-Canada Highway mitigation in Banff National Park. Manuscript on file, Archaeological Research Services Unit, Canadian Parks Service, Western Region, Calgary.

Ferguson, M. 1980. Ungulates and cross-country skiing, Elk Island National Park, Alberta. M. S. Thesis. Univ. of Wisconsin. Madison, Wisconsin. 57 p.

Filion, F. L. S. W. James, J. Ducharme, W. Pepper, R. Reid, P. Boxall, and D. Teillet. 1983. The importance of wildlife to Canadians: highlights of the 1981 national survey. Report published by Can. Wildl. Serv., Env. Canada for the 47th FederalProvincial Wildl. Conf. 40 p.

Foster, J. 1978. Working for wildlife: the beginnings of preservation in Canada. Univ. of Toronto Press, Toronto. 283 p.

Fuller, W. A. 1959. The horns and teeth as indicators of age in bison. J. Wildl. Manage. 23: 342-344.

Fuller, W. A. 1960. Behavior and social organization of the wild bison of Wood Buffalo National Park, Canada. Arctic 13(1):1-19.

Fuller, W. A. 1962. The biology and management of the bison of Wood Buffalo National Park. Can. Wildl. Serv. Wildl. Manage. Bull., Ser. 1, No. 16. 52 p.

Geist, V. and P. Karsten. 1977. The wood bison (*Bison bison athabascae* Rhoads) in relation to hypotheses on the origin of the American bison (*Bison bison bison* Linnaeus). Z. Saugetierk. 42(2):119-127.

Guthrie R. D. 1980. Bison and man in North America. Can. J. Anthropol. 1(1):55-73.

Haines, F. 1970. The buffalo. Thomas Y. Crowell. Co. New York. 242 p.

Halloran, A. F. 1968. Bison (Bovidae) productivity on the Wichita Mountains Wildlife Refuge, Oklahoma. Southwestern Nat. 13:23-26.

Harington, C. R. 1984. Mammoths, bison and time in North America. p. 299-309 *in* W. C. Mahaney (ed.). Quaternary dating methods. Elsevier Science Pub. B. V. Amsterdam. 431 p.

Haugen, A. O. 1974. Reproduction in the plains bison. Iowa State J. Res. 49:1-8.

Hawley, A. W. L., D. G. Peden, and W. R. Stricklin. 1981a. Bison and hereford steer digestion of sedge hay. Can. J. Anim. Sci. 61:165-174.

Hawley, A. W. L., D. G. Peden, and H. W. Reynolds. 1981b. Bison and cattle digestion of forages from the Slave River Lowlands, Northwest Territories. Can. J. Range Manage. 34:126-130.

Head, T. H. and S. Van Dyke. 1986. Archaeological resources site survey and assessment, Banff peripheral land use study area, Phase II, Phase III, and overview areas. Manuscript on file, Archaeological Research Services Unit, Canadian Parks Service, Western Region, Calgary.

Hendee, J. C. and D. R. Potter. 1971. Human behavior and wildlife management: needed research. Trans. N. Am. Wildl. Nat. Resour. Conf. 36:383-395.

Herrig, D. M. and A. D. Haugen. 1969. Bull bison behavior traits. Iowa Acad. Sci. 76:245-262.

Heusser, C. J. 1956. Postglacial environments in the Canadian Rocky Mountains. Ecol. Monogr. 26(3): 263-302.

Holland, W. D. and G. M. Coen. (general eds.). 1982. Ecological (biophysical) land classification of Banff and Jasper National Parks. Volume II: Soil and vegetation resources. Alberta Inst. of Pedology. Pub. No. SS-82-44. 540 p.

Holland, W. D., P. L. Achuff, and B. D. Walker. 1982. Climate. p. 4-12. *in* Ch. I. Physical environment. W. D. Holland and G. M. Coen. (general eds.). 1982. Ecological (biophysical) land classification of Banff and Jasper National Parks. Volume II: Soil and vegetation resources. Alberta Inst. of Pedology. Pub. No. SS-82-44. 540 p.

Holland, W. D., G. R. Hillman, and D. T. Allan. 1982. Physiography. p. 12-17. *in* Ch. I. Physical environment. W. D. Holland and G. M. Coen. (general eds.). 1982. Ecological (biophysical) land classification of Banff and Jasper National Parks. Volume

II: Soil and vegetation resources. Alberta Inst. of Pedology. Pub. No. SS-82-44. 540 p.

Holland, W. D. and G. M. Coen. (general eds.). 1983. Ecological (biophysical) land classification of Banff and Jasper National Parks. Volume I: summary. Alberta Inst of Pedology. Pub. No. M-83-2. 193 p.

Holroyd, G. L. and K. J. vanTighem. 1983. Ecological (biophy ical) land classification of Banff and Jasper National Parks. Volume IIi. the wildlife inventory, Parts A and B. Can. Wildl. Serv., Edmonton. 691 p.

Holsworth, W. N. 1960a. Buffalo range and food habits of buffalo in Wood B[illegible] Park Report prepared for Can. Wildl. Serv., Edmonton. 15 p.

Holsworth, W. N. 1960b. Interactions between moose, elk, and buffalo in Elk Island National Park, Alberta M. S. Thesis. Univ. of Br[illegible]sh Columbia, Victoria. 92 p.

Hornaday, W. T. 1889. The extermination of the american bison with a sketch of its discovery and life history. p. 367-548 *in* Part 2 (1889) Rep. U. S. Natl. Mus. 1886-1887.

Houston, D. B. 1982. The northern Yellowstone elk: ecology and management. Macmillan Pub. Co., Inc., New York. 474 p.

Hudson, R. J., T. Tennessen, and A. Sturko. 1976. Behavioral and physiological reactions of bison to handling during an anthrax vaccination program in Wood Buffalo National Park. p. 120-145. *in* Wildlife productivity-annual report 1976. Dept. Anim. Sci., Faculty of Agric. and For. Univ. of Alberta. Edmonton, Alberta.

I. R. Wilson Consultants, Ltd. 1985. Banff townsite peripheral land use study, heritage resources. Microfiche Rep. Series. No. 180. Parks Canada, Ottawa.

Jackson, J. J. 1982. Public support for nongame and endangered wildlife management: which way is it going? Trans. N. Am. Wildl. Nat. Resour. Conf. 47:432-440.

Janz, B. and D. Storr. 1977. The climate of the contiguous mountain parks: Banff, Jasper, Yoho, and Kootenay. Atm. Env. Serv. Proj. Rep. No. 30. Toronto. 324 p.

Jennings, D. C. and J. Hebbring. 1983. Buffalo management and marketing. Natl. Buffalo Assoc., Custer. 370 p.

Kellert, S. R. 1980. Needed research on people-animal interactions in national parks. Proc. 2nd Conf. on Sci. Res. in National Parks, Vol. 6 Sociology:165-167.

Kellert, S. R. and P. J. Brown. 1985. Human dimensions information in wildlife management, policy, and planning. Leisure Sciences. 7:269-280.

Ledwidge, M. 1982. Bison exhibit in Banff National Park. Report prepared for Parks Canada, Banff National Park. 3 p.

Lothian, W. F. 1981. A history of Canada's national parks. Vol. IV. Minister of Supply and Services, Canada. 154 p.

Lott, D. F. 1974. Sexual and aggressive behavior of adult male American bison (*Bison bison*) p. 382-394. *in* V. Geist and F. Walther (eds.). The behavior of ungulates and its relation to management Internatl. Union Cons. Nature, New Series No 24. Morges, Switzerland. 940 p.

Lott, D. F. and S. C. Minta. 1983. Home ranges of American bison cows on Santa Catalina Island, Ca. J. Mamm. 64:161-162.

Luxton, E. G. 1975. Banff - Canada's first national park. Summerthought, Banff. 157 p.

Lyons, J. R. 1982. Non-consumptive wildlife associated recreation in the United States: identifying the other constituency. Trans. N. Am. Wildl. Nat. Resour. Conf. 47:677-685.

McCorquodale, S. M. and R. F. DiGiacomo. 1985. The role of wild North American ungulates in the epidemiology of bovine brucellosis: a review. J. Wildl. Dis. 21:351-357.

McCullough, Y. B. 1980. Niche separation of seven North American ungulates on the Nat[illegible] Bison Range, Montana. Ph. D. Diss. Univ. of Michigan. Ann Arbor. 239 p.

Mc[illegible] J. N. 1981. N[illegible] bison: their classification and evolution. Univ. of California Press, Berke[illegible].

McHugh, T. 1958. Social behavior of the American bison. Zoologica 43(1):1-40.

McHugh, T. 1972. The time of the buffalo. Univ. of Nebraska Press, Lincoln. 339 p.

McIntyre, M. L. and B. O. K. Reeves. 1985. Archaeological investigations: Lake Minnewanka site (EhPu-1). Manuscript on file, Archaeological Research Services Unit, Canadian Parks Service, Western Region, Calgary.

Meagher, M. M. 1973. The bison of Yellowstone National Park. Natl. Park Serv. Sci. Monogr. No. 1. 161 p.

Meagher, M. M. 1974. Yellowstone's bison: a unique wild heritage. Natl. Parks and Conserv. Mag. May:9-14.

Meagher, M. M. 1976. Winter weather as a population regulating influence on free-ranging bison in Yellowstone National Park. p. 29-38 *in* Research in the parks. Trans. Natl. Park Centennial Symp. Amer. Assoc. Advancement Sci. Dec. 28-29, 1971. Ser. No. 1. U. S. Govt. Print. Office, Washington. 232 p.

Meagher, M. M. 1978. Bison. p. 123-133 *in* J. L. Schmidt and D. L. Gilbert (eds.). Big game of North America: ecology and management. Stackpole Books, Harrisburg. 494 p.

Meagher, M. M. 1986. *Bison bison*. Mammalian Species. No. 266. Amer. Soc. Mammalogists. 8 p.

Minion, P. F. and G. T. Schmidt. 1984. Status review of free-ranging bison in Prince Albert National Park. Jan. 1969 - Dec. 1983. Report prepared for Parks Canada, Prince Albert National Park. 58 p.

More, T. A. 1979. The demand for non-consumptive wildlife uses: a review of the literature. U. S. Dept. of Agric., For. Serv. Gen. Tech. Rep. NE-52. Northeastern For. Exper. Sta. Broomall, Pennsylvania.

National Research Council. 1984. Nutrient requirements of beef cattle. 6th revised edition. Natl. Acad. Press. Washington, D. C. 90 p.

Norland, J. F. 1984. Habitat use and distribution of bison in Theodore Roosevelt National Park. M. S. Thesis. Montana State Univ., Bozeman, Montana. 131 p.

Norland, J. E., L. R. Irby, and C.B. Marlow. 1985. Determination of optimum bison stocking rate in Theodore Roosevelt National Park, North Dakota. J. Env. Manage. 21:225-239.

North-West Territories. 1877. Journals of the council of the North-West Territories of Canada. Session of 1877. Regina. 27 p.

Novakowski, N. S. 1978. Status report on wood bison (*Bison bison athabascae*) in Canada. Committee on the Status of Endangered Wildlife in Canada. 19 p.

Novakowski, N.S., J. G. Cousineau, G. B. Kolenosky, G. S. Wilton, and L. P. E. Choquette. 1963. Parasites and diseases of bison in Canada Part II: Anthrax epizootics in the Northwest Territories. Trans. N. Am. Wildl. Nat. Resour. Conf. 28:233-239.

Ogilvie, S. C. 1979. The park buffalo. Natl. and Prov. Parks Assoc. of Canada, Calgary. 68 p.

Olsen, W. 1982. Banff townsite peripheral land use wildlife component, initial environmental evaluation (interim report) Oct. 1982. Nat. Hist. Res. Div., Parks Canada, Calgary. 137 p.

Olsen, W. 1984. Banff townsite peripheral land use, wildlife component, initial environmental evaluation (final report) Jan. 1984. Nat. Hist. Res. Div., Parks Canada, Calgary. 210 p.

Oosenbrug, S. M. and L. N. Carbyn. 1985. Wolf predation on bison in Wood Buffalo National Park. Report prepared for Can. Wildl. Serv., Edmonton. 264 p.

Parks Canada. 1981. Manual on application of the Environmental Assessment and Review Process within Parks Canada. Nat. Resources Div., National Parks Branch, Parks Canada.

Parks Canada. 1983. Parks Canada Policy. Minister of Supply and Services, Canada. 47 p.

Parks Canada 1984. Banff townsite peripheral land use initial environmental evaluation (interim report) May, 1984. Nat. Hist. Res. Div., Parks Canada, Calgary. 35 p.

Peden, D. G. and G. J. Kraay. 1979. Comparison of blood characteristics in plains bison, wood bison, and their hybrids. Can. J. Zool. 57(9):1778-1784.

Peden, D. G., G. M. van Dyne, R. W. Rice, and R. M. Hansen. 1974. The trophic ecology of *Bison bison* L. on shortgrass plains. J. Appl. Ecol. 11:489-498.

Peters, H.F. and S.B. Slen. 1964. Hair coat characteristics of bison, domestic X bison hybrids, cattalo, and certain domentic breeds of cattle. Can. J. Anim. Sci. 44:48-57.

Petersburg, S. J. 1973. Bull bison behavior at Wind Cave National Park. M. S. Thesis. Iowa State Univ. Ames, Iowa. 302 p.

Popp, J. K. 1981. Range ecology of bison on mixed grass prairie at Wind Cave National Park. M. S. Thesis. Iowa State Univ. Ames, Iowa. 59 p.

Price, R. A. and E. W. Mountjoy. 1970. Geologic structure of the Canadian Rocky

Mountains between Bow and Athabasca Rivers - a progress report. p. 7-26 *in* J. O. Wheeler (ed.). Structure of the southern Canadian Cordiliera. Geological Assoc. of Canada. Special Paper No. 6. 166 p.

Ream, C. H. 1980. Impact of backcountry recreationists on wildlife: an annotated bibliography. U. S. Dept. of Agric., For. Serv. Gen. Tech. Rep. INT-84. Intermountain For. and Range Exper. Sta. Ogden, Utah. 62 p.

Reynolds, H. W. 1976. Bison diets of Slave River Lowlands, Canada. M. S. Thesis. Colorado State Univ. Ft. Collins. 66p.

Reynolds, H. W. 1980. Wood bison: past, present and future. Can. Wildl. Admin. Vol. VI 75-78. Ontario Ministry of Nat. Resources.

Reynolds, H. W., R. D. Glaholt, and A. W. L. Hawley. 1982. Chapter 49: Bison. p. 972-1007 *in* J. A. Chapman and G. A. Feldhamer (eds.). Wild mammals of North America biology/management/economics. John Hopkins Univ. Press, Baltimore. 1147 p.

Reynolds, H. W., R. M. Hansen, and D. G. Peden. 1978. Diets of the Slave River Lowland bison herd, Northwest Territories, Canada. J. Wildl. Manage. 42(3):581-590.

Reynolds, H. W. and A. W. L. Hawley. (eds.). 1987. Bison ecology in relation to agricultural development in the Slave River Lowlands, NWT. Can. Wildl. Serv. Occas. Pap. No. 63. Minister of Supply and Services, Canada. 74 p.

Reynolds, H. W., R. McFetridge, and F. Didzena. 1985. A management plan for wood bison in Alberta. Report prepared for Alberta Fish and Wildl. Div. and Can. Wildl. Serv., 26 p.

Richmond, R. J., R. J. Hudson, and R. J. Christopherson. 1977. Comparison of forage intake and digestibility by American bison, yak, and cattle. Acta. Theriol. 22:225-230.

Robinson, S. 1980. A report on the natural and human history of Banff National Park (The Book of Banff). Revised edition. Prepared for Parks Canada. 67 p.

Roe, R. G. 1957. Western penetration of the historic buffalo in the Upper Bow River Valley. Alberta Hist. Rev. 5(1): 21-24.

Roe, R. G. 1970. The North American buffalo: a critical study of the species in its wild state. (2nd edition). Univ. of Toronto Press, Toronto. 991 p.

Rorabacher, J. A. 1970. The American buffalo in transition. North Star Press, St. Cloud. 142 p.

Rutberg, A. T. 1984. Birth synchrony in American bison (***Bison bison***): response to predation or season? J. Mamm. 65:418-423.

Rutter, N. W. 1972. Geomorphology and multiple glaciation in the area of Banff, Alberta. Geol. Surv. of Canada. Bull. 206. Ottawa. 54 p.

Schulz, R. A. 1985. User profile study, Alberta Rocky Mountain National Parks. Report prepared for the Govt. of Canada, Dept. of Regional Industrial Expansion. PCM Construction Control Consultants. 84 p.

Scotter, G. W. 1972. Carrying capacity of the summer and winter bison paddocks, Banff

National Park. Report prepared for Can. Wildl. Serv., Edmonton. 9 p.

Shackleton, D. M. 1968. Comparative aspects of the social organization of American bison. M. S. Thesis. Univ. of Western Ontario, London. 67 p.

Shaw, G. G. and H. W. Reynolds. 1985. Selenium concentrations in forages of a northern herbivore. Arctic 36:61-64.

Shaw, W. W. and T. Cooper. 1980. Managing wildlife in national parks for human benefits. Proc. 2nd Conf. on Sci. Res. in National Parks. Vol. 6 Sociology: 189-198.

Shaw, W. W. and W. R. Mangun. 1984. Nonconsumptive use of wildlife in [illegible] United States: An analysis of data from the 1980 national survey of fishing, hunting [illegible] wildlife associated recreation. U. S. Dept. of the Interior. Fish and Wildl. Serv. [illegible] Pub. 154. Washington, D.C. 20 p.

Shaw, W. W., W. R. Mangun, and J. R. Lyons. 1985. Residential enjoyment of w[illegible] resources by Americans. Leisure Sciences 7:361-375.

Skinner, M. F. and O. C. Kaisen. 1947. The fossil bison of Alaska and preliminary revision of the genus. Bull. Amer. Mus. Nat. Hist. 89:123-256.

Soper, D. J. 1941. History, range and home life of the northern bison. Ecol. Monogr. 11(4):347-412.

Soper, D. J. 1942. Mammals of Wood Buffalo Park, northern Alberta and District of Mackenzie. J. Mamm. 23:119-145.

Soper, D. J. 1964. The mammals of Alberta. The Queen's Printer, Edmonton. 402 p.

Spry, I. M. 1963. The Palliser Expedition. Macmillan Co., Toronto. 310 p.

Telfer, E. S. and A. Cairns. 1979. Bison-wapiti interrelationships in Elk Island National Park, Alberta. p. 114-121 *in* M. S. Boyce and L. D. Hayden-Wing (eds.). North American elk: ecology, behavior and management. Univ. of Wyoming, Laramie. 294 p.

Telfer, E. S. and J. P. Kelsall. 1979. Studies of morphological parameters affecting ungulate locomotion in snow. Can. J. Zool. 57:2153-2159.

Van Camp, J. 1975. Snow conditions and the winter feeding behavior of *Bison bison* in Elk Island National Park. Report prepared for Can. Wildl. Serv., Edmonton. 91 p.

Van Camp, J. 1987. Predation on bison. p. 25-33 *in* H. W. Reynolds and A. W. L. Hawley (eds.). Bison ecology in relation to agricultural development in the Slave River Lowlands, NWT. Can. Wildl. Serv. Occas. Pap. No. 63. Minister of Supply and Services, Canada. 74 p.

Van Camp, J. and G. W. Calef. 1987. Population dynamics of bison. p. 21-24 *in* H. W. Reynolds and A. W. L. Hawley (eds.). Bison ecology in relation to agricultural development in the Slave River Lowlands, NWT. Can. Wildl. Serv. Occas. Pap. No. 63. Minister of Supply and Services, Canada. 74 p.

Van Dyke, S. 1987. Final report: archaeological survey and assessment, upper Red Deer River valley, Banff National Park, 1987. Manuscript on file, Archaeological Research Services Unit, Canadian Parks Service, Western Region, Calgary.

Van Vuren, D. 1979. Ecology and behavior of bison in the Henry Mountains, Utah. M. S. Thesis. Oregon State Univ., Corvallis. 39 p.

Van Vuren, D. 1983. Group dynamics and summer home range of bison in southern Utah. J. Mamm. 64:329-332.

van Zyll de Jong, C. G. 1986. A systematic study of recent bison with particular consideration of the wood bison (*Bison bison athabascae* Rhoads 1898). Natl. Mus. of Nat. Sci., Pub. in Nat. Sci. No. 6, Ottawa. 69 p.

Vaske, J.J., A.R. Graefe, and F. R. Kuss. 1983. Recreation impacts: a synthesis of ecological and social research. Trans. N. Am. Wildl. Nat. Resour. Conf. 48:96-107.

Waggoner, V. and M. Hinkes. 1986. Summer and fall browse utilization by an Alaskan bison herd. J. Wildl. Manage. 50(2):322-324.

White, C. 1985. Wildland fires in Banff National Park 1880-1980. Natl. Parks Br., Parks Canada, Env. Canada. Occas. Pap. No. 3. 106 p.

Wilkins, B. J. and S. R. Peterson. 1979. Nongame wildlife. p. 178-183 *in* R. D. Teague and E. Decker (eds.). Wildlife conservation. The Wildl. Soc. Washington, D. C. 280 p.

Wilson, M. 1971. Banff National Park archaeological survey 1969: faunal remains. Manuscript on file, Dept. of Archaeology, Univ. of Calgary, Calgary.

Witter, J. F. 1981. Brucellosis. Ch. 24. p. 280-287 *in* Davis, J. W., L. J. Karstad, D. D. Trainer. (eds.). Infectious diseases of wild mammals. 2nd edition. Iowa State Univ. Press. Ames, Iowa. 446 p.

Wood Bison Recovery Team. 1987. Status report on wood bison (*Bison bison athabascae*) in Canada, 1987. C. Gates (chairman), Northwest Territories Wildl. Serv., Fort Smith, N. W. T. 87 p.

Yamane, T. 1967. Elementary sampling theory. Prentice-Hall Inc., Englewood Cliffs, New Jersey. 405 p.

Ying, K. L. and D. G. Peden. 1977. Chromosomal homology of wood bison and plains bison. Can. J. Zool. 55:1759-1762.

13. APPENDIX

13.1 Observation Loop Schedule

	THURSDAY	FRIDAY	SATURDAY	SUNDAY	MONDAY	TUESDAY	WEEK TOTAL
WEEK 1	May 15 0600 0700 1300 1500	May 16 1000 1100 1600 1700	May 17 0800 0900 1400 1500	May 18 0600 1800 1900 2000	May 19 1100 1200 1700 1800	May 20 0600 0700 0800 1300	24
WEEK 2	May 22 1300 1400 1900 2000	May 23 0800 1000 1500 1600	May 24 0600 0700 1200 1300	May 25 1000 1100 1600 1700	May 26 0800 0900 1400 1500	May 27 0700 0800 1800 1900 2000	25
WEEK 3	May 29 1100 1200 1700 1800	May 30 0600 0700 0800 1400	May 31 1300 1400 1900 2000	June 1 0900 1000 1500 1600	June 2 0600 0700 1200 1300	June 3 1000 1100 1600 1700	24
WEEK 4	June 5	June 6 0800 0900 1400 1500	June 7 0800 1800 1900 2000	June 8 1100 1200 1700 1800	June 9 0600 0700 0800 1500	June 10 1300 1400 1900 2000	20
WEEK 5	June 12 0900 1000 1500 1600	June 13 0600 0700 1200 1300	June 14 1000 1100 1600 1700	June 15 0800 0900 1400 1500	June 16 0900 1000 1900 2000	June 17 1100 1200 1700 1800	24
WEEK 6	June 19 0600 0700 0800 1600 1700	June 20 1300 1400 1900 2000	June 21 0900 1000 1500 1600	June 22 0600 0700 1200 1300	June 23 1000 1100 1600 1700	June 24	21
WEEK 7	June 26 0800 0900 1400 1500	June 27 1000 1800 1900 2000	June 28 1100 1200 1700 1800	June 29 0600 0700 0800 1700	June 30 1300 1400 1900 2000	July 1 0900 1000 1600 1800	24
WEEK 8	July 3 0600 0700 1200 1300	July 4 1000 1100 1600 1700	July 5 0800 0900 1400 1500	July 6 1100 1600 1900 2000	July 7 1100 1200 1700 1800	July 8 0600 0700 0800 1800	24
WEEK 9	July 10 1300 1400 1900 2000	July 11 0900 1000 1500 1600	July 12 0600 0700 1200 [illegible]	July 13 1000 1100 1600 1700	July 14 0800 0900 1400 1500	July 15 1200 1800 1900 2000	24
WEEK 10	July 17	July 18 1100 1200 1700 1800	July 19 0600 0700 0800 1800	July 20 1300 1400 1900 2000	July 21 0800 1000 1500 1600	July 22 0600 0700 1200 1300	20
WEEK 11	July 24 1000 1100 1600 1700	July 25 0800 0900 1400 1500	July 26 1300 1400 1800 1900 2000	July 27 1100 1200 1700 1800	July 28 0600 0700 0800 2000	July 29 1300 1400 1900 2000	25
WEEK 12	July 31 0900 1000 1500 1600	August 1 0600 0700 1200 1300	August 2 1000 1100 1600 1700	August 3 0800 0900 1400 1500	August 4 1100 1200 1800 1900 2000	August 5 0900 1000 1500 1600	25
						TOTAL	280

13.2 Field Instructions and Forms for Conducting Observation Loops, Bison Sightings, and Traffic Observation Periods

13.2.1 Observation loop, bison sighting, and traffic observation period procedures

1. Five minutes before loop start time, park outside Buffalo Paddock entrance, well on edge of road
2. Record **Loop #**, **Day of Study**, **Date**, **Observer**, and **Loop Start Time** on *Paddock Observation Loop Form*
3. Record **Loop #** and **Sighting #** on *Bison Sighting Form*
4. Record **Day of Study**, **Date**, and **Observer** on *Bison Location Form*
5. Record **Day of Study**, **Date**, and **Observer** on *Paddock Traffic Observation Form I*
6. At loop start time begin a loop (*Paddock Observation Loop Form*)
7. Enter Buffalo Paddock and drive slowly to paddock traffic counter while looking for bison
8. Record any traffic observed under **Vehicles Observed** as described in 14. c. below
9. Stop before passing through paddock traffic counter beam (well on the edge of the road)
10. Walk over to counter, being careful not to disrupt beam, read paddock traffic counter and return to car
11. Record number under **Paddock Counter, Counter Reading (Start)** for both **Loop** and **Hour**
12. If there were vehicles recorded under **Vehicles Observed** since loop start time, adjust the paddock traffic counter reading to what it would have been at the start of the loop
13. Observe **Sky Condition** and **Precipitation** and complete codes
14. Proceed with loop
    a. Drive slowly, average less than 10 km/h
    b. Look carefully for bison, using binoculars and stopping when necessary
    c. Record all traffic observed during the loop (including any sightings - see 14. g. 9) below) under **Vehicles Observed**
        1) **Private** includes all vehicles except buses, rented or privately owned which are

operated by non-commercial [illegible]ivers (cars, trucks, vans, campers, motorhomes)

2) **Bus Tour** includes all commercial tour buses and school buses, specify name of company using numbered 'X' codes defined under **Other Observations**

3) **Other Tour** includes all commercial tour vehicles other than buses (vans, taxi cabs), specify name of comp[illegible] using numbered 'X'codes defined under **Other Observations**

4) **Other** includes all non-visitor vehicles such Warden Service, co[illegible]truction, and maintenance vehi[illegible] specify type [illegible] non-visitor where p[illegible]ble using numbered 'X' codes defined under **Other Observations**

5) Also note the presence of motorcycles and cyclists using numbered 'X' codes defined under **Other Observations**

d. Move over if necessary to allow vehicles to pass

e. Note changes in **Sky Condition** and **Precipitation** as they occur

f. If you sight the bison, stop when you have the best view possible from that location

g. Begin a bison sighting (***Bison Sighting Form***)

1) Record the **Time of Sighting (Start)**, **Sky Condition** and **Precipitation** codes and begin the tape (ten minute recording of thirty second audio prompts)

2) Record the type of bison being observed across the top of the columns (eg. adult female, calf, calf, adult female, etc.)

3) Observe each animal for each one minute interval and complete distance, percent visible and screening codes under **View, D, P, and S**, and activity codes under **Act** for each animal. Specify any other screening or activity codes by using numbered 'X' codes, defined under **Other Observations**. More than one code can be given for each animal if the distance, percent visible, screening, or activity changes during the one minute interval.

4) Record for each minute if binoculars were used to observe the bison by placing a check under **Binocs**

5) Move the research vehicle to maintain the best possible sighting or to allow

vehicles to pass as necessary. Record any such movement for each minute by placing directional arrows under **Vehicle Move**. Specify if the movement was to allow a vehicle to pass by using a numbered 'X' code defined under **Other Observations**

6) When the recording signals that one minute has passed move to the row for the next minute and record observations for each animal, binocular use and vehicle movement again

7) Record unusual visitor behavior under **Other Observation** with as much detail as possible

8) Note changes in **Sky Condition** and **Precipitation** as they occur

9) Tally traffic observed during the sighting under **Vehicles Observed, Sighting # 1, Stop and Do Not Stop** on the *Paddock Observation Loop Form*

10) Repeat the bison observations for a maximum of ten minutes or until all bison move out of sight and cannot be seen for more than one minute even by moving the research vehicle

11) Terminate the bison sighting

12) Record the **Time of Sighting (End)**, **Total Sighting Time** and **Sighting Form __of__**

13) Indicate location of bison during sighting on *Bison Location Form* map, and record **Legend** information

14) As soon as possible complete any additional **Other Observations** for sighting

h. Resume loop, continuing to look for bison in a new location

i. If bison are sighted again, repeat above process from 14. g.

j. The loop is complete upon reaching the island opposite the Buffalo Paddock entrance

15. Record the time under **Loop End Time** on the *Paddock Observation Loop Form* and in the **first space** under **Time of Observation** on the *Paddock Traffic Observation Form I*

16. Begin recording information on the *Paddock Traffic Observation Form I* as described in 23 below

17. Proceed to the paddock traffic counter, stop and read the counter as before

18. Record number under **Paddock Counter, Counter Reading (End)** for **Loop** on the *Paddock Observation Loop Form* and in the **first space** under **Paddock Counter** on the *Paddock Traffic Observation Form I*

19. Adjust reading for any vehicles which have passed the counter since the loop end time

20. Back up to the Buffalo Paddock entrance and leave paddock

21. Turn around and park on the edge of the road facing the entrance

22. As soon as possible tally **Vehicles Observed**, record **Total Loop Time**, **Total Number of Sightings**, and **Total Number of Bison Seen** and complete any additional **Other Observations** on the *Paddock Observation Loop Form*

23. Conduct a traffic observation period until the end of the hour as follows

    a. Begin the traffic observation period at loop time end (*Paddock Traffic Observation Forms I & II*)

    b. Record the paddock traffic counter reading as described above in the **first space** under **Paddock Counter**

    c. Observe **Sky Condition** and **Precipitation** and record codes

    d. For each vehicle observed during the traffic observation period

        1) Record the vehicle type code (specifying private rentals, bus tour and other tour companies, and the identity of non-visitors) under **Vehicle Type**

        2) Record the liscence plate under **Liscence Plate**

        3) Record a description of the vehicle to enable you to identify it if seen it again under **Vehicle Description**

    e. For vehicles entering the paddock record the time to the nearest minute (round up or down as appropriate) under **Time, Enter**

    f. For vehicles passing the island and beginning a second loop, record the time to the nearest minute under **Time, 2nd Loop**

    g. For vehicles leaving the paddock record the time to the nearest minute under **Time, Exit**

h. Note changes in **Sky Condition** and **Precipitation** as they occur

i. Use *Paddock Traffic Observation Form II* as required being sure to record the **Day of Study**, **Date**, **Observer**, and **Page __of__**

j. At the end of the hour, terminate the traffic observation period and begin the next loop if appropriate (see 6. above)

k. Record the time in the **second space** under **Time of Observation** and the total traffic observation period time in the **third space**

l. As soon as possible calculate the total times and averages under **Minutes**, **1st Loop**, **2nd Loop**, and **Total** for each vehicle and complete summary statistics for **Vehicle Type**

24. Proceed into the Buffalo Paddock to the paddock traffic counter, stop and read the counter as before

25. Record number under **Paddock Counter, Counter Reading (End)** for **Hour** on the *Paddock Observation Loop Form*, in the **second space** under **Paddock Counter** on the *Paddock Traffic Observation Form I*, and under **Paddock Counter, Counter Reading (Start)** for **Loop** if beginning another loop

26. Adjust reading for any vehicles which have passed the counter since end of the hour

27. Backup and leave the Buffalo Paddock or proceed with the next loop as appropriate

28. As soon as possible calculate the total paddock traffic count in the **third space** under **Paddock Counter** and the **Observed Paddock Counts** on the *Paddock Traffic Observation Form I* and compare the two to determine any counter error

29. Ensure all forms are completed fully and place in appropriate binders

13.2.2 Examples of field forms used

PADDOCK OBSERVATION LOOP FORM

Loop # __ __ __

Day of study: __ __

Date: __ __ (day) __ __ (01-May, 02-Jun, 03-Jul, 04-Aug) __ __ (01-Sun, 02-Mon, 03-Tue, 04-Wed, 05-Thu, 06-Fri, 07-Sat)

Observer: ____________

Loop start time: __ __ __ __
Loop end time: __ __ __ __
Total loop time: __ __ minutes.

Total number of sightings: __ __
Total number of bison seen: __ __

	Gate Counter		Paddock Counter	
	loop	hour	loop	hour
Counter reading (start)				
Counter reading (end)				
Total Vehicles				
Researchers went through				
Non-visitor vehicles				
Total visitor vehicles				

Sky conditions: __ __

01 - Sunny (scattered clouds) 0 - 5/10 cloud cover
02 - Cloudy (Broken cover) 6/10 - 9/10 cloud cover
03 - Overcast, high clouds
04 - Overcast, low clouds

Precipitation: __ __

01 - No precipitation
02 - Intermittent rain
03 - Light, steady rain
04 - Heavy steady rain
05 - Intermittent snow
06 - Light, steady snow
07 - Heavy steady snow

	Vehicles Observed	Private	Bus Tour	Other Tour	Non-Visitor
	Total During Loop				
sighting # 1.	Stop				
	Do not stop				
sighting # 2.	Stop				
	Do not stop				
sighting # 3.	Stop				
	Do not stop				

Other observations:

BISON SIGHTING FORM

Loop # ___ ___ ___
Sighting form ___ of ___
Sighting # ___ ___ ___

Time of sighting (start): ___ ___ ___ ___
Time of sighting (end): ___ ___ ___ ___
Total sighting time: ___ ___ minutes.

Sky condition: ___ ___
Precipitation: ___ ___

Minutes	[illegible]	View, DPS	Act.	View, DPS	Act.	View, DPS	Act.	View, DPS	Act.	View, DPS	Act.	View, DPS	Act.	View, DPS	Act.	View, DPS	Act.	View, DPS	Act.	[illegible]
0																				
1																				
2																				
3																				
4																				
5																				
6																				
7																				
8																				
9																				
10																				

View codes:

Distance
1- 0-10m
2- 11-50m
3- 51-100m
4- 100+m

Percent visible
1- 100%
2- 75-99%
3- 50-74%
4- 25-49%
5- 0-24%

Screening
B- other bison
V- vegetation
T- topography
X- other (specify)

Activity Codes
F- feeding
W- Walking
S- Standing
L- Laying down.
R- Running
X- Other (SPECIFY: charging, threatening, vocalization, etc.)

Other observations:

PADDOCK TRAFFIC OBSERVATION FORM I page 21 of _ _

Day of study: _ _ Date: _ _ (date) _ _ (month) _ _ (day) Observer: ____________

Time of observation: _ _ _ _ to _ _ _ _ = _ _ minutes

Gate counter: _ _ _ _ _ to _ _ _ _ _ = _ _ _ counts = _ _ _ _ counts/minute
Paddock counter: _ _ _ _ _ to _ _ _ _ _ = _ _ _ counts = _ _ _ _ counts/minute

Observed gate counts (Totals A + C): _ _ _ counts
Observed paddock counts (Totals A + B): _ _ _ counts

Vehicle codes: P - private
B - bus tour
OT - other tour
R - researcher
N - other non-visitor

Gate counter error: _ _ counts
Paddock counter error: _ _ counts

Weather Changes			Vehicle	Liscence	Vehicle	Time			Minutes		
Time	Sky	Percip	Type	Plate	Description	Enter	2nd Loop	Exit	1st loop	2nd loop	Total
Totals/Sub Ts.			vehicles			A counts	B counts	C counts	min.	min.	min.
								Averages:	min/P	min/B	min. in padk.

Paddock Traffic Observation Form II

page __ __ of __ __

Day of study: __ __ Date __ __ (date) __ __ (month) __ __ (day) Observer: ____________________

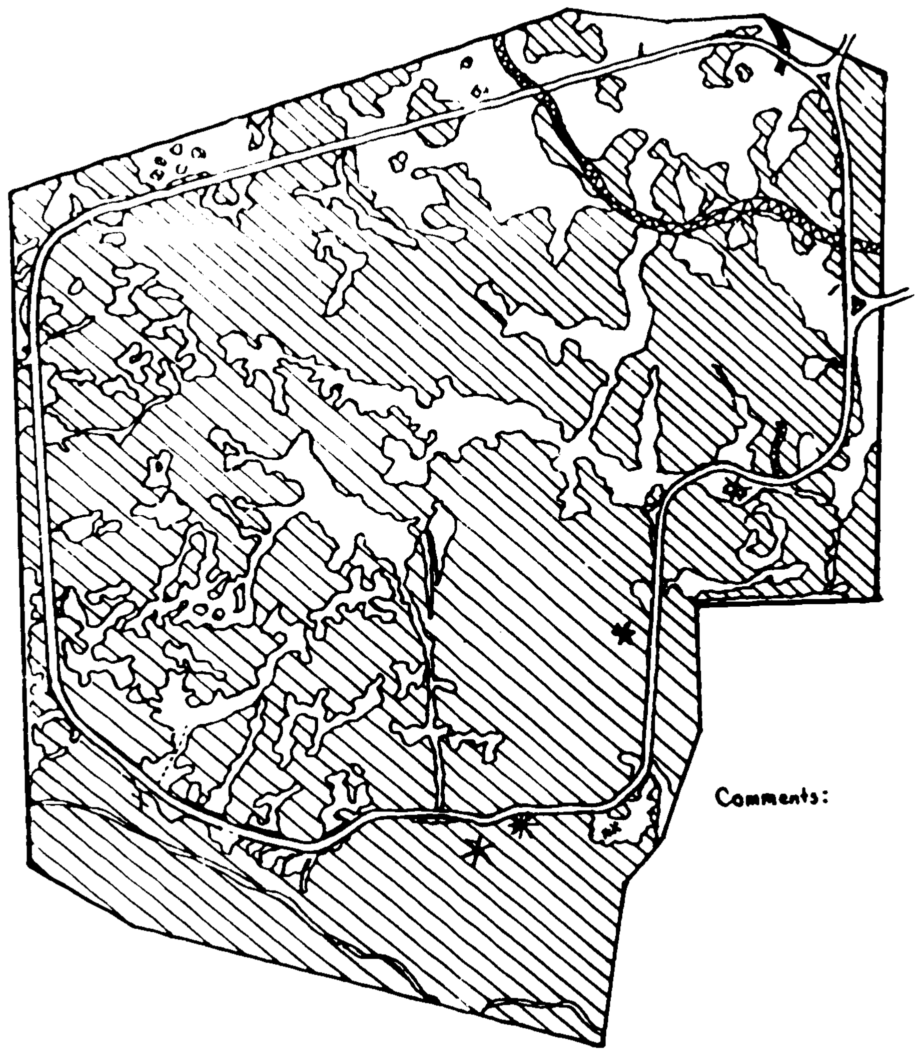
Vehicle Observations (cont'd)

Weather Changes			Vehicle	Licence	Vehicle	Time			Minutes		
Time	Sky	Percip	Type	Plate	Description	Enter	2nd loop	Exit	1st loop	2nd loop	Total

Subtotals:	vehicles	counts	counts	counts	min.	min.	min.
Totals from previous page:	vehicles	counts	counts	counts	min.	min.	min.
Totals:	vehicles	A counts	B counts	C counts	min.	min.	min.
Averages:					min/veh	min/veh	min in padd.

CATION FORM

Day of study Date ___ ___ ___ Observer ___________
date month day



Comments:

LEGEND:

__ __	= Loop	___	Sighting	___
__ __		___		___
__ __		___		___
__ __		___		___
__ __		___		___
__ __		___		___
__ __		___		___
__ __		___		___
__ __		___		___

________ = 100m. (approx.)

13.3 Tour Agency Form for Buffalo Paddock Tours

BUFFALO PADDOCK TOURS - SUMMER 1986

Dear Driver/Guide:

Hi!! Welcome to the Buffalo Paddock Study Research Team. We are conducting a study of the Buffalo Paddock this summer to gather information about the amount and quality of visitor use.

Please fill out this form for each tour that you take through the Buffalo Paddock this summer. Any details and comments you may care to add are welcome.

I will be collecting these forms from your company office every two weeks. If you have any questions about the forms, the Buffalo Paddock, or the bison, please feel free to leave me a note with your forms and I'll get back to you.

Your assistance with my study is greatly appreciated!! THANKS!!

Sincerely yours,

Nora Kopjar

Date of Tour: ____ ____ (Month Day)   Time of Arrival at Paddock: __________   Number of Passengers: __________

Weather (Sunny, Cloudy, Rainy, Hot, Cool, Windy, etc.) ______________________

____

Description of Tour Through Buffalo Paddock:
(Include brief notes on how many bison (if any) you saw, what they were doing (feeding, laying down, walking), the comments/reactions/actions of your passengers, and any other observations of other visitors, wildlife, etc.)

____

____

____

____

____

____

____

____

____

Any Other Comments: ______________________________

____

Your Initials: __________