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Long-Term Ecosystem States and Processes
in
Banff National Park
and
the Central Canadian Rockies



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**Long-Term Ecosystem States and Processes
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and
the Central Canadian Rockies.**

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TABLE OF CONTENTS

	Page
ACKNOWLEDGEMENTS	iii
TABLE OF CONTENTS	v
LIST OF TABLES	vii
LIST OF FIGURES	ix
ABSTRACT	xiii
CHAPTER	
I. INTRODUCTION	1-1
LEGISLATIVE MANDATE	1-1
BANFF MONTANE ECOSYSTEM MODEL	1-1
THE PROBLEM	1-9
METHODS	1-10
II. HISTORICAL OBSERVATIONS	2-1
INTRODUCTION	2-1
RESULTS AND DISCUSSION	2-3
Foothills	2-3
Rocky Mountains	2-5
Columbia Valley	2-19
TABULAR SUMMARIES	2-20
JUDGING THE VALIDITY OF EARLY REPORTS	2-31
WHY DID EARLY EXPLORERS SEE SO LITTLE GAME?	2-33
SUMMARY AND CONCLUSIONS	2-36
III. ARCHAEOLOGICAL EVIDENCE	3-1
INTRODUCTION	3-1
BANFF NATIONAL PARK	3-2
JASPER NATIONAL PARK	3-8
KOOTENAY NATIONAL PARK	3-11
YOHO NATIONAL PARK	3-11
ALBERTA'S EASTERN SLOPES	3-11
BRITISH COLUMBIA	3-14
SUMMARY	3-18
WHY ARE ELK SO RARE IN ARCHAEOLOGICAL SITES?	3-19
BONE GREASE PROCESSING	3-25
IV. REPEAT PHOTOGRAPHS	4-1

INTRODUCTION	4-1
PAIRED PHOTOS	4-2
SUMMARY AND CONCLUSIONS	4-26
COMPARISON WITH OTHER AREAS	4-26
V. FIRE HISTORY AND ECOLOGY	5-1
INTRODUCTION	5-1
FIRE IGNITION	5-1
FIRE BEHAVIOR	5-8
LANDSCAPE LEVEL BURNING PATTERNS	5-12
AREA FIRE REGIMES	5-12
HUMAN INFLUENCES	5-19
BANFF'S ECOSYSTEM MODEL	5-27
VI. ASPEN ECOLOGY	6-1
INTRODUCTION	6-1
BANFF NATIONAL PARK	6-2
Inside-Outside Park Comparisons	6-2
Aspen Exclosures	6-8
Aspen Burns	6-18
KOOTENAY NATIONAL PARK	6-23
YOHO NATIONAL PARK	6-26
SUMMARY AND CONCLUSIONS	6-28
VII. SUMMARY AND DISCUSSION	7-1
ASPEN	7-1
FIRE	7-1
ELK	7-2
WOLVES	7-3
HUMANS	7-7
MOUNTAIN BISON	7-11
MANAGEMENT CONSIDERATIONS	7-12
VIII. FURTHER RESEARCH NEEDS	8-1
LITERATURE CITED	9-1

LIST OF TABLES

Table	Page
2.1 Foothills: Part I – Animals observed	2-21
2.2 Foothills: Part II – Animal sign.....	2-22
2.3 Foothills: Part III – Animals killed	2-23
2.4 Rocky Mountains: Part I – Animals observed.....	2-24
2.5 Rocky Mountains: Part II – Animal sign	2-25
2.6 Rocky Mountains: Part III – Animals killed.....	2-26
2.7 Columbia Valley: Part I – Animals observed.....	2-28
2.8 Columbia Valley: Part II – Animal sign.....	2-29
2.9 Columbia Valley: Part III – Animals killed	2-30
3.1 Ungulate remains recovered from the Vermilion Lake sites (153R, 502R; EhPv-8) in Banff National Park	3-3
3.2 Ungulate remains recovered from archaeological sites in Banff National Park. Part 1: Number of identified specimens	3-4
3.3 Ungulate remains recovered from archaeological sites in Banff National Park. Part 2: Minimum number of individuals.....	3-5
3.4 Comparison of the relative abundance of ungulates wintering in the Bow Valley portion of Banff National Park during the 1980s with the relative abundance of ungulate remains recovered from archaeological sites in the same area.....	3-7
3.5 Ungulate remains recovered from Jasper House (230R) in Jasper National Park	3-10

Table	Page
3.6 Ungulate remains recovered from Alberta eastslope archaeological sites	3-12
3.7 Ungulate remains recovered from archaeological sites in British Columbia. Part 1: Number of identified specimens	3-16
3.8 Ungulate remains recovered from archaeological sites in British Columbia. Part 2: Minimum number of individuals	3-17
5.1 Ignition source, location, and timing of fires in the northern Rocky Mountains	5-3
5.2 Recent burn area statistics and current fire cycles for the Canadian Rockies	5-14
5.3 Mean historical fire intervals for forests in the northern Rocky Mountains	5-15
5.4 Area burned and number of fires greater than 40 ha during natural and historic periods in Banff National Park	5-20
6.1 Summary of elk use and aspen regeneration on burns in Banff National Park	6-22
7.1 The impact of carnivore predation on caribou populations in Canada and Alaska	7-5

LIST OF FIGURES

Figure	Page
1.1 Map of the Southern Canadian Rockies and the Central Canadian Rockies Ecosystem.....	1-2
1.2 A simple model for Banff's lower Bow Valley and the Central Canadian Rockies that incorporates elk, aspen, wolves, fire, and humans as key ecosystem components.....	1-4
2.1 The combined routes of early explorers in the Canadian Rockies.....	2-2
3.1 An example of ungulate bones typically unearthed at archaeological sites in the Canadian Rockies	3-26
4.1 Mount Norquay and Banff townsite viewed northwest from Tunnel Mountain in 1902 and 1984	4-2
4.2 Banff townsite and the Bow Valley viewed northeast from Sulphur Mountain in 1898 and 1981	4-4
4.3 Cascade Mountain viewed north from the Bow Valley in 1886 and 1981	4-6
4.4 Hoodoos near Banff townsite viewed southeast in 1890 and 1981	4-8
4.5 Banff's Hoodoos viewed northwest in 1894 and 1985.....	4-10
4.6 Banff's Bow Valley viewed north above the Hoodoos in 1889 and 1985	4-12
4.7 View west up the Bow Valley in 1914 and 1983.....	4-14
4.8 Hillsdale Meadows west of Banff townsite in ca. 1907 and 1986	4-16
4.9 The Ya Ha Tinda viewed north in 1937 and 1986.....	4-18
4.10 Viewed south over Kootenay Plains in 1907 and 1993	4-20

Figure	Page
4.11 Viewed southeast over Kootenay Plains in 1907 and 1993	4-22
4.12 The Columbia River Valley viewed north from Swansed Peak in 1906 and 1990.....	4-24
5.1 Factors influencing Rocky Mountain fire regimes	5-2
5.2 Spatial pattern of lightning-caused fires in the Canadian Rockies from 1961 to 1994.....	5-5
5.3 Known burn periods for fires greater than 40 ha in Banff National Park from 1888 to 1980	5-11
5.4 Cumulative stand-age distributions for Rocky Mountain forests	5-17
5.5 The distribution of lightning-caused fires in Banff, Kootenay, and Yoho National Parks	5-28
5.6 The area burned by lightning fires in Banff, Kootenay, and Yoho National Parks.....	5-29
6.1 A typical aspen stand in Banff National Park's Bow Valley	6-3
6.2 Typical aspen stands along the North Saskatchewan and on Kootenay Plains	6-4
6.3 Typical aspen stands on the Ya Ha Tinda east of Banff National Park.....	6-6
6.4 Aspen communities inside and outside Banff's 10.5 mile aspen exclosure.....	6-9
6.5 Repeat photoset of Banff's 10.5 mile aspen exclosure's outside plot.....	6-12
6.6 Repeat photoset of Banff's 10.5 mile aspen exclosure's inside plot.....	6-14
6.7 Aspen inside and outside the fenced Trans- Canada right-of-way in Banff's Bow Valley.....	6-16
6.8 Aspen protected from elk at the Two Jack burn in Banff's Bow Valley	6-20

Figure		Page
6.9	The relationship between ungulate use and aspen regeneration in Kootenay National Park	6-25
6.10	The impact of cutting and ungulate browsing on aspen regeneration west of Yoho National Park	6-27
6.11	Fire initiated age classes of aspen stands in Kootenay and Yoho National Parks.....	6-29
7.1	Model of Alaska wolf-ungulate interactions simulated under circumstances in which human harvest triggered a decline in both predator and prey.....	7-6

ABSTRACT

Aspen, elk, wolves, fire, and humans were used to assess the long-term ecosystem states and processes in Banff National Park and the Central Canadian Rockies. These components were selected because they effect both community structure and function, and because they can be used to judge ecosystem integrity. In addition, these species and processes have been susceptible to change during the period of European influence, and they are understood, at least to some degree, from previous research and monitoring. We used archaeological evidence, observations recorded by early explorers, aspen ecology measurements, historical and repeat photographs, and fire-history data to describe the ecosystem in pre-Columbian times and during the late 1800s when Banff was established as Canada's first national park. For as Aldo Leopold noted over 40 years ago, "if we are serious about restoring ecosystem health and ecological integrity, then we must know what the land was like to begin with." We then compared the state of aspen, elk, wolves, fire, and human influences in pre-Columbian times and ca. 1885, with conditions today, not only to understand what has changed and why, but also to measure the ecological integrity of the present system.

Aspen in Banff's Bow Valley has been in decline since the early 1900s due, primarily, to repeated browsing by large numbers of elk, not other factors such as climatic change or fire suppression. Under present conditions, burned aspen stands have failed to successfully regenerate due to intense ungulate browsing. Aspen, unlike most plants, seldom grows from seed, and during the period of recorded history, no aspen clones are known to have established from seed in the Canadian Rockies or anywhere in the Intermountain West. It is thought that environmental conditions have not been favorable for clonal establishment since shortly after the glaciers retreated 10,000 or more years ago. During the intervening millennia, Banff's aspen survived climatic change and other factors, yet under park management, aspen is approaching ecological extinction. Aspen in Kootenay and Yoho are declining for similar reasons. This suggests that conditions in Banff's Bow Valley are different today than at any time in the past.

This conclusion is supported by archaeological evidence and historical observations recorded by the first explorers who visited the Canadian Rockies. Although elk are exceedingly common today and dominate Banff's ungulate community, this was not the case in the past. Between 1792 and 1872, 26 different expeditions spent 369 days traveling through the Canadian Rockies on foot or horseback but reported seeing elk on only 12 occasions or once every 31 party-days. Similarly, elk are one of the least frequent ungulates whose bones are unearthed from archaeological sites in the Canadian Rockies, Alberta Foothills, and Columbian Trench. Archaeological data also suggest that all ungulate species were relatively rare in pre-Columbian times. The unbrowsed condition of woody vegetation, like aspen, depicted in historical photographs also suggests that ungulate populations, and especially elk, were much lower ca. 1885 than they are today.

Repeat photographs also show that Banff's Bow Valley, and other montane valleys in the Central Canadian Rockies, were much more open in the past than is the case at present. Under park management, grasslands, open-timber types, shrublands, and regenerating aspen communities have all declined markedly reducing available ungulate winter range by approximately 90%. Conversely, since Banff National Park was established, forests have both grown-up and thickened-up due to fire exclusion and fire suppression policies. Repeat photographs indicate that frequent low-intensity fires were the norm prior to park establishment, and that historically, large-scale high-intensity crown fires were rare, especially in lower-elevation montane forests. These photographs also suggest that frequent low-intensity fires created and maintained the open-vegetation mosaic seen at park establishment.

Fire-history studies support the same conclusion. Historically, and probably in pre-Columbian times as well, Banff's montane fire regime was dominated by frequent but low intensity burns. One hundred years of fire exclusion and suppression, however, have not only altered the park's original vegetation communities,

but they have also changed the area's fire regime. In the absence of fire, forest fuels have accumulated setting the stage for high-intensity crown fires, especially under extreme burning condition. If those fires occur, they will create a vegetation mosaic that has never before been seen in the park.

Fire-history data, aspen ecology, and ethnographic accounts all indicate, however, that Banff's original low-intensity, high-frequency fire regime was caused, primarily, by native burning, not lightning fires. Fires set by hunter-gatherers differ from lightning fires in terms of seasonality, frequency, intensity, and ignition pattern. Most aboriginal fires were set in spring, between snowmelt and vegetation green-up, or late in the fall when burning was not severe. Unlike lightning fires, which tend to be infrequent high-intensity conflagrations, native burning produced a higher frequency of lower-intensity fires. So, aboriginal burning and lightning fires create different vegetation mosaics, and in many instances, entirely different plant communities. Aboriginal peoples burned to modify their lands to meet human needs, such as the production of plants used for food or to create grazing areas favored by game.

Moreover, native hunting acted in concert with wolf and other carnivore predation to keep ungulate populations low historically and in pre-Columbian times – this explains why Banff's Bow Valley was not heavily used by ungulates in the past and how aspen prospered in the park until recent times. Aboriginal activities, though, promoted biodiversity and created the plant and animal communities found when Europeans first entered the Canadian Rockies. Contrary to prevailing beliefs, North America was not a "wilderness" waiting to be discovered. Instead, it was home to as many as 100 million native people before European-introduced disease decimated their numbers. The modern concept of wilderness as areas without human influence did not apply to the Americas in pre-Columbian times. Any wilderness that existed did so only in the minds of Europeans. In short, Native Americans were the ultimate keystone species that structured entire ecosystems prior to European arrival in the New World.

This has important implications for park management. A hands-off, let-nature-take-its-course approach, also called "natural regulation," will not, for instance, recreate the conditions that existed in the past. If the goal is to maintain the biological diversity and ecosystem integrity of pre-Columbian times, as some have suggested, then the system must be actively managed to duplicate the aboriginal practices that once structured those communities. Instead of being a window on the past or an environmental benchmark, conditions in Banff National Park today have not existed at any other time in the last 10,000 years.

CHAPTER 1

INTRODUCTION

LEGISLATIVE MANDATE

The management of Canada's national parks is governed by the Canadian National Parks Act as amended in 1988. According to that legislation,

"The National Parks of Canada are hereby dedicated to the people of Canada for their benefit, education and enjoyment ... and the National Parks shall be maintained and made use of so as to leave them unimpaired for the enjoyment of future generations." [Section 5.1.2].

"Maintenance of ecological integrity through the protection of natural resources shall be the first priority when considering park zoning and visitor use in management plans." [Section 5.1.2].

To comply with these legal directives, national parks have implemented ecosystem-style management because natural resources and biological processes often transcend administrative boundaries (Woodley 1992, 1993; Woodley et al. 1993; Grumbine 1994; Woodley and Forbes 1995). To insure that Canada's National Parks retain their ecological diversity unimpaired for future generations, Parks Canada must not only coordinate its management with that of lands surrounding its parks, but it must also become more involved in ecosystem research (Lieff 1992, Woodley and Theberge 1992, Woodley 1993, Gauthier 1994, Hodgins 1994, Skibicki et al. 1994, Bernard et al. 1995, Gauthier et al. 1995, Krakauer 1995, Pacas et al. 1995, Peterson et al. 1995).

In 1991, Federal, British Columbia, and Alberta land managers established the Central Rockies Ecosystem Interagency Liaison Group (CREILG) as a first step to coordinate resource management in Banff, Yoho, and Kootenay National Parks with that on adjoining provincial lands – collectively termed the Central Rockies Ecosystem (Komex International 1995) – see Figure 1.1. CREILG has recognized that ecosystem indicators must be quantified and monitored to ascertain ecosystem status (Bernard et al. 1995, Komex International 1995, Pacas et al. 1995). To fulfill its legislative mandate, Parks Canada must assess the long-term processes that created today's ecosystems, as well as those which structured ecosystems in pre-Columbian times, for it is impossible to define ecological integrity without a historical perspective (Woodley 1993, Woodley et al. 1993, Skibicki et al. 1994, Winterhalder 1994). As Aldo Leopold noted over 40 years ago, "if we are serious about restoring ecosystem health and ecological integrity, then we must know what the land was like to begin with" (Covington and Moore 1994:45).

BANFF MONTANE ECOSYSTEM MODEL

To assist this cooperative initiative, Parks Canada developed a preliminary ecological model for Banff's lower Bow Valley (White et al. 1994) that is also helpful in understanding the larger Central Rockies Ecosystem. Lower montane zones are important because they provide critical habitat for ungulates and other species.

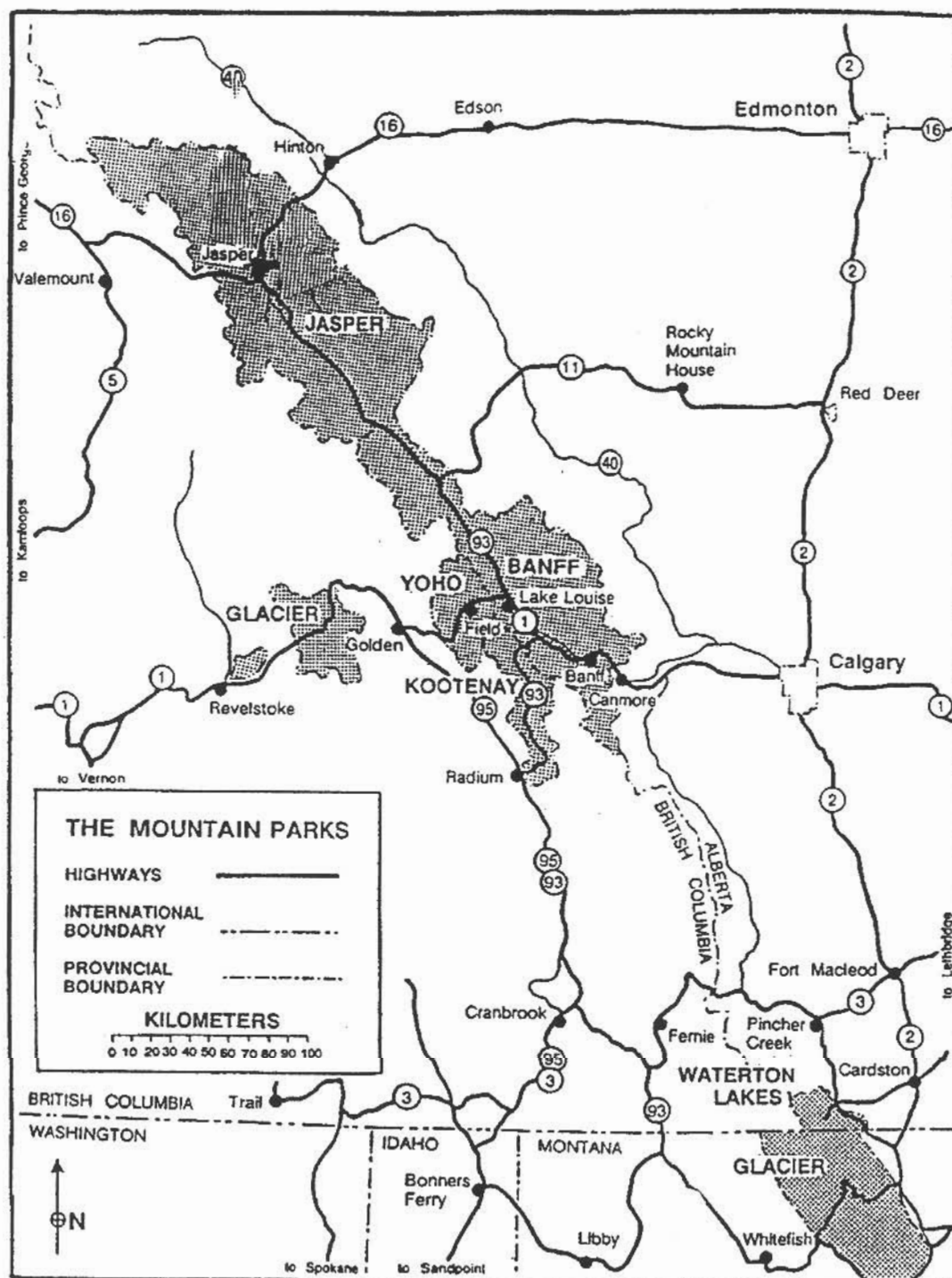


Figure 1.1 Map of the Southern Canadian Rockies and the Central Canadian Rockies Ecosystem.

Without these wintering areas, few ungulates would be able to survive, and biological diversity would be greatly reduced. The fact that their distribution is very restricted in the Canadian Rockies underscores the importance of montane bioregions (Komex International 1995). In addition, montane valleys are the part of the ecosystem most heavily impacted by modern development and the areas most frequented by today's park visitors (Bernard et al. 1995). Moreover, they were also the focus of prehistoric human activities.

Banff National Park and adjoining lands contain nearly the complete assemblage of biota present at European contact except that free-ranging bison (Bison bison) are no longer present. The subsistence impacts of native peoples, including hunting and aboriginal burning, are also absent (Kay 1995a, in press b; Kay and White 1995). On the other hand, since 1885 the Bow Valley has been impacted by Banff townsite, the Trans-Canada Highway, the Canadian Pacific Railway, Minnewanka Dam, and other projects (Bernard et al. 1995, Komex International 1995).

Since it is not necessary to model an entire ecosystem to capture its essential dynamics, Parks Canada selected a key set of closely linked elements in developing its ecosystem model (Woodley et al. 1993, White et al. 1994, Kay and White 1995). Included were aspen (Populus tremuloides), elk (Cervus elaphus), wolves (Canis lupus), fire, and humans (see Figure 1.2). The structural elements and linkages in this model all have value as indicators of ecological integrity, and are understood, at least to some degree, from previous research and monitoring (Kay 1991a, 1991b; Westman 1991; Woodley and Theberge 1992; Woodley 1993; Woodley et al. 1993; White et al. 1994; Bernard et al. 1995; Kay and White 1995; Pacas et al. 1995). Aspen, elk, wolves, fire, and humans were selected because they effect both ecosystem structure and function, and because they represent the species and processes most susceptible to change during the period of European influence (Woodley 1993, Woodley et al. 1993, Grumbine 1994, Henry et al. 1995, Kay and White 1995, Pacas et al. 1995, Shrader-Frechette and McCoy 1995).

Aspen

Although not the primary food for elk in the Central Canadian Rockies (Nelson and Legee 1982, Woods 1991), aspen is still an excellent indicator of ecosystem status (Kay 1990, 1996). As a relatively short-lived tree (< 150 years), aspen is often dependent on periodic disturbance such as fire to stimulate vegetative regeneration via root suckering, and to reduce conifer competition. Aspen generally occur as clones in which all the individual trees (ramets) are genetically identical, having grown from a common root system by vegetative shoots. Aspen, however, are sensitive to elk numbers and range use levels because they provide preferred forage (Cowan 1947a, Flook 1964). High-density elk populations commonly strip bark from mature aspen and severely browse aspen suckers which prevents stand regeneration and eventually leads to the loss of aspen clones (Kerbill 1972; Olmsted 1977, 1979; Kay 1985, 1990, 1996; Shepperd and Fairweather 1994). Unlike herbaceous plants, the long-term condition and trend of aspen communities can be judged from historical photographs (Kay and Wagner 1994).

Aspen is also a sensitive indicator species because it does not commonly grow from seed due to its demanding seed bed requirements (Kay 1993). There are no known instances of aspen clones having established from seed on natural substrates anywhere in the Intermountain West during the period of recorded history (Kay 1990, 1993, 1996). It is thought that environmental conditions have not been conducive to aspen seedling growth and clonal establishment since shortly after the glaciers retreated 10,000 or more years ago (McDonough 1979, 1985; Jelinski and Cheliak 1992; Mitton and Grant 1996). So, the aspen clones found in the Central Canadian Rockies today have likely maintained their presence on

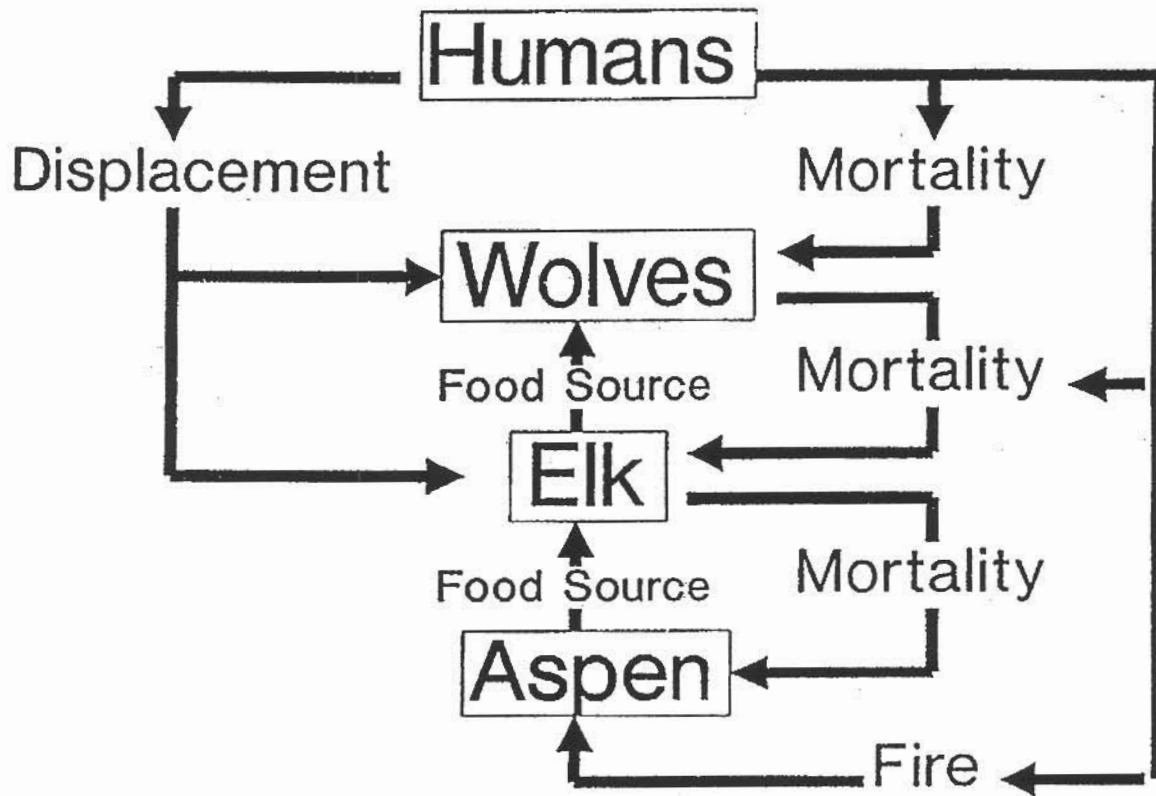


Figure 1.2. A simple model for Banff's lower Bow Valley and the Central Canadian Rockies that incorporates elk, aspen, wolves, fire, and humans as key ecosystem components.
Adapted from White et al. (1994).

those sites for thousands of years via vegetative regeneration. Thus, aspen may be among the oldest living things on Earth (Mitton and Grant 1996). Aspen seedlings are more common in the Northern Canadian Rockies (Peterson and Peterson 1992) and there may be "windows of opportunity" that allow seedling establishment at infrequent, 200 to 400 year intervals (Jelinski and Cheliak 1992:728), but successful sexual reproduction of aspen is still exceedingly rare. Because of these factors, Peterson et al. (1995:14-17) classified aspen in the Central Canadian Rockies as old-growth ancient forests. If aspen is lost due to forest succession or overgrazing, there are no known means of reestablishing those clones (Kay 1990, 1996).

In the Central Canadian Rockies, aspen stands usually occur on lower elevation fluvial landforms with southerly aspects (Holland and Coen 1982; Achuff et al. 1984, 1993). Aspen forest cover also tends to increase with decreased elevation, and is therefore more common in the lower Bow Valley and adjoining areas outside Banff National Park. Areas occupied by aspen in the Canadian Rockies are rated as prime winter habitat for elk and other ungulates (Holroyd and Van Tighem 1983, Poll et al. 1984, Poll 1989, Timmermann 1991). Aspen communities also support an array of other species and have extremely high biological diversity (DeByle and Winokur 1985; Peterson and Peterson 1992, 1995; Enns et al. 1993; Pojar 1995; Stelfox 1995). Bird communities, for instance, vary with the size, age, and location of aspen clones, as well as with grazing intensity and history (Young 1973, 1977; Balda 1975; Flack 1976; Page et al. 1978; Winternitz 1980; Casey and Hein 1983; Oakleaf et al. 1983; Taylor 1986; Putman et al. 1984; Johns 1993; Westworth and Telfer 1993). If aspen is lost, many birds and small mammals will decline; some precipitously (Daily et al. 1993, Ehrlich and Daily 1993). Moreover, aspen may be the largest living organism on Earth (Grant et al. 1992, Grant 1993, Mitton and Grant 1996). One clone in central Utah contains an estimated 47,000 stems, covers 43 ha, and weighs approximately 200,000 kg. (McLean 1993).

Elk

Elk are a good ecological indicator because they are now the dominant large herbivore in most of the Central Canadian Rockies (Holroyd and Van Tighem 1983, Woods 1991), they are the main prey of wolves, and they can have a dramatic impact on plant communities (Kay 1990, Woodley and Theberge 1992, Woodley 1993, Kay and White 1995). The size of prehistoric elk populations is not known, but elk nearly disappeared from the Canadian Rockies by 1900 due to over-hunting (Millar 1915; Cowan 1947a, 1950). With the establishment of Banff, Jasper, Kootenay, and Yoho National Parks and concomitant protection, as well as reintroductions, elk numbers grew until park managers became concerned that too many animals were overgrazing the range (Cowan 1947a, 1950; Flook 1964). In Banff's Bow Valley, park wardens killed nearly 4,000 elk between 1941 and 1969 to reduce the herd and prevent range damage (Flook 1970, Woods 1991). Beginning in the late 1960s, though, Parks Canada adopted a policy of non-interference, allowing natural processes to proceed unhindered (McCormack 1992). The agency terminated its culling program, but elk were still killed by vehicles on the Trans-Canada Highway and by Canadian Pacific trains (Bernard et al. 1995).

When a portion of the Trans-Canada Highway through Banff's Bow Valley was twinned during the 1980s, a game-proof fence was constructed along either side to reduce ungulate-vehicle collisions (Woods 1988, 1991). About that same time, the number of elk living in Banff townsites noticeably increased and began to be a problem, attacking and injuring people (Bernard et al. 1995). Beyond national park boundaries where they are hunted, however, elk are very sensitive to disturbance, and often move long distances to avoid human contact (Edge et al. 1985a). About 3,000 elk now summer in Banff National Park. Approximately 1,300 winter in the Bow Valley while another 1,500 or so winter on the Panther, Red Deer, and Clearwater Rivers (Skjongsberg 1993). These estimates, however, may be low as 2,086 elk were recently photographed in one herd on the Ya Ha Tinda (Cal Hayes, pers. comm. 1993; Morgantini 1995:33).

Wolf

Although data on historic and prehistoric populations are lacking, wolves were once widely distributed throughout the Canadian Rockies, but with the arrival of Europeans, wolf eradication campaigns were initiated. The goal was to prevent loss of domestic livestock and to reduce predation on favored big game species, such as elk. Wolves were eliminated from the Canadian Rockies by the 1920s, even in national parks (Cowan 1947b). During the late 1930s, though, when human attention focused on national and international events, natural recolonization and subsequent range expansion allowed wolves to reoccupy most of western Canada (Cowan 1947b, Stelfox 1969, Carbyn 1974a, Dekker 1989). Wolves again were eliminated in the 1950s under a carnivore reduction program to check the spread of rabies (White et al. 1994). Following cessation of wolf control in the mid-1960s, wolves began a second recolonization of the Canadian Rockies.

Today, wolves are well established in Banff, Jasper, Kootenay, and Yoho National Parks but are still hunted and trapped on provincial lands (Dekker 1989, 1994; Paquet 1993; Weaver 1994). Wolves in the Central Canadian Rockies prey primarily on elk and secondarily on white-tailed deer (*Odocoileus virginianus*), mule deer (*O. hemionus*), bighorn sheep (*Ovis canadensis*), moose (*Alces alces*), and Rocky Mountain goats (*Oreamnus americanus*) (Carbyn 1974a; Huggard 1993a, 1993b, 1993c; Paquet 1993; Weaver 1994). The effect of wolf predation on elk population dynamics has not been fully assessed, but deterministic predator-prey models suggest that wolf predation, in conjunction with other mortality factors, is limiting or depressing elk numbers in some parts of Banff National Park (Paquet 1993, White et al. 1994). Wolves, though, appear to avoid Banff townsites and other developed areas in the ecosystem (Paquet 1993). It has even been suggested that elk may have moved into Banff townsites to avoid wolf predation (Dekker 1994). Wolf ecology research is presently underway in Banff and Jasper National Parks, as well as other regions of the Central Canadian Rockies (e.g., Paquet 1993, Weaver 1994). When those studies are completed, they will be incorporated into Banff's ecosystem model, but for now we will only summarize observations of wolves left by early explorers (see Chapter 2).

Humans

The Canadian Rockies were first occupied around 10,000 years ago by native peoples who affected the ecosystem by gathering and hunting, and by using fire to enhance human subsistence activities. It is commonly believed that Native Americans did not overuse their resources and that aboriginal peoples were, in fact, original conservationists (e.g., Byrne 1968; Nelson 1969a, 1969b, 1970; Nelson et al. 1972; and others). Recently, though, this "ecologically noble savage" view has come under increasing attack (Brightman 1987; Hames 1987, 1991; McCay and Acheson 1987; Diamond 1988, 1992; Flannery 1990, 1994; West and Brechin 1991; Bowden 1992; Butzer 1992; Denevan 1992; Gomez-Pompa and Kaus 1992; Heinen and Low 1992; Simms 1992; Alvard 1993a, 1993b, 1994, 1995; Birkedal 1993; Steadman 1995; and others). It has now been suggested that native peoples limited the distribution and abundance of ungulates throughout the Intermountain West by intense hunting and it has also been demonstrated that aboriginal peoples used fire to purposely modify plant communities (Kay 1994, 1995a; Kay and White 1995). If these views are correct, native peoples may have structured entire ecosystems, including the Canadian Rockies (Flannery 1990, Blackburn and Anderson 1993b, Shippek 1993). It has also been postulated that European-introduced diseases, such as smallpox, to which Native Americans had no immunological resistance, decimated aboriginal populations ca. 1600 A.D., 200 years before the first Europeans entered in the Rockies (Dobyns 1983, Ramenofsky 1987, Campbell 1990).

As the term is used by most biologists, there are two hallmarks of a keystone species. "First, their presence is crucial in maintaining the organization and diversity of their ecological communities. [and] Second, it is implicit that these species are exceptional, relative to the rest of the community, in their importance" (Mills et al. 1993:219). We believe that Native Americans were the ultimate keystone species prior to European presence in the New World. Aboriginal activities promoted biodiversity and created the plant and animal communities found when Europeans arrived (Western and Gichohi 1992, Blackburn and Anderson 1993b, Lewis 1993, Shipek 1993). North America was not a "wilderness" waiting to be discovered (Callicott 1991). Instead, it was home to tens of millions of aboriginal peoples before European-introduced disease decimated their numbers. The modern concept of wilderness as areas without human influence did not apply to the Americas prior to 1492 (Anderson 1991; Callicott 1991; Foster 1992; Blackburn and Anderson 1993a, 1993b; Lewis 1993:395). Any wilderness that existed did so only in the minds of Europeans. As Gomez-Pompa and Kaus (1992) have pointed out, North Americans today view the Amazon as wilderness, but to indigenous people it is home. A home they have modified to suit human needs (Balee 1989). If this view is correct, then the removal of Native Americans from the Canadian Rockies and other areas has completely changed those ecosystems (Western and Gichohi 1992; Blackburn and Anderson 1993a, 1993b; Shipek 1993; Wagner and Kay 1993; Kay 1994, 1995a, in press a, in press b; Budiansky 1995; Wagner et al. 1995).

During the early mountain fur trade era (1800-1840), Europeans rarely used the Bow Valley or the passes to the south because their way was blocked by Peigan (Kidd 1986). Instead, early fur traders were forced north and crossed the Rockies by way of Howse Pass (1807-1811) and, when that route was closed by armed natives, Athabasca Pass (post-1811). Only after the Peigan lost their warriors and power to repeated epidemics did explorers gain access to the Central and Southern Canadian Rockies. As a result, the first Europeans known to have traveled Banff's Bow Valley did so only in 1841, and the area comprising Banff, Kootenay, and Yoho National Parks was not fully explored until Dr. James Hector of the Palliser Expedition arrived in 1858 (Patton in press). By then, the fur trade was effectively over, and the region's mineral-poor rocks failed to attract an onrush of prospectors as occurred further west in British Columbia. So, relatively few people visited the Central Canadian Rockies until the coming of the railroad. Men and supplies for British Columbia's mines arrived primarily from Canada's west coast or south from the States, not across the Canadian Rockies.

With construction of the Canadian Pacific Railway (1883) and establishment of Banff National Park (1885), visitor use increased from fewer than 10,000 in 1900 to over 180,000 by 1930 (White et al. 1994). At present more than 4 million people a year visit the Banff-Bow Valley corridor and up to 250,000 people use the park's backcountry for day hikes or overnight stays (Bernard et al. 1995, Komex International 1995). Human use is now so high in many parts of the Central Canadian Rockies that sensitive species like wolves and grizzly bears (*Ursus arctos*) are being displaced from otherwise prime habitat, even in national parks (Purves et al. 1992, Bernard et al. 1995, Komex International 1995).

Fire

It has been estimated that eight million bolts of lightning strike our planet each and every day, making fire a basic element of the physical environment just about everywhere on Earth (Leighton 1987). Fire has been described as the concomitant factor in the history and biology of plant communities around the world. "Fire has been part of forest, brush and grassland ecosystems as long as such flammable vegetation has existed" (Kilgore 1984). Fire is one of the forces that has influenced plants over evolutionary time.

Individual species evolved a variety of mechanisms that allow them to survive and even prosper in the face of repeated fires (Wright and Bailey 1982). Some trees, like Douglas-fir (*Pseudotsuga menziesii*), developed thick, corky bark which protects against fire — the non-flammable bark insulates the tree's living

tissues from the flame's killing heat better than an equal thickness of asbestos (Agee 1994:5). Since bark thickness increases with age, fire can kill young trees but older trees most often survive. Other trees, such as lodgepole pine (*Pinus contorta*), evolved cones that open and shed their seeds only after being heated by fire, a process called serotiny, though not all lodgepole are serotinous.

The above-ground parts of many woody plants, such as aspen, willows (*Salix* spp.), and some shrubs, are destroyed by fire, but new shoots emerge from their roots, termed root suckering or sprouting. Grasses evolved to withstand frequent fires by locating their meristematic tissue, the part of the plant that initiates new growth, below the soil surface where it is insulated from fire. On the other hand, some species are readily killed by fire, but neighboring unburned plants shower the area with seeds, quickly recolonizing the burn. A few species even evolved seeds that remain dormant in the soil for up to 100 years or more until heated by passing flames (Wright and Bailey 1982).

From an ecological perspective, fire is neither good nor bad, but the presence or absence of fire favours certain plants or plant communities over others. Fire frequency and intensity largely determine what vegetation will actually grow on a given site. High fire frequencies favour grasslands and prevent the encroachment of fire-sensitive shrubs and conifers. By killing younger trees, frequent fires produce open park-like forests with herbaceous understories (Covington and Moore 1994).

In the absence of fire, fuels accumulate in Rocky Mountain forests because the cold climate and acidic conifer needle-fall prevent rapid decomposition of litter or dead trees (Agee 1989, 1993, 1994). Standing live fuels also increase with time. After a fire, grasses, forbs, and shrubs predominate until overgrown by reestablished trees. Certain conifers, like lodgepole pine, are first to recolonize a burn only to be replaced by more shade tolerant species as the years pass. This replacement of one species by another is termed post-fire plant succession. The earlier plants are called seral plant species or seral plant communities, while the site's potential vegetation is termed climax or climatic climax, the vegetation that would develop on a site in the absence of disturbance.

As forests grow and age, they become more susceptible to attack by diseases and insects, including spruce budworms (*Choristoneura occidentalis*) and mountain pine beetles (*Dendroctonus ponderosae*) (McCune 1983, Holland 1986, Anderson et al. 1987, Arno and Brown 1991). There is also a corresponding shift in animal communities. Species such as deer, elk, and other ungulates, which favor seral vegetation decrease over time while animals requiring old growth forests increase. In general, however, wildlife habitat tends to decline as forests age (Gruell 1984).

Prior to European influence, fire cycles on the eastslopes of the Canadian Rockies likely ranged from less than 40 years on warm dry montane sites to greater than 100 years in subalpine forests at higher elevations (Tande 1979, White 1985a, Masters 1990, Johnson and Larson 1991, Tymstra 1991). With the establishment of Banff National Park, however, fire suppression was implemented following national and provincial policy for all lands in Canada (Pyne 1982, Wright and Bailey 1982, Murphy 1985a). This permitted forest succession to progress and allowed fuels to accumulate setting the stage for high-intensity fires (Pyne 1982, 1991; Murphy 1985b; White 1985a, 1989, 1990; White and Pengelly 1992; Agee 1993, 1994; Swetnam 1993; Covington and Moore 1994). It also allowed fire-sensitive conifers to invade grasslands and to replace aspen communities, decreasing wildlife habitat, especially for wintering ungulates like elk.

In 1984, though, Banff National Park approved a new fire management program that recognized fire's role in the ecosystem (Canadian Parks Service 1984; Lopoukhine 1985, 1993; Day et al. 1990; Hawkes 1990; Wierzchowski 1995; Wierzchowski et al. 1995; Woodley 1995). The plan partitioned Banff's Bow Valley into 67 prescribed fire units, and between 1983 and 1993, the park purposely burned 9 units totalling about 2,000 ha (White and Pengelly 1992). In addition, six units totalling approximately 4,400 ha were burned in other parts of the park (White and Pengelly 1992). Fire intensities ranged from light understory fires to intense crown fires, although in some units substantial areas did not burn (White and Pengelly 1992, White et al. 1994). The ecological objectives of Banff's burning program are to evaluate the use of planned ignitions in

the maintenance of natural vegetation and wildlife habitat conditions, and to reduce fuels so that high intensity firestorms do not sweep through the ecosystem (Lopoukhine 1985; White 1989, 1990; White and Pengelly 1992; White et al. 1994), like they did in Yellowstone during the summer of 1988 (Romme and Despain 1989a, 1989b; Schullery 1989a, 1989b).

THE PROBLEM

Records indicate that the area occupied by aspen has declined since Banff National Park was established. Similar situations exist in the Yellowstone Ecosystem and in Colorado's Rocky Mountain National Park, but there the decline of aspen has been attributed to repeated browsing by unnaturally high elk populations, not normal plant succession, climatic change, or fire suppression (Olmstead 1977, 1979; Kay 1990; Hess 1993). Why is aspen declining in Banff, and what was that species' abundance in prehistoric times? Are the park's aspen disappearing because fires have been suppressed for the last 100 or so years, or is it due primarily to ungulate browsing? If burned, will Banff's aspen stands be able to successfully regenerate, despite elk browsing, as has been postulated by the U.S. National Park Service (Houston 1973, 1982; Despain et al. 1986; Kay 1985, 1990)?

Elk are now the most abundant ungulate in Banff National Park and other parts of the Canadian Rockies, but are these populations reflective of past conditions or have they changed due to European influences? What was the historical and pre-Columbian distribution and abundance of elk and other ungulates in the Central Canadian Rockies? Were elk as abundant in the past as they are today? Again a comparable situation exists in the Yellowstone Ecosystem, but there historical and archaeological evidence indicate that elk were not abundant prior to park establishment (Kay 1987, 1990, 1992, 1994, 1995b; Chadde and Kay 1988, 1991; Kay and Chadde 1992; Kay and Wagner 1994; Budiansky 1995; Wagner et al. 1995; Kay and Platts in press).

According to some researchers, fires set by Native Americans are thought to have been unimportant and not to have substantially increased the area burned in prehistoric times (Byrne 1968, Nelson 1970, Christensen et al. 1989:679-680, Romme and Despain 1989c, Johnson et al. 1990, Johnson and Larsen 1991). Others, though, have presented evidence that aboriginal burning was widespread and important throughout western North America (White 1975; Arno 1976, 1980, 1985; Barrett 1980a, 1980b, 1981; Lewis 1973, 1980b, 1982a, 1985, 1990a, 1990b, 1992; Barrett and Arno 1982; Gruell 1984, 1985; White 1985a; Boyd 1986; Reid 1987; Turner 1991; Pyne 1993, 1994, 1995a, 1995b; Gottesfeld 1994). In northern Alberta, anthropologists reported that native peoples set fires for at least 17 different reasons (Lewis 1977, 1980a, 1982b; Ferguson 1979; Lewis and Ferguson 1988). Native Americans commonly used fire (1) to modify plant communities so as to increase the production of favored vegetal foods, like berries, seeds, and roots; (2) to clear brush and trees making travel easier; (3) to facilitate hunting by producing plants favored by game animals; or (4) to chase prey to waiting hunters, called fire drives. Even in British Columbia with its wetter climate, aboriginal burning was once widespread (Gottesfeld 1994), but now the "Abundance and productivity of some traditional foods [such as berries and various root crops] is said by aboriginal leaders to have decreased in recent decades due to active fire suppression practices of the British Columbia government" (Turner 1991).

What is and was the role of fire in the Banff Ecosystem, and did native peoples once structure the park's plant communities by accidentally or intentionally setting fires? Were fires started primarily by lightning, often called "natural fires," or were Native Americans the main source of ignitions? Determining how the fires started is critical because, "Fires set by hunter-gatherers differ from [lightning] fires in terms of seasonality, frequency, intensity, and ignition patterns" (Lewis 1985:75). Most aboriginal fires were set in the spring, between snowmelt and vegetation greenup, or late in the fall when burning conditions were

not severe (Lewis 1982b, Turner 1991, Gottesfeld 1994). Unlike lightning fires, which tend to be infrequent high-intensity blazes, native burning produced a higher frequency of lower-intensity fires. So, aboriginal burning and lightning fires create different vegetation mosaics, and in many instances, entirely different plant communities (White 1975, Blackburn and Anderson 1993a, Swetnam 1993). Moreover, aboriginal burning reduces or eliminates the number of high intensity lightning-generated blazes (Pyne 1982, 1984, 1989, 1991, 1993, 1994, 1995a, 1995b; Reid 1987:34).

Besides burning, what impact did Native Americans have on the Central Canadian Rockies Ecosystem prior to European arrival? Did Native Americans have minimal environmental impacts, or were they keystone predators that structured the entire ecosystem? Did hunting by Native Americans determine the distribution and abundance of ungulates, and especially elk, in prehistoric times?

METHODS

To address these questions, we gathered data from a number of disciplines and employed methods commonly used in those fields. If these varied types of evidence support a single conclusion or a single set of conclusions, then those findings will be very robust because the individual data sets are independent, termed *consilience* (Gould 1989:282-284). Dr. Charles Kay synthesized existing archaeological data and wrote the aspen ecology chapter, while Brian Patton conducted the analysis of first-person historical accounts written by people who explored the Canadian Rockies during the early 1800s. Cliff White and Ian Pengelly were responsible for the fire-ecology material, while White and Kay analyzed the repeat photographs. Dr. Kay edited the entire report and wrote the introduction and summary sections. Dr. Kay also edited and revised the original report (Kay et al. 1994) to produce this Occasional Paper. The original report (Kay et al. 1994) contains more data and photographs than can be reproduced here, so that document should be consulted if more detail is needed. The original report, for instance, includes site-specific archaeological data that is only summarized here.

Historical Observations

Many people have used selected quotes from historical journals as evidence that certain species of ungulates were abundant during the late 1700s and early 1800s (e.g., Byrne 1968; Nelson 1969a, 1969b, 1970; Nelson et al. 1972; Morgantini 1995). With selective quotations, however, there is always a question of whether or not the author included only those passages that supported his or her preconceived hypothesis. To overcome any problems of bias, we systematically recorded all observations of ungulates and other large mammals found in first-person historical accounts of exploration in the Central Canadian Rockies from 1800 to 1873. We then tabulated those data in three ways (Kay 1990, in press a; Kay and White 1995).

First, game seen. We listed the observer, the date of his trip, the length of his trip within the Central Canadian Rockies Ecosystem, the size of the party, and the number of occasions on which the explorers actually saw large game animals. If they reported seeing one animal, that was recorded as a single observation, and if they reported seeing more than one animal together at one time, that was also recorded as a single observation. If an explorer reported killing one or more animals of a particular species at one time, that was recorded as one sighting of that animal.

Second, game sign encountered or referenced. We listed the number of occasions on which specific animal sign, usually tracks, was seen or referenced. For instance, if explorers said they were going deer hunting, that was recorded as a single reference to deer. If they said they were going deer and elk hunting, that was recorded as a single reference to each of those species. Included in these counts are any references to hearing specific animals, such as wolves howling or mountain lions screaming, as well as references to Native American artifacts. If explorers, upon meeting Native Americans, noted that those people had specific animal skins, each of those observations was recorded as a single reference to that species. We also listed the number of occasions on which Native Americans were seen or their sign, footprints, trails, and such were referenced. In addition, we included the number of references made by each party to a lack of food or lack of game. Acts such as shooting a horse for food were each considered a single reference to a food shortage.

Third, game shot. We listed the number of ungulates each explorer reported as having killed within the Central Canadian Rockies Ecosystem. In nearly every instance, early travelers recorded the exact number of animals that they had killed.

We used only first-person journals penned at the time of the event or edited versions written soon afterwards because latter narrative accounts are less accurate (White 1991:613-632). Even "the humblest narrative is always more than a chronological series of events" (McCullagh 1987:30). The ideological implications of most narrative historical accounts are "no different from those of the narrative form in fiction" (Galloway 1991:454), because narratives are always influenced by prevailing cultural myths, such as the idea that the West was a Garden of Eden teeming with wildlife but filled with hostile savages (White 1991:618). In addition, we used standard techniques developed by historians to gauge the accuracy of all historical journals analyzed for this study (Forman and Russell 1983).

Finally, if smallpox or other European diseases decimated native populations ca. 1600 A.D. as postulated by Dobyns (1983), Ramenofsky (1987), and Campbell (1990), which we believe happened, then even the first European descriptions of the Canadian Rockies do not adequately convey the effect that much larger pre-Columbian aboriginal populations had on their environment. That is to say, if Native Americans limited ungulate populations as has been proposed (Kay 1994, 1995a), and if smallpox decimated aboriginal populations 500 years ago, then wildlife numbers would have increased before the first European explorers arrived. Thus, journal accounts may suggest higher ungulate populations than what existed in pre-Columbian times. This pattern, in fact, is reflected in the archaeological record. Easily overexploited ungulates such as elk and moose first appear in archaeological sites in any numbers only 500 years ago (Frison 1978, 1991; Yesner 1989; Kay 1994). Before then, native hunting was so intense and ungulate populations so low, that few animals were actually killed (see Chapter 3 – optimal-foraging theory).

Archaeological Evidence

To determine the relative abundance of ungulate species in pre-Columbian times, we reviewed archaeological reports for sites in Banff National Park and the Canadian Rockies. In all, we consulted more than 200 studies. We also conducted an extensive review of the archaeological literature on site formation processes so that we could make informed interpretations from the available archaeological record. Taphonomic and transportation questions were given major consideration. Moreover, we reviewed ethnographic material for tribes that inhabited the Canadian Rockies and the intermountain western United States at historical contact.

Many recent archaeological excavations have been salvage projects mandated under federal and provincial antiquities laws (Ronaghan 1986). Unfortunately, most of those studies have only appeared in the

"grey literature," if at all (Reeves 1986). To ensure that our evaluation of the archaeological record was as complete as possible, we searched files of Parks Canada's Western Region Archaeological Research Services Unit located in Calgary, Alberta's Archaeological Survey housed in the Provincial Museum at Edmonton, and British Columbia's Archaeology Branch in Victoria. We also interviewed the following Canadian archaeologists -- anthropologists: (1) Dr. Brian Reeves, University of Calgary; (2) Mrs. Gwyn Langemann, Parks Canada Western Region Office; (3) Dr. Gerald Oetelaar, University of Calgary; (4) Dr. Brian Ronaghan, Alberta Provincial Museum; (5) Dr. Jack Brink, Alberta Provincial Museum; (6) Dr. Patricia McCormack, Alberta Provincial Museum; (7) Dr. Jack Ives, Alberta Provincial Museum; (8) Mr. James Pike, British Columbia Archaeology Branch; (9) Mr. John McMurco, British Columbia Archaeology Branch; and (10) Mr. Ian Whitbread, British Columbia Archaeology Branch. In addition, we interviewed University of Calgary paleontologist Dr. Len Hills because of his interest in the prehistoric distribution of elk and other ungulates.

Repeat Photographs

To compile repeat photosets, one must first search archives for pictures taken at some point in the past, preferably those taken in the late 1800s or early 1900s. The photographs are then taken into the field to find the approximate locations from which the pictures were made. Finally, the scenes are rephotographed as they appear today, forming sets of images taken, or repeated, from the same points. The comparative photographs are then analyzed to determine if the abundance or distribution of plant communities has changed over time.

This technique works best for species that are clearly identifiable by photographic analysis, such as aspen, willows, and conifers. It can also be used to document if grasslands have expanded or contracted over the years. Repeat photographic studies of vegetative change are common in the western United States (Progulske 1974; Wyoming State Historical Society 1976; Heady and Zinke 1978; Vankat and Major 1978; Bureau of Land Management 1979a, 1979b, 1984; Gruell 1980a, 1980b, 1983; Hastings and Turner 1980; Houston 1982; Rogers 1982; Baker 1987; Johnson 1987; Vale 1987; Kay 1990; Veblen and Lorenz 1991; Skovlin and Thomas 1995; Hart and Laycock 1996), but are rare in Canada (Rogers et al. 1984). To the best of our knowledge, this is the first study to extensively use repeat photographs for monitoring vegetative change in the Canadian Rockies, though earlier, Nelson (1970) did publish a small selection of repeat photographs made in Banff National Park.

Historical photographs can also be used to judge the number of ungulates that occupied the range in the past. If elk were as abundant in the 1800s as they are now, then favored forage species, like aspen, should show the effects of elk browsing similar to plants today (Kay 1990). In other words, historical photographs of aspen communities should show that aspen was as heavily browsed in the 1800s as it is at present. If aspen depicted in historical images do not show evidence of browsing or bark damage, that would indicate few elk used the park in the past. In the Yellowstone Ecosystem where this has been done, the earliest historical photographs of aspen and other woody species show no evidence of ungulate browsing (Kay 1990, 1995b, in press a; Chadde and Kay 1991; Kay and Wagner 1994).

We reviewed over 500 historical photographs of the Central Canadian Rockies obtained by Cliff White from Banff's Whyte Museum of the Canadian Rockies, Calgary's Glenbow Museum, the Geologic Survey of Canada Photograph Archives in Ottawa, and the National Air Photograph Library also in Ottawa. Although these photographs were primarily collected to provide an overview of historical conditions in the Canadian Rockies including landuse, forest fires, and glacial recession, many can also be used to evaluate our ecosystem model (see Figure 1.2).

To obtain a regional perspective, we selected several historical photographs for paired comparison with current retakes of montane ecoregions along the North Saskatchewan, Red Deer, Bow, and Columbia Rivers. We chose photographs that illustrate both the general level of vegetation cover, and also specific

forest conditions. Current retakes of the historical photographs were made by Cliff White and others between 1980 and 1991, and as part of this study by Dr. Charles Kay in 1993. Wherever possible, repeat photographs were taken from the same exact location, and at a similar time of day and period of the year as the original pictures. The repeat photosets were then analyzed using methods developed by previous researchers (Rogers et al. 1984).

Fire History

To evaluate the fire history component of our ecosystem model (see Figure 1.2), we first developed a submodel of fire activity in the Rocky Mountains that links ignition source, location, and timing to smoldering combustion and more active phases of fire behavior. As active fires grow in size, our submodel proposes that major terrain features such as valley orientation and gradient winds determine burning patterns. Repeated fires over space and time create fire regimes that are characterized by fire frequency, intensity, and severity.

We then used this submodel as a framework for a detailed review of fire history research conducted in the southern Canadian and northern U.S. Rocky Mountains — Wyoming, Montana, Idaho, Alberta, and British Columbia. We reviewed studies on dendrochronology, written records (explorer diaries and fire reports), historical photographs, stand-age analysis, fire frequency, ignition sources, burn patterns, and anthropology. All elevation zones and ecotypes were included to evaluate regional trends. In short, we attempted to synthesize existing information into one coherent presentation of fire in the Central Canadian Rockies. We did not, however, undertake any additional field studies.

Aspen Ecology

Due to contractual restraints, we were not able to conduct detailed measurements of aspen communities in Banff National Park as we would have liked (Kay 1990, 1996; and see Chapter 8). Nevertheless, we were able to compile the following information on aspen ecology in the Central Canadian Rockies Ecosystem. First, we surveyed and photographed aspen stands throughout Banff National Park, including those along the North Saskatchewan River. We also surveyed aspen at three locations adjacent to the park, Kootenay Plains, the Ya Ha Tinda (Morgantini 1995), and the area from Eastgate to Canmore, Alberta. This permitted us to compare aspen stand dynamics and community development inside the park, where aspen have been subject to high elk populations, with areas outside the park where elk numbers have been controlled by hunting — similar to Kay's (1990) work in the Yellowstone Ecosystem.

Second, we surveyed Banff National Park's aspen exclosures. The park's only permanent aspen exclosure was constructed in 1944 on an alluvial fan 17.7 km west of Banff townsite near Highway 1A (Trottier 1976). The 18x30 m fenced plot was last measured in 1981 (Trottier and Fehr 1982). We reviewed all previous reports on this exclosure, plus we located 1944 photos of inside and outside plots which we rephotographed in 1993. In addition, we studied the park's two de facto aspen exclosures.

As previously noted, when the Trans-Canada Highway was twinned through Banff's lower Bow Valley in the early 1980s, the roadway was fenced to exclude ungulates (Woods 1988), which in essence created an exclosure. Aspen within the fenced right-of-way have now been protected from elk for a number of years. As part of our research, we surveyed and photographed those communities, though, we were not able to measure any stands.

Banff's Bison Paddock is another de facto aspen enclosure (Cowan 1947a:225). Bison have been on public display north of Banff townsite since 1897 (Kopjar 1987). The present 40 ha paddock was established in the early 1900s and a 2.4 m high woven wire fence has, for the most part, kept bison in and elk out, although a few elk have gained access to the paddock in recent years. The fenced area is a mixture of aspen and grassland communities (Kopjar 1987). The paddock is divided into summer and winter pastures. The summer pasture was originally 32 ha, of which 75% is aspen, and the winter pasture is 8 ha, with 70% aspen (Kopjar 1987:18). Bison are fed hay in winter but free-range during summer. A one-way paved road allows park visitors to view bison from the safety of their vehicles, and more than 120,000 people visited the paddock in 1986 (Kopjar 1987).

Bison are primarily grazers and do not normally browse aspen, but they do horn and rub trees. So, aspen stands inside the paddock have not been subjected to the level of browsing seen in other parts of Banff's Bow Valley. That changed though in 1985 when Parks Canada removed the southern portion of the summer pasture from the paddock. This was done to facilitate wildlife movements around Banff townsite, after earlier studies found that the paddock blocked travel corridors (Kopjar 1987). This exposed the previously "protected" aspen to large numbers of elk. We surveyed and photographed aspen in the remaining paddock, as well as those now exposed to elk; but, again, we were not able to measure any stands.

Third, as discussed above, since 1983 Parks Canada has set prescribed fires in several areas of Banff National Park. The majority of those burns have been in lower-elevation montane forests where most of the park's elk and other ungulates winter. Several of those fires burned aspen communities, including Two Jack, Sawback, Palliser, Mount Norquay, upper Minnewanka, and lower Minnewanka. We surveyed aspen burned in those areas, and we measured representative stands. At Two Jack, Palliser, and upper and lower Minnewanka we counted the number of regenerated aspen stems on five, randomly-placed, 2x30 m belt transects, following the work of Kay (1990). We also recorded the height of each aspen sucker and counted the number of conifer seedlings by species. We noted if the aspen stems had been browsed by ungulates or effected by shepherds crook (*Pollaccia radiosa*), a fungus that attacks and kills the terminal growth on aspen, especially regenerating suckers (Hinds 1985:88).

In the fall of 1992, a 20x20 m ungulate-proof enclosure was constructed by Parks Canada in an aspen stand burned that spring by the Mount Norquay fire northwest of Banff townsite. When the Escargot enclosure was constructed, permanent sample plots were not established nor were any measurements taken. During August 1993, however, we established five permanent 2x20 m belt transects inside the enclosure, and four 2x20 m and one 2x30 m permanent belt transects outside the enclosure. On each plot, we counted all the suckers, recorded each sucker's height, and noted if they had been browsed or injured by shepherds crook.

During May 1993, aspen in the Muleshoe area north of Highway 1A west of Banff townsite were killed by the 1200 ha Sawback II and III prescribed burns. In August, we established eight 2x15 m permanent belt transects in one of those aspen stands. Again, on each plot we counted all the suckers, recorded each sucker's height, and noted if they had been browsed or attacked by shepherds crook. Later that summer, Parks Canada constructed a 20x20 m ungulate-proof enclosure around four of the belt transects we had previously established. That is to say, four of the Sawback aspen burn transects are now protected from ungulates while four are subject to browsing. The enclosures at Mount Norquay and Sawback are the first permanent grazing enclosures built in Banff's Bow Valley in nearly 40 years. Both the Mount Norquay and Muleshoe aspen burn enclosures were remeasured by Parks Canada in 1994.

In 1994 and 1995, Kay (1996) conducted a detailed study on the condition and trend of aspen communities in Kootenay and Yoho National Parks. In all, 269 aspen stands were measured at various locations inside and outside the two parks. No aspen has recently burned in Kootenay or Yoho, but stands outside both parks have been logged, which should have stimulated aspen sucker regeneration (Crouch

1983, 1986; Shepperd 1993; Shepperd and Smith 1993). Unfortunately, there are no aspen exclosures in either Kootenay or Yoho (Kay 1996).

At each aspen community that was measured in Yoho and Kootenay, 2x30 m belt transects were used to record the number of aspen stems and conifers by size classes. Within each stand the following information was also recorded: (1) the age of various sized aspen stems, (2) understory species composition, (3) percent conifer canopy-cover, (4) percent of aspen suckers that were browsed, and (5) an estimate of the mean percent of each aspen stem that had been damaged by ungulate bark stripping. The last two measurements were then combined to produce an ungulate use index (0 to 200) for each stand which was then correlated with aspen sapling regeneration. Banff, Kootenay, and Yoho all have similar ungulate-fire-aspen histories (Kay and White 1995, Kay 1996).

CHAPTER 2

HISTORICAL OBSERVATIONS

INTRODUCTION

This chapter provides insight into the relative abundance of wildlife in the Central Canadian Rockies prior to European settlement by systematically examining first-person historical accounts left by early fur traders, explorers, and travelers. All known journals between the years 1792 and 1873 that might bear on this question are included in the synopses and summary tables which follow. It must be understood, though, that some journals utilized in this study were recopied or rewritten from original field notes, and in several cases obviously edited. As this occurred soon after the trips were made utilizing the original accounts, and since these edited journals were judged to be true to the originals and no inconsistencies with other observations utilized in this report were noted, we chose to include this material. The combined routes of all early explorers are displayed in Figure 2.1.

A number of journals kept by travelers on the Athabasca Trail (Athabasca Valley and Pass) after 1828, though, were not used. The decision to eliminate these documents stemmed from the fact that few wildlife observations and virtually no kills were made by people utilizing this route after 1825. By this time, the Athabasca Trail was well established as the primary trans-mountain trade route and hunters no longer accompanied parties to provide food. Instead, fur trade brigades crossed the range as quickly as possible between provision stations at Jasper House in the Athabasca Valley and Boat Encampment on the Columbia River. In addition, ungulates such as bison and moose that were observed and hunted by David Thompson on his first crossing of the route in 1811, appear to have declined at a relatively early date, probably due to harvesting by hunters employed at Jasper House and natives drawn to the valley's two trading posts.

Three early journals kept by residents or visitors at Jasper House and the Athabasca Valley were included in the synopses, but not the summary tables (Michel Klyne 1828-1831, Paul Kane 1847, R.M. Rylatt 1872-1873). Since these accounts were written by static observers, they differ in nature from those made by mobile parties. They were included in our synopses, however, because they contained observations germane to this study. Similarly, the journals kept by David Thompson (1800-1812) at Kootenay House on Windermere Lake in the Columbia Valley were included in our synopses but not in our summary tables.

In order to draw comparisons between different environments within the Central Canadian Rockies, our study focused upon three distinct but contiguous geographic regions – the Alberta Foothills, the main Rocky Mountains, and British Columbia's Columbia Valley or Rocky Mountain Trench. While these divisions are primarily physiographic, each is also strongly identified with different biogeoclimatic zones or ecoregions.

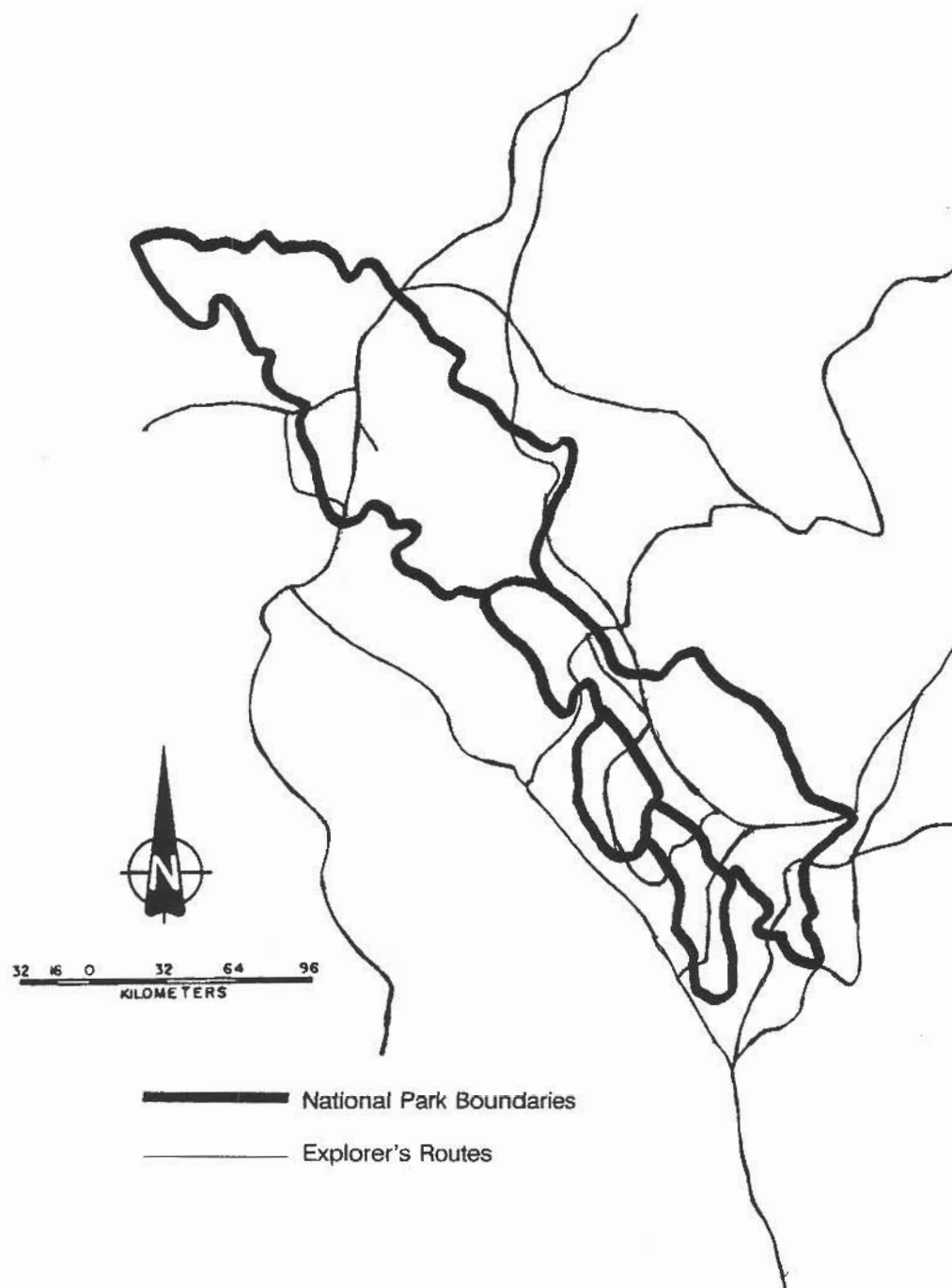


Figure 2.1. The combined routes of early explorers in the Canadian Rockies. Some routes were used by more than one expedition – see text.

RESULTS AND DISCUSSION

FOOTHILLS

The Foothills area as defined in this section extends from the Athabasca River on the north to the Oldman River on the south, and is bounded on the west by the Front Ranges of the Rocky Mountains. The prairies are the eastern boundary in the south, while to the north there is a less defined border where the Foothills merge into the more even terrain of the boreal forest.

Early fur traders, explorers, and travelers generally traversed the Alberta Foothills by canoe in the north, utilizing the Athabasca or North Saskatchewan Rivers. While to the south, travel was primarily by horseback, and thus was less restricted. In the Foothills, the Athabasca and North Saskatchewan Rivers flow through lower boreal-cordilleran and upper boreal-cordilleran ecoregions. To the south, however, explorers also traveled through montane and aspen parkland zones.

For the purposes of this section, Athabasca River travelers were considered to have crossed the eastern boundary of the Foothills at the mouth of McLeod River. On the North Saskatchewan River, the boundary was in the vicinity of the old fur trade encampment at Boggy Hole, near present-day Lodgepole, Alberta. While south of the North Saskatchewan, the eastern boundary followed roughly the north-south course of Highway 22.

The synopses which follow are the most detailed known accounts for the Foothills between 1792 and 1863. Many of the journals for this region included in the summary tables are not discussed in the synopses because few wildlife observations or kills were made and there were no references to a lack of game. This can be attributed to the fact that most travelers were passing through quickly via canoe, primarily on the Athabasca River, and little time was spent hunting.

Journal Synopses in Chronological Order

Peter Fidler, 1792-1793

The earliest known journal for the Central Canadian Rockies Ecosystem is that of Hudson's Bay Company surveyor Peter Fidler (MacGregor 1966). Fidler (1990) wintered with Piegan natives in the Foothills near present-day Longview, Alberta, during the winter of 1792-93. For most of that period, he resided in large native encampments on or near the Highwood River where he witnessed the use of pounds to kill over 300 bison. Since these camps were located on the edge of the prairie, it is impossible to calculate the number of Foothills bison killed as opposed to those driven in from the plains.

The only journey through the Foothills completed by Fidler was made from December 30 to January 2 -- a brief round-trip to the Oldman River to trade horses with a group of Kootenay natives. The only animal observed on that trip was seen in the early morning of December 31st when, nearing the Oldman Valley and traveling under a full moon, the party encountered a bison bull which they killed.

Over the remainder of the winter, Fidler (1991:58) mentioned Piegan going out to hunt elk, noting the preference of that species' hides for "Jackets, stockings, shoes, &c. which is more durable & neater than the Buffalo leather." In January, while still camped in the vicinity of the Highwood River, Fidler (1991:59) noted that the Piegan make several hunting trips "towards the Mountain" because the buffalo were "plentiful there." A number of bison were killed on those trips and, on one occasion, "some red deer [elk]" (p. 61). When Fidler (1991:63) made his own trip on horseback into the Foothills, he saw a number of bison "upon one of these high hills," but made no mention of elk or other wildlife.

David Thompson 1800-1812

During a dozen years of mountain exploration, David Thompson (1800-1812) made an equal number of trips through the Foothills region. Eleven of those journeys are documented in his largely unpublished journals (Belyea 1994). While traveling up the Red Deer River to near the base of the Front Ranges in October 1800, he wrote, "Buffalo, Red Deer [elk], Moose & small Deer are also Plenty and Grisdled Bears but too many" (Dempsey 1965:4). Despite this reference to abundant game, only one ungulate was actually reported during the party's four days in the Foothills, a bison shot by Thompson. On a subsequent trip to the Bow River later that autumn, the only animals reported in the Foothills were bighorn sheep, and they were at the very front of the mountains near present day Exshaw, Alberta.

Going to and from the mountains between 1807 and 1810, Thompson traversed the Foothills region on the North Saskatchewan River west of Rocky Mountain House seven times. Bison were observed on 17 occasions and 21 animals were killed, elk were observed 13 times with 15 killed, and there were five deer observations with three kills.

Thompson's most extended journey through the Foothills took place during the last two months of 1810 when he and a party of twenty-four traveled north from Rocky Mountain House to the Athabasca Valley. Over a period of 62 days, which included more than three weeks encamped near Brule Lake at the foot of the mountains in the Athabasca Valley, total animals killed included 18 bison, three elk, two moose, and one deer. The forested country between the North Saskatchewan and Athabasca Rivers did not appear to have been particularly bountiful, however, as the party's hunters frequently returned empty-handed and Thompson made three separate references to lack of game.

George Simpson, 1824-1825

George Simpson (Merk 1931:29) ascended the Athabasca River in early October 1824 and, after passing through the Foothills, wrote that, "The Country seems rich in large and small Animals as we saw numerous tracks Daily...." Returning eastward down the same section of the Athabasca the following spring, he (p. 148) noted, "Saw about 50 Moose & Red Deer [elk], but time was too valuable to amuse ourselves in hunting. I however shot one of the former of which we only took the Tongue & Nose." Simpson is the only early traveler who reported abundant game in this northern Foothill region. As his observations for the Foothills in both 1824 and 1825 are not presented in the form of a daily journal but are instead only summarized, their accuracy is open to question (see below).

James Hector, 1858

Although his references to animals during his mountain explorations were reasonably frequent, Dr. James Hector of the Palliser Expedition made few notes on animals observed or killed during his six

traverses of the Foothills in 1858 and 1859, however, there also were no entries concerning a lack of game (Spry 1968). Two entries referring to an abundance of white-tailed deer in the Foothills near the Bow River were made in December of 1858. On December 11th he wrote, "The Virginian [white-tailed] deer is very abundant in this district, and we are continually starting them.... there is one killed nearly every day by some of us" (Spry 1968:356). Again, on December 13 Hector wrote, "...we started band after band of deer, just as if we were passing through a deer park. This is the only time that I have ever seen game in such plenty in the country, excepting of course buffalo herds" (Spry 1968:357).

James Carnegie, 1859

James Carnegie, Earl of Southesk, passed through the Foothills twice during his hunting expedition to the Rocky Mountains in 1859 (Southesk 1969). He followed up the McLeod River on his approach to the mountains and, like David Thompson fifty years earlier, found game to be scarce in the northern Foothills forest. His party managed to kill only one moose, but saw the tracks of one additional moose. "Old camps and other traces of the Assiniboines were numerous,—which quite accounted for the scarcity of game in the district" (Southesk 1969:187). Carnegie left the Rocky Mountains via the Bow River in October 1859 and observed "that 'bounding deer' (*Le Chevreuil*) were plentiful in the neighbouring woods" (Southesk 1969:255), a report which coincides with that made by James Hector in the same area ten months earlier. His party killed seventeen deer, white-tailed and mule, over the course of five days.

ROCKY MOUNTAINS

The Rocky Mountains region as defined here includes the Front Ranges, Main Ranges, and Western Ranges of the mountain belt that form the Canadian Cordillera. It is bounded on the east by the Foothills and on the west by the Rocky Mountain Trench. For the purposes of this section, the southern boundary of this region on the east side of the continental divide is the Oldman River, while on the west side it is Canal Flats. The northern boundary east of the continental divide is the Athabasca and Miette Valleys, while west of the divide it is the Fraser River.

The majority of early travel and exploration in the Rocky Mountains took place within subalpine and montane ecoregions. West of the divide, interior cedar-hemlock and sub-boreal spruce zones were also traversed in the northern half of the region. Alpine terrain was crossed, briefly, by only three explorers — Palliser in 1858, Southesk in 1859, and Moberly in 1872.

Journal Synopses in Chronological Order

Peter Fidler, 1792-1793

Fidler (1990) was the first European known to have entered the Canadian Rockies. On New Year's Eve, 1792, he rode into the Front Ranges and spent a day camped with Piegan and Kootenay. While the natives traded horses, Fidler climbed a nearby mountain to an elevation of nearly 2400 m (also see page 4-32). "On the top of the Mountain I found a deal of [bighorn] sheep Dung but saw none of these Animals, altho' they are very plentiful all thro the Mountain, & never leave it to visit the Plains more than a mile or 2 from the Mountain" (Fidler 1991:47).

David Thompson, 1807-1810

David Thompson (1800-1812) made six trips through the Howse Valley section of present day Banff National Park on his way to and from trading posts in the Columbia and Kootenay Valleys. In June 1807, he ascended the North Saskatchewan and camped near the confluence of the Howse and the North Saskatchewan Rivers for two weeks prior to crossing Howse Pass and descending the Blaeberry River to the Columbia Valley. While camped at Saskatchewan Crossing, Thompson (June 8, 1807) and his men hunted every day but, as he recorded in his journal, "the Country seems nearly destitute of Animals." On another hunt he "saw no Animals of any Kind - but Beavers [*Castor canadensis*] are about here from the cuttings of Willows &c - Saw the Tracks of a fine Moose @ two Deer" (June 9, 1807). Later he (June 12, 1807) commented that "there are a few Moose in the woods but the trees are too close set for me to find them." The only large mammals killed near the Howse River encampment were two black bear (*Ursus americanus*) and one elk. The party had to rely on meat, primarily bison, sent up by hunters on the Kootenay Plains approximately 30 km down-valley.

Thompson's subsequent trips over the pass were usually rapid, and he seldom lingered in Howse Valley or at the forks of the Saskatchewan for more than a couple of days. One of the reasons he moved through the area so quickly appears to have been a general lack of game, since hunting was usually unproductive between Kootenay Plains and the Columbia Valley.

In June 1808 while passing down Howse River on his way east from the Columbia, Thompson (June 21, 1808) "saw no Animals tho' I went ahead for that purpose - the Men saw 4 Bears @ 1 Red Deer [elk] @ where we are camped the Buffalo have lately been." They were living off a horse that Thompson had shot on the Blaeberry River and that meat was going bad. Upon reaching Kootenay Plains, they finally killed some bighorn sheep.

Ascending the North Saskatchewan and Howse Rivers in late October 1808, Thompson's Saulteaux hunter killed two mountain goats and, a short while later, a male bison. Thompson (Oct. 26, 1808) remarked that "we took the... Meat as we have very little Hopes of getting any more." The next day "4 Buffalo came close to us but got off." Then the Saulteaux killed two female bison near "Kootenae Pound," approximately 7 km east of the summit of Howse Pass (see Alexander Henry below). Beyond Kootenae Pound "a Herd of Cows [bison]" stayed ahead of the party and were, apparently, "herded" over Howse Pass and down the Blaeberry into British Columbia.

In late May and early June of 1809, Thompson made an eastward passage on the Howse Pass trail and reported no wildlife until near Kootenay Plains where he got "1 Buck Red Deer [elk] @ some Cow Meat [bison]" from an Iroquois hunter (June 13, 1809). While at Kootenay Plains, 14 mountain sheep, two bison, and one elk were killed.

Traveling west in early August 1809, Thompson made his only mid-summer crossing of Howse Pass. Mountain sheep and bison were taken at Kootenay Plains, and when he reached the forks of the Saskatchewan on August 9th, he reported that the "Kootenae killed a very poor Bull [bison]."

Thompson's final traverse of Howse Pass was made in June 1810. His party was on short rations all the way from the Columbia River to Kootenay Plains where "thank Heaven... Pembook killed a Bull [bison]" (June 19, 1810). The next day "we killed a young Red Deer [elk] @ a Bull [bison] -- which we took @ lost a [bighorn] Sheep."

It is obvious from the six traverses of Howse Pass which David Thompson made over a three-year period that the region around Howse Valley and the forks of the North Saskatchewan did not support large numbers of ungulates. With the exception of bison encountered on several occasions near Saskatchewan Crossing and in the Howse Valley, ungulate sightings and sign on succeeding trips were similar to what one might encounter today -- occasional moose and, less frequently, elk. There are bighorn sheep at Saskatchewan Crossing today, whereas Thompson made no mention of sheep west of Kootenay Plains. It is also clear that Kootenay Plains, whose western margin lies approximately 20 km east of Banff National Park, were a reliable place to find bighorn sheep, bison, and an occasional elk. Today, bison are absent, elk are rare, and few bighorn sheep now frequent Kootenay Plains' montane grasslands, though, sheep are still found in the surrounding mountains (see Chapters 4 and 6).

Alexander Henry, 1811

Fur trader Alexander Henry (Coues 1965) made one round-trip from Rocky Mountain House to Howse Pass by dog team in February 1811. His journal stands as the most complete and literate of the early fur trade records. He was a very astute observer of natural history and he recorded detailed descriptions of birds, as well as mammals.

After camping at Kootenay Plains, Henry set off for the forks of the North Saskatchewan on February 8th. He noted that, "I determined to leave one of my men to procure meat for our return; animals will be scarce as we advance in the mountains" (Coues 1965:688). Beyond Kootenay Plains, "we had more than a foot of snow on the ice, and scarcely was the track of an animal to be seen" (p. 688), but near the forks (Saskatchewan Crossing) "we saw the tracks of several herds of buffalo, which had crossed the river" (p. 690).

That evening Henry camped at "Kootenay Parc," approximately 7 km east of the summit of Howse Pass, also called "Kootenae Pound" by David Thompson on the first recorded European crossing of Howse Pass in 1807, an indication the name was in use prior to that date. As described by Henry, two promontories in this section of Howse Valley create a narrow corridor that "ends at a precipice ... Over [which] the Kootenays used to drive animals, after enticing them upon this narrow strip of soil.... On shoveling away the snow we found buffalo dung in abundance, but it seems these animals come up thus far only in summer, as we have not seen a track of any animal whatever since leaving the forks" (Coues 1965:690-691).

On February 9th, Henry reached the summit of Howse Pass. "The only track we saw after leaving camp this morning was that of a straggling wolverene [*Gulo luscus*]. This place appears destitute of animals of all kinds, and presents a dreary appearance" (p. 694). After a failed attempt to secure one of "three large white goats on the mountains directly over Kootenay Parc" (p. 695), Henry returned to Kootenay Plains the following day.

Like David Thompson before him, Alexander Henry found the country west of Kootenay Plains generally "destitute of animals." His record of buffalo tracks near Saskatchewan Crossing, though, and his description of "Kootenae Pound" provide additional evidence that, at one time, bison were seasonally found near the forks of the North Saskatchewan.

Again, consistent with David Thompson's reports, Henry found game abundant on and near Kootenay Plains. "At this time there was not more than two inches of snow, and in many places the snow was entirely eaten up by the buffalo.... Formerly that nation [the Kootenay] frequented this place to make dried provisions, for which purpose it must have been very convenient, as buffalo and sheep are always more numerous than in any other place. Moose and red deer [elk] are also plenty; jumping deer, grizzly bears, and other animals peculiar to this country are also found here" (Coues 1965:687). On his return trip across Kootenay Plains, he observed that, "The wolves had destroyed a fat [bighorn] sheep which had been left here to take home with us, but my men had killed another. They had also killed a large black wolf and a loup-cervier [wolverine?]" (Coues 1965:696).

David Thompson, 1811-1812

Starting on December 30, 1810 from an encampment at Brule Lake in the Athabasca Valley near the eastern boundary of today's Jasper National Park, David Thompson and a party of thirteen traveled by dog team up the Athabasca River to its confluence with the Whirlpool. From there, they followed the Whirlpool River to its source at Athabasca Pass, reaching the summit on January 10, 1811. Leaving the pass, the party descended the west slope of the Rockies via Wood River to the Big Bend of the Columbia River, where Thompson spent the remainder of the winter.

On December 30th, near the foot of Roche Miette, Thompson saw "fresh Buffalo tracks" and his hunter returned "havg (sic) killed a good cow [bison]." As they made their way up the Athabasca Valley, the hunter killed three mountain sheep and "2 good young Bulls [bison]" (Jan. 1, 1811).

In describing the valley between Brule Lake and the confluence of the Athabasca and Miette Rivers, Thompson (Jan. 4, 1811) observed that, "There are very many low rocky Hills, with plenty of wild Sheep, but saw no Goats @ the many Defiles afford room @ made pasturage for a few Buffalo @ Red Deer @ a chance Moose." This particular quote contains Thompson's only mention of "Red Deer" [elk], and it is a vague reference at best. Thompson left no reports of elk tracks or animals, despite the fact that he traveled through a section of the Athabasca Valley which is a major wintering ground for elk today and during a period of severe cold (temperatures around -35° C. every morning) – a factor which would usually insure that any animals in the district would be near the valley floor.

They reached Buffalo Prairie (later known as Prairie de la Vache), approximately 15 km south of today's Jasper townsite, on January 6th where "a Herd of Buffalo had been lately feeding" and "wounded a Bull, but very slightly." No other game, though, was encountered the rest of the way to Athabasca Pass nor until they reached the Wood River at the foot of the western slope where their guide killed "2 Buck Moose." Thompson spent the remainder of the winter at the Big Bend of the Columbia River living primarily on moose.

In the autumn of 1811, after charting the Columbia River from its mouth upstream to the Big Bend, Thompson crossed Athabasca Pass to Henry's House, near today's Jasper townsite, and returned. That journal, though, was not transcribed for this study. Then, in May 1812, he recrossed the pass once more from the Columbia and, after securing a canoe at Henry's House, descended the Athabasca River.

The crossing of the pass to Henry's House seems to have been organized to be completed as rapidly as possible utilizing provisions on hand. There was no indication that the party spent any time hunting. Thompson (May 9, 1812) noted that a cache of meat left on the upper Whirlpool had been "almost wholly devoured by a Bear," but the only sign of game on the trip was a set of fresh moose tracks near the confluence of the Whirlpool and Athabasca Rivers. While at Henry's House preparing for the canoe voyage east, Thompson (May 12, 1812) recorded that the post's hunters arrived "in the evening with 4 [bighorn] Sheep." Canoeing down the Athabasca on May 13th, Thompson again described the hills along the river as

he did in January 1811, as being "well wooded with small Pines -- on them the Bisons and Red Deer [elk] feed all the Summer." While further downstream, he mentioned bison and bighorn sheep.

Gabriel Franchere, 1814

Franchere's (1969) party came up the Columbia River by canoe and then traveled on foot over Athabasca Pass. They lost provisions in fording Wood River and their food supply was almost exhausted when they crossed the height of land. There is no indication that they tried to hunt anywhere on the traverse, only that they were attempting to make it over the mountains as rapidly as possible in the hope of resupplying at Jasper House.

Descending the Whirlpool River on May 16th, Franchere wrote, "We killed a partridge." Continuing on, they forded the Athabasca near the mouth of the Whirlpool and noted that, "As this crossing was the last, we dried ourselves and went on our way... coming upon buffalo carcasses, and camped on the edge of a prairie that our guide told us was called Cow prairie [Prairie de la Vache]." There they shared "a very sparse supper... a few handfuls of corn that we roasted in a frying pan that we had brought with us" (Franchere 1969:160-161). Several days later Franchere reported that he and an Iroquois "shot seven birds" and had a "reasonably good meal" but the others "who remained behind were without food." When they arrived at Jasper House on the shores of Brule Lake, however, there was little food. "We therefore killed a dog on arrival, and towards evening one very emaciated horse" (Franchere 1969:162). He mentioned that the hunters were searching for game in the direction of Smoke River (probably Snake Indian River). This reference to the difficulty of securing food at Jasper House is only the first of many that appear in subsequent journals (also see Chapter 3).

George Simpson, 1824-1825

George Simpson (Merk 1931) followed the Athabasca Trail from east to west in early October 1824. At the mouth of the Miette River on October 12th, he commented that, "Our Road was rugged and bad frequently covered with fallen Timber the country having been over run by Fire; it appears well stocked with Animals as we found many tracks of Buffalo & Deer; the Mountain Goat and [bighorn] Sheep are likewise numerous, our Hunter killed two of each kind say of the Goats & Sheep" (Merk 1931:32).

Simpson returned over Athabasca Pass in April 1825. His party expected to be supplied with provisions and horses on the east side of the divide but were disappointed to learn that neither would be forthcoming. They reached "Mountain House" (located near present-day Jasper townsite) on April 27th, where Chief Trader La Rocque reported on his winter trip to Cranberry Lake (Yellowhead Lake), saying "no Establishment can be maintained further in the interior of the Mountain than where now situated [because] large Animals being scarce and the Lakes producing no Fish" (Merk 1931:147).

Simpson's optimistic report in 1824 concerning abundant animals in the Athabasca Valley does not coincide with that of other travelers or the journals kept at Jasper House during the 1820s. It should be noted that Simpson was known for traveling at breakneck speed (for that day and age) during his journeys as Governor of the Hudson's Bay Company and his observations often appear rather cursory compared to other travelers. Although he was quite optimistic about the number of animals in the region during his westbound excursion, he mostly reported tracks, while mountain goat and bighorn sheep were the only ungulates actually killed by his hunter. On his eastbound journey six months later, provisions were a problem and his only sightings of game were well east of the present-day boundary of Jasper National Park. Therefore, we suspect that Simpson's early optimistic report on the availability of game had more to do with his desire to promote the fur trade than with actual conditions (see below).

David Douglas, 1827

David Douglas (1959), a British botanist, was one of the most careful natural history observers to cross the Rockies during the first half of the 19th century. During his eight day traverse of the Athabasca Trail from the Columbia River to Jasper House, he noted every species of tree, plant, bird, and mammal encountered. Despite his keen desire to observe all forms of flora and fauna, the only large mammals that he reported were two bighorn sheep killed by Hudson's Bay Company hunters.

Edward Ermatinger, 1828

Traveling from Jasper House on Brule Lake to Athabasca Pass in October 1828, trader Edward Ermatinger (1912) recorded that his hunter killed two moose near "Campment de Cardinale," probably near the mouth of Jacques Creek. The following day, on the way to the crossing at the Miette River, his hunter shot another moose. The fur brigades split at the mouth of the Miette, and Ermatinger continued on to Athabasca Pass where his hunter killed a young grizzly.

Michel Klyne, 1828-1831

Michel Klyne was periodically in charge of Jasper House from 1824 until around 1835. Klyne was barely literate, but his post journals from 1828 through 1831 give some indication of the game situation in the Athabasca Valley (Hudson's Bay Company 1828-1831). During his tenure, probably in 1829, Jasper House was moved from Brule Lake to the west shore of the Athabasca River near the north end of Jasper Lake (also see Chapter 3).

During the month of January 1828, Klyne indicated that his hunter was having difficulty finding game, though he occasionally killed a few bighorn sheep. On February 29th, Jacques Cardinal, the horse keeper, reported that one of his mares was missing and suspected that Shuswap natives, who were camped nearby, had killed the horse for food. One of the freemen told Cardinal that, "two of their Childrens [were] starving to Dead." There apparently was a severe shortage of game throughout the winter.

In November 1829, game was still very hard to find around Jasper House and on December 3rd Klyne reported that, "in the Evening I was oblige to kill one of my horses to Eat on account of the Childrens." Several horses were killed that winter and conditions were very grim, worse than the previous year.

In the autumn of 1830, Klyne noted that wolves were after his horses. On November 12th, "Loyer [killed] a large wolf" and Klyne offered "every men at this place for every wolf they would kill I will give them one plug [of tobacco] for each." He also wrote of going below "the old house" (into the Foothills east of Brule Lake) to hunt.

On April 10, 1831, he recorded how a Shuswap woman and three children arrived at the post in a starving condition. The woman told Klyne that "[her] Children and her husband Died of Hunger at Mr. La Rocque House." (La Rocque's "Mountain House" near the confluence of the Miette and the Athabasca, the site of present-day Jasper townsite.)

While Klyne's notes are very abbreviated and his journals were not fully transcribed for this study, these entries indicate that game was very scarce while he was stationed at Jasper House. The frequent reports of both Shuswap and Assiniboine may be an indication of increased native visitation to the area, perhaps due to the two trading posts in the valley.

George Simpson, 1841

George Simpson (1841) left Fort Edmonton in July to traverse the Rockies via a new route. Entering present-day Banff National Park through Devil's Gap, he traveled along Lake Minnewanka to the Bow River, over Simpson Pass, down the Vermilion River to the Kootenay River and then over Sinclair Pass to the Columbia Valley. This is the first known written account of Banff's Bow Valley.

Simpson's party entered the mountains at Devil's Gap on August 2nd expecting to rendezvous with their native guide's family at Lake Minnewanka, but that camp was deserted "probably on account of a scarcity of game." The following morning they ate a porcupine (*Erethizon dorsatum*) for breakfast "which we found to be very good fare, but we could at that meal have relished anything having produced a fast of 20 hours, in this bracing Mountain region." They then continued around Lake Minnewanka and into the Bow Valley where, that night, they camped on the bank of the Bow River near the mouth of Healy Creek. Despite spending most of the day in the Bow Valley, they saw nothing except a few mountain goats and bighorn sheep on "some of the highest peaks... but were unable to get within shot of them."

Leaving the Bow Valley, they ascended Healy Creek and crossed Simpson Pass without mentioning wildlife except for some vicious biting insects. On the Kootenay River, they camped and once again breakfasted "off a porcupine, the third we had killed; in fact it was the only meat we could get, as although the banks of the river were in most places beaten up with the recent tracks of Bear, Buffalo, Cabri [deer], [bighorn] Sheep, Moose, Red Deer [elk], & Wolves none of them ever came in sight, the noise of our march no doubt scaring them to the woods" (Aug. 5, 1841). One member of the party did manage to bring them "a few pounds of meat, being part of a Biche [probably a cow elk] which he had shot." Simpson (Aug. 7, 1841) reported, however, that "Whilst traversing the Mountains, we had noticed in places where the soil was composed of clay, large holes at the roots of trees, burrowed by the Mountain sheep, which at certain seasons come down from the Mountain tops to the vallies for the purpose of eating the Argillaceous Earth." This most likely was a reference to the mineral lick at Hector Gorge that Simpson had passed on the way (also see Hector 1858-1859).

As discussed earlier, George Simpson was noted for being a very rapid traveler and as such probably gave his hunters little opportunity to search for game. Yet, he passed along Lake Minnewanka and through a section of the Bow Valley where large numbers of elk can be seen today without reporting even a single animal.

Henry J. Warre, 1845

Traveling with a brigade of traders bound for the Columbia, Lieutenant H.J. Warre (1845) entered the Rocky Mountains along the north side of the Bow River, crossed the river near present-day Canmore, and ascended to Spray Lakes via Whiteman Pass. He then crossed the divide at White Man Pass and descended the Cross River to the Kootenay River. After crossing the Kootenay, the party followed up that river and traversed Sinclair Pass to the Columbia Valley.

Warre's party entered the Rockies along the Bow River on July 24th "through wooded mountains, which were magnificent but covered by smoke of an immense fire, probably ignited accidentally." Soon after observing that fire, Warre met a hunting party of Stoney and Cree natives who had just killed a buffalo bull "of the 'strong wood kind', much more savage than those usually found on the plains." Since Warre would have made his diary entry at the end of the day, his comment about the fire being started accidentally probably refers to an escaped campfire used by the native hunting party he subsequently met.

Warre's party left camp at present-day Canmore on July 25th for White Man Pass and "commenced the ascent of the lower steps of the mountains, meeting with the greatest difficulty from the fallen burnt wood, which, notwithstanding our having sent Men forward to make a road, impeded our progress." Near Spray

Lakes, they reported numerous tracks of bighorn sheep and mountain goats but did not actually see any animals. Warre indicated that they killed several grouse and rabbits, but complained that "the Indians have driven off all the larger Game." The next day, however, their hunter did manage to kill a moose. While descending Cross River two days later, Warre took a shot at a mountain goat, but missed — his last mention of game until reaching the Columbia Valley.

With the exception of the bison killed by natives at the entrance to the mountains, the pattern of wildlife sightings on this trip across the range is consistent with other historical accounts. Today, though, one would expect to encounter elk and deer in the lower Bow Valley and in the Kootenay Valley below Sinclair Pass, but there is no record that Warre saw any of those animals. Warre did note, however, that in typical fur trade brigade fashion the pace was fast, the days long, and there was little time for hunting.

Paul Kane, 1847

The artist Paul Kane (1968:345) stopped at Jasper House in early November 1847 and observed that "A great number of mountain [bighorn] sheep had been driven down into the valleys by the intensity of the cold, which had set in this winter with unusual severity. I have counted as many as five large flocks of these animals grazing in different directions from the house at one time, and the Indians brought them in every day." Twenty-two kilometers east of Jasper House, Kane's party stopped at a lodge where the native owner had just killed four sheep. The hunter told Kane (1968:347) that "he had seen thirty-four sheep that day, and that he never remembered a winter in which so many sheep had come down from the mountains."

James Hector, 1858-1859

Dr. James Hector was one of the most astute explorers of the early historical period (Spry 1968). His observations, recorded on three separate excursions into the mountains, are all the more valuable because they were not made simply on in-transit crossings of the range, but as part of an exploration of all major passes and valleys within the Southern and Central Canadian Rockies for John Palliser's British North American Exploring Expedition of 1857-1860 (Spry 1968). Although trained as a geologist, Hector was well versed in biology, and his mandate was to record all aspects of natural history that might be of interest.

In 1858, Hector made a thorough survey of several valleys in present-day Banff, Kootenay, and Yoho National Parks. Over the course of 36 days, his party of five traveled up the Bow Valley from "Old Bow Fort" to Castle Mountain, crossed over Vermilion Pass and descended the Vermilion River to the Kootenay River. After following the Kootenay upstream to its headwaters and the Beaverfoot downstream to the Kicking Horse River, the party ascended the latter to Kicking Horse Pass. Just east of the pass, the Bow River was rejoined near Lake Louise and followed to its headwaters on Bow Summit. The explorations ended in early September with an investigation of Saskatchewan Crossing and Kootenay Plains.

Hector started up the Bow Valley on August 11th with minimal victuals "as I was assured that in the part of the mountains I intended to explore, there was abundance of game..." (Spry 1968:289). The party camped near present-day Canmore where its hunter killed a male "black-tailed deer" (mule deer) and wounded a moose. Natives, who accompanied Hector, spoke of hunting on Cascade Mountain and that they "often get the white [mountain] goat on it and the grey [bighorn] sheep is common" (Spry 1968:293). When Hector actually reached Cascade Mountain near present-day Banff townsite (see Figure 4.3), his hunter killed two bighorn sheep and, while scrambling up the mountain, Hector came across "a large band of sheep" (Spry 1968:294). The following day Hector's party returned to Cascade Mountain near the falls where they "saw a band of ewes, and succeeded in killing two of them" (Spry 1968:295).

On the way up the Bow Valley from the site of present-day Banff, Hector's hunter reported "many wapiti [elk] tracks" (Spry 1968:297). Near the confluence of Johnston Creek with the Bow, Hector shot a bull moose and, while climbing Castle Mountain, he saw "several bands of sheep" (Spry 1968:299). The party

left the Bow Valley for Vermilion Pass on August 20th. Hector then examined the goat lick near the upper end of Hector Gorge, before journeying upstream along the Kootenay River. While stalking a deer, his native hunter came upon a cougar or mountain lion (*Felis concolor*) and returned to camp "as white as it is possible for a red Indian to be with fear" (Spry 1968:303). In camp the following evening, they heard the cry of a "panther [mountain lion]."

As they neared the divide between the Kootenay and Beaverfoot Rivers, their on-hand supply of moose meat began to spoil, which Hector considered a "serious" turn of events since "we now seldom see any tracks of game" (Spry 1968:304). They saw numerous beaver, marten (*Martes americana*) tracks, and signs of other fur bearing animals, "but the absence of game, which is very unaccountable, prevents the Indians tenting up this way to trap" (Spry 1968:305).

Above Wapta Falls on the Kicking Horse River, Hector was kicked by his saddle horse and rendered unconscious. He later noted that this accident was unfortunate "as we had seen no tracks of game in the neighbourhood, and were now without food" (Spry 1968:309). He laid down under a tree to recover, first sending his men off to hunt. The hunters tracked some elk and discovered a native camp that was several months old. "At one of these camps he found the wool of the mount [ain] goat, and also wapiti [elk] hair" (Spry 1968:309). As the party ascended the valley to the summit of Kicking Horse Pass, Hector's hunter reported elk on a couple of occasions, but was unable to get close enough for anything more than a "long shot." After crossing the pass, however, they did manage to kill a "very lean" cow moose.

On September 4th, Hector arrived at a Stoney encampment by a small lake near the base of Mount Hector. "They had reached this valley, like ourselves, starving, but already there had been killed in the last two days seven moose deer, including Nimrod's one.... At evening a half-breed arrived... and made me a present of a fine buck moose. Other Indians also returned, and altogether they had killed three moose to-day. They had, however, gone long distances" (Spry 1968:314). It would appear that this Stoney hunting party was busy harvesting many of the moose on the headwaters of the Bow River.

Hector then decided to continue north over Bow Summit to reach the North Saskatchewan River despite his guide telling him that "we would get nothing but white [mountain] goats that way" (Spry 1968:316). Descending the Mistaya Valley below Waterfowl Lakes, his hunter followed "wapiti [elk]" tracks but was unable to locate the animals. There was no report of moose or moose tracks, the only ungulate common on the floor of this valley today.

From the forks of the North Saskatchewan (Saskatchewan River Crossing), Hector and his men ascended Howse River a short distance and then climbed through the forest towards Glacier Lake where "a big-horn sheep came down the mountain almost close to us, but seeing us first, made off without getting a shot" (Spry 1968:320). Hector's native hunter told him that "this is the only place where these are to be seen so far in the mountains" (Spry 1968:321). Hector spent the next three days scrambling over the peaks above his camp on Glacier Lake. On September 13th, one of the campfires he left burning escaped and consumed "a large area of the forest."

On the Howse River, near its confluence with the North Saskatchewan, Hector penned the following report.

Near our camp we found some old buffalo dung, and the Indians told us that not many years ago there were many of these animals along the valley of the North Saskatchewan, within the mountains. Eleven years ago, they say, there were great fires all through the mountains, and in the woods along their eastern base; and after that a disease broke out among all the animals, so that they used to find wapiti, moose, and other deer, as well as buffalo, lying dead in numbers. Before that time (somewhere about 1847 or 1848) there was abundance of game in all parts of the country; but since then there has been great

scarcity of animals, and only the best hunters can make sure of killing. I have heard the same description of the sudden change that took place in the abundance of game from half-breed hunters in different parts of the country; so there is little doubt that there is some foundation for the account given by the Indians. [Spry 1968:326].

While this is an interesting explanation for a supposed decline in ungulates (Morgantini 1995:25), there is no indication from Hector's account that, with the exception of bison, numbers of animals were any lower than what travelers had found in the early part of the century (see above). There is also no evidence that disease decimated ungulate populations anywhere in western North America ca. 1800-1870. Even if European-introduced livestock diseases, such as anthrax or hoof-and-mouth disease, were somehow transmitted to wildlife, it is doubtful that they would have completely decimated game populations (Carbyn et al. 1993). Then too, burning of the forest would have created feeding areas and favored game populations, not contributed to their decline (Van Egmond 1990; see Chapters 4 and 5). There are, however, indications that native hunting in the main valleys east of the divide may have increased during the 1840s (see below).

On September 15th, Hector's party descended the North Saskatchewan River to Kootenay Plains where large numbers of mountain sheep were seen, including "a flock of at least a hundred rams [which] rushed close past me, so close, indeed, that I hit them with stones" (Spry 1968:328). So in 1858, bighorn sheep appeared to have been every bit as numerous on Kootenay Plains as they were earlier in the 1800s (see above), which does not support the hypothesis that some unknown disease ravaged game animals ca. 1850. During the fall of 1859, Hector again reported "several hundred" bighorn sheep near Kootenay Plains (see below).

Like other early mountain travelers, Hector primarily sighted bighorn sheep and mountain goats. Moose, however, were seen in both the lower and upper Bow Valley. Although the party reported elk tracks in the Bow Valley west of Banff and, apparently, in the Mistaya Valley, none of those animals were actually seen east of the divide. The only elk encountered on the trip were in British Columbia's Kicking Horse Valley.

During 1859, Dr. James Hector made two additional trips into the Rocky Mountains. The first was in February when he visited Jasper House and the Athabasca Valley. Then, in August and September, he examined the Bow, Pipestone, Siffleur, North Saskatchewan and Howse Valleys before crossing Howse Pass and descending to the Columbia.

Hector's February trip to the Athabasca did not cover much territory. Primarily, it was a three week examination of the valley in the vicinity of Jasper House. Yet, his journal provides insight into the wildlife composition of that area in 1859 and hints at the impact of nearly half-a-century of fur-trade activity.

Upon his arrival at Jasper House on January 31st, Hector described the environs and the operation of the post in some detail.

During the whole winter the hunters climb the mountains in search of the big-horn sheep, and only rarely have to use snow shoes, although they generally carry a small strong-made pair to use in crossing drifts. The big-horn is very plentiful in this part of the mountains, and forms the principal food of the people here, who are often put to great straits, as it has to be hunted from day to day. There are two or three Iroquois hunters attached to the trading post, and they are sent off every morning before daybreak, and seldom return till late afternoon. Early in the morning the sheep descend the mountains to the 'Salinas' or salt licks, and if the hunter can succeed in intercepting them in the woods before they regain the bald part of the mountains they fall an easy prey, but otherwise, to get a shot at them involves a great deal of hard and often dangerous climbing. The hunters generally use dogs, which are beautifully trained to turn the sheep as they rush up the mountain to reach the most inaccessible precipices.... we could always see bands of the sheep on the

mountains round the fort with the aid of a good glass, and once in this manner I watched the progress of a hunt upon the Roche de Smelt [Roche de Smet]. [Spry 1968:370-371].

Hector reported that moose, which were once relatively common in the valley, were now scarce. "This winter the hunters have only killed two, but they know where another has his feeding ground, and do not intend to kill him until spring. The perfection to which the Iroquois carry moose-hunting may be judged from the fact that one of them has visited this moose several times during the winter, and seen him once, yet without disturbing him" (Spry 1968:371).

Hector went on to explain how difficult it was to secure food for this depot and hinted at the impact of its presence on the valley's wildlife populations. "In order to save game around the fort until the depth of winter, Moberly had abandoned it on his first arrival, and for two months they all lived in a camp about 20 miles up the valley, at a place where there are plenty of big-horn sheep. Until a few years ago this trading post was not altogether abandoned during the summer, but the person in charge made a hunting tour for several months to accumulate provisions for next winter's support, and during these trips as many as 30 to 40 moose deer would be killed and several hundred big-horn sheep" (Spry 1968:377). Another curiosity noted by Hector was that the post factor, Henry Moberly, "has been feeding his people this winter the wild cat or Canadian lynx [*Lynx canadensis*]" and that "up to this date they have killed 83, more than half of them having been shot by Moberly himself, as he has a splendid dog that hunts them till they climb a tree" (Spry 1968:371).

Moberly also apparently initiated a policy of "killing foxes [*Vulpes fulva*] and wolves with baits poisoned with strychnine." When, a few days after Hector's arrival, one of the post's horses was killed by wolves, the carcass was salted with strychnine and "four enormous wolves, besides five or six of a smaller species [coyotes? – *Canis latrans*]" were killed. Hector noted that, "The large wolves, who were the real offenders, were splendid brutes. The two youngest were nearly black, while the old ones were grizzled grey, like Scotch stag-hounds. The largest measured two and a half feet at the shoulder, and was five feet eight inches in length" (Spry 1968:374).

In mid-February Hector made a trip up the Athabasca Valley, traveling to the vicinity of Athabasca Falls before returning. He saw bighorn sheep, some mountain goats and, about four miles south of Prairie de la Vache, "the tracks of nine reindeer [caribou – *Rangifer caribou*] that had come down on the river" (Spry 1968:380). The area that Hector traveled through is now one of the prime wintering grounds for elk in the Athabasca Valley, but he did not report seeing even a single elk nor any sign of their presence.

On August 17, 1859, Dr. James Hector and a party of nine set off from Old Bow Fort near present-day Seebe, Alberta, on another journey of exploration through the Rocky Mountains on behalf of the Palliser Expedition. The group ascended the Bow River to the mouth of the Pipestone, then continued up that tributary to Pipestone Pass and down the Siffleur River to Kootenay Plains. From there they followed up the North Saskatchewan and Howse Rivers to Howse Pass and descended the Blaeberry River to the Columbia Valley.

While camped in the Bow Valley near present-day Canmore, Hector reported that one of his men "killed a black-tailed deer [mule deer], and I killed a Virginian deer [white-tailed deer], and had a shot at a black bear" (Spry 1968:435). While scrambling on a mountain on the east side of the valley Hector wounded a mountain goat and saw a large band of bighorn sheep. Traveling up the Bow Valley from a point near today's Eastgate to Lake Louise, the party did "nothing to increase our stores" and was forced to live off pemmican, this despite the fact that two hunters were ranging out in search of game every day. The present summer elk population in this 70 kilometer-long section of the Bow Valley is around 700 animals, yet Hector passed through in 1859 without reporting a single sighting.

Continuing on their journey, they wounded a moose near the mouth of the Pipestone, but it escaped across the river. One of the hunters, though, did kill a young moose on the lower Pipestone, and further up the valley, Hector and one of his men killed five mountain goats. While camped on the headwaters of the Pipestone River, another of his native hunters told Hector that "two years ago he killed a buffalo cow at this place, and that he saw at the time a band of seven, – two bulls, four cows, and a calf" (Spry 1968:440). Hector added that these bison "were of the thick-wood variety, which are larger and blacker, and with more spreading horns, than those of the prairies" (Spry 1968:441). The following day, in the Siffleur Valley, Hector observed a fresh buffalo track, but was unable to follow over the rocky ground.

When they arrived in the North Saskatchewan Valley near the west end of Kootenay Plains, they saw two moose swimming the river. They also observed "several large bands of the big-horn sheep feeding on the Kootenie Plain," and one of the hunters returned at nightfall "having wounded a moose deer and killed three sheep, having come on a band of several hundred a little way up the river" (Spry 1968:443). By the time he reached Saskatchewan Crossing, however, Hector had lost both of his native hunters to desertion, and his party was reduced to himself and four men. "We were now wholly dependent on ourselves for obtaining any food beyond what we carried" (Spry 1968:446). There was no further mention of hunting or ungulate sightings until after they crossed Howse Pass and reached the Columbia Valley, where they enjoyed a meal of skunk (*Mephitis mephitis*).

Again, during his second exploration of the Bow and other major valleys in present-day Banff Park, Hector recorded ungulate species similar to what one might expect to encounter today, except for bison and elk. While Hector's traverse of the Bow Valley during the third week of August was early for the annual rut, by today's standards it still seems incredible that not one elk was seen.

James Carnegie (Earl of Southesk), 1859

The Earl of Southesk (1869) was the first tourist-sportsman to visit the Canadian Rockies. After entering the mountains via Rocky Pass, he spent the month of September working his way south via the Medicine-tent River, Southesk Pass, Cairn River, Brazeau River, Cline Pass, Cline River, Kootenay Plains, Siffleur River, Pipestone Pass, Pipestone River and Bow River.

Southesk spent one month hunting the Front Ranges of the Rockies. He was interested in collecting trophies and specimens of most every Rocky Mountain species and killed everything from moose to marmots (*Marmota caligata*). He even considered shooting a ground squirrel (*Citellus* sp.) but refrained because "my rifle bullet would have cut so small a creature into atoms" (Southesk 1969:191). Despite a thorough scouring of the Rocky Mountains by this dedicated sportsman and his ten companions, all fur trade men and experienced hunters, not one elk was killed or seen, even though they passed through major valleys such as the North Saskatchewan and Bow during the height of the rut.

W.B. Cheadle, 1863

As tourists traveling from Fort Edmonton to the Cariboo gold fields of British Columbia, Dr. W.B. Cheadle (1971) and his traveling companion Viscount Milton left the earliest written account of a journey up the Miette River and across Yellowhead Pass (Milton and Cheadle 1865). Upon entering the mountains overlooking the Athabasca River on June 29th, the travelers encountered a forest fire and were forced to chop their way through the charred, still smoldering, deadfall. "Although this was encouraging, as evidence of the recent presence of man, we made very slow progress" (Milton and Cheadle 1865:231). They found tracks of sheep on the slopes of the mountains and, while searching for bighorns, their guide killed two

mountain goats. They also saw bighorns on the slopes near Jasper House, and while there, the post factor returned from a hunting trip with ten sheep. "He informed us that a winter rarely passed now without a great scarcity of provisions at Jasper House, and their being driven to horse-flesh as a last resource" (Milton and Cheadle 1865:243). Cheadle also noted that Shuswap natives were always visiting the post at mealtime and commented that the "Poor devils, they were starving."

As with earlier descriptions of the Athabasca Valley, bighorn sheep were the most frequently seen ungulate, and the main source of meat. Other than mountain goat, no ungulates were mentioned by Cheadle.

Walter Moberly, 1871-1872

As supervisor of the Canadian Pacific Railway survey through Howse Pass, Walter Moberly (1871-72) made a trip from the Blaeberry River to Kootenay Plains and back in October 1871. Near Saskatchewan Crossing he reported "tracks of Cariboo, Elk, Grizzly Bears, & some deer tracks" as well as "the skull and horns of an enormous Buffalo bull and numerous signs to show those animals had once been plentiful in this locality" (Oct. 19, 1871). He also noted that a "large fire has destroyed the timber from the vicinity of the Glacier Lake Stream for about 4 or 5 miles below it" (Oct. 21, 1871). At Kootenay Plains, Moberly again reported signs of previous bison habitation. In addition, he "saw the horns of the Elk and we passed a fresh track where a number of Mountain Sheep had evidently only passed a short time before" (Oct. 20, 1871).

During late August and the first week of September 1872, Moberly (1872-1873) and three natives hiked from Boat Encampment on the Columbia River to Yellowhead Pass via Athabasca Pass and the headwaters of the Fraser River. As one of the first explorers to travel into true alpine terrain (a high pass north of Mount Brown), Moberly appropriately encountered caribou and grizzly bear.

R.M. Rylatt (Athabasca Valley), 1872-1873

Rylatt (1991) was hired as an on-the-scene agent in charge of supplies and equipment for the Canadian Pacific Railway survey of the Athabasca Valley. He kept a diary while he lived in the mountains and often traveled between Athabasca Depot near the mouth of the Miette River and another at Fiddle River. Many of his observations are general and non-specific, but they do provide an overview of conditions in the Athabasca Valley during the early 1870s.

Rylatt (1991:133) reached Athabasca Depot on November 2, 1872, after crossing Athabasca Pass from the Big Bend of the Columbia and noted that "On my way here I passed the whitened skulls of many Buffalo, but the half-breeds tell me there have been none in this vicinity for some time; having been so hunted and killed by the Indians as to compel them to seek safer feeding grounds." He also mentioned that his sleep was disturbed when he first arrived "by the howling of a pack of Kayottes (a small species of wolf, or wild dog)" and that "wolves are plenty, large gaurt brutes." In late November he wrote that a cold snap killed "some eight or ten of our animals [horses]... four having been devoured by the wolves, the balance dying from exposure" (Rylatt 1991:134).

While visiting Jasper House he observed that "buffalo used to herd in the Valley we are wintering upon in vast numbers. I can well believe this from the many bones and bleached skulls of Buffalo I saw through the Valley, and that it must have been a sheltered spot to yard in during the winter." In talking about what appears to be the Snake Indian Valley, Rylatt reported that "the halfbreeds say this section of country is still a favorite summer hunting ground, being well stocked with Mountain Sheep, Rabbits, Grouse, Bear, and Moose, also some Cariboo" (Rylatt 1991:142-143).

Bighorn sheep were "occasionally" seen on the slopes above the valley floor "in bands of from ten to twenty" (p. 146) and hunters killed sheep on at least one occasion. As for other ungulates in the valley, Rylatt

(1991:172) wrote, "Unlike the western slope of the Rocky's, small game of any kind are scarce on this side, in fact the only game is large; Moose, Cariboo and Mountain Sheep principally." Despite his six month residency in the valley, though, Rylatt never once mentioned elk. Instead, Rylatt (1991:173) reported that the "Bear family are numerous on this side [of the mountains]" and considers grizzly bears "especially... numerous." During his travels between Athabasca and Fiddle River depots, Rylatt observed grizzly bear tracks and droppings and on one occasion described how a grizzly attacked one of his horses.

Rylatt also made several references to wolves during his stay. Once while sketching near Jasper House he "heard a crackling of dried twigs, and quickly turning, beheld three large timber wolves; they observed me at the same moment... their great jaws were open, their tongues hanging out, and their cruel teeth fairly gleamed" (p. 171). A few weeks later he stated that, "Fires had to be kept going the entire night, as the wolves are congregating somewhat thicker than is agreeable, and have attacked the pack animals [horses] during the nights" (p. 179).

Rylatt was a newcomer to the mountains and much of his local knowledge came second-hand from residents of the valley. He displayed obvious prejudices concerning natives, and may also have been somewhat prone to sensationalism. Yet the following quote, biased as it may be, provides one man's opinion on native use of the valley.

Heavy fires have at some period devastated the Valley, leaving the standing timber in places bare and scathed, bleached white by the winds and rain.... Yet why is this beautiful Valley so rich, and yet so empty? Why is the devastation by scathing fire? Where are the Buffalo herds that should be grazing here? For their whitened skulls lie thickly around. Certain it is they come here no more, and why? Ask the redman; he can answer it. But he does not seem to make his home here now. No; he has driven the herds from this place, and as they depart, so does he, he goes after the meat. He it is who has lighted the fires that has devastated spots in the Valley.... the cause is clear, the cunning savage year after year crept past the herds as they fed, and attained the upper end, then fired the long grass during the heated term, driving a thundering living mass in terror to the only Outlet at the end of the Valley, where the main body of their enemy waited to destroy as the opportunity offered. If this mode of warfare against them was the only means of securing or lessening their numbers, the buffalo would be in their ancient haunts in bands of many thousands, where today not a single head can be found. [Rylatt 1991:163-164].

It should be noted that no other explorer or traveller ever observed activity as described by Rylatt. His vision of a "thundering living mass" of bison in the Athabasca Valley has no precedent in the historical record dating back to 1811 and it would appear that he may have been the victim of folklore. His reference to native use of fire may be of some interest, however, since there are other reports of fire in the vicinity during the previous decade (Cheadle 1971, and see Chapter 5).

COLUMBIA VALLEY

As defined in this section, the Columbia Valley region of the Rocky Mountain Trench extends from the river's headwaters in Columbia Lake on the south to its "Big Bend" on the north. The valley is bounded on the east by the Main and Western Ranges of the Rocky Mountains and on the west by the Purcell and Selkirk Ranges of the Columbia Mountains. For the purpose of this survey, Canal Flats was considered to be the southern point of entry and departure for early travellers. The Big Bend, at the confluence of the Columbia and Canoe Rivers, was the northern boundary for historical observations in all but one case – David Thompson's exploration of the southern 80 km of the Canoe River in April 1811. The southern and

central sections of the study area are within the montane ecoregion, while the northern portion is within interior cedar-hemlock zone. The Canoe River extends into the sub-boreal spruce ecoregion.

Journal Synopses in Chronological Order

David Thompson, 1807-1811

Thompson's (1800-1812, White 1950) journal record of eight separate trips in the Columbia and Canoe Valleys stands as the best early record for the Rocky Mountain Trench. Out of 133 days spent traveling in this long intermountain valley, Thompson made reference to lack of food or game on nine separate occasions, compared to eight such references in 117 days of travel through the Rocky Mountains. This may seem surprising since much of his time was spent in the montane zone near the Columbia's headwaters where game should have been more plentiful than at higher elevations. Deer were the ungulate most frequently observed and killed, followed by elk, though numbers for elk were only half those of deer. The only section of the Rocky Mountain Trench where Thompson found game abundant was along the Canoe River where "Moose Deer and Beaver were plentiful" in 1811. Moreover, Thompson and his men had survived for three months the previous winter at the mouth of the Canoe River by living on local game, primarily moose, without outside provisions. On later trips across the Rockies, however, Thompson failed to find many animals at the mouth of the Canoe River.

David Thompson built Kootenay House on Windermere Lake during the summer of 1807 and he and his men suffered near starvation through early autumn. In October, however, native hunters began arriving at the post on an almost daily basis with deer and elk to trade. By early spring, though, the people at Kootenay House were again short of food. Thompson's journal entries indicate that elk and deer were also brought to the post in fair numbers during October and November of 1808 but thereafter Thompson recorded a near constant shortage of game. Other than these brief abundances, Thompson generally reported few ungulates west of the Continental Divide (Tyrrell 1916, Belyea 1994).

George Simpson, 1841

Simpson entered the Columbia via Sinclair Canyon on a hot day in August and ascended the valley to Canal Flats in just over two days of hard travel. No wildlife was noted, but at Columbia Lake his party observed a forest fire. "These woods had been on fire for some weeks & the devouring element was still carrying devastation through the forests..." (Aug. 9, 1841).

Henry J. Warre, 1845

As with most fur brigades, Warre's party moved rapidly up the Columbia Valley after entering via Sinclair Canyon. He wrote, "We saw several of the Red Mountain [bighorn] sheep but they were too far to be shot and innumerable tracks of Moose Deer. Bears &c. of all the country through which we have passed I should think we saw more evidence of the existence of wild animals in this days journey than on any other. But our time did not admit of Hunting" (July 30, 1845).

James Hector, 1859

While traveling south in the Columbia Valley from the mouth of the Blaeberry River, Hector penned the following comment, "Elk or wapiti must at one time have been very numerous in this district, as we saw a

great many antlers lying on the ground, and sometimes the Indians had piled them in heaps of 50 or 60 together; but the open nature of the woods, and the limited range, excepting up and down the valley, must have made them an easy prey to the Indians as soon as they acquired firearms. We have not seen a single track of an elk yet in the valley, and but only a few of the smaller deer" (Spry 1968:459).

TABULAR SUMMARIES

Three separate tables summarize animal sightings, observation of animal sign, and numbers of animals killed for each of the three geographic regions of the Central Canadian Rockies Ecosystem – the Foothills, the Rocky Mountains, and the Columbia Valley.

Foothills

Table 2.1 summarizes animal sightings by species in the Foothills between 1792 and 1863. Twenty-nine explorers recorded trips in this region, traveling for a total of 212 days. Bison were the most commonly observed ungulate with 35 sightings. Deer were second at 32+ sightings, though the total would likely have been greater had James Hector recorded individual observations of deer in December 1858. Elk sightings were third at 18.

TABLE 2.1. FOOTHILLS: PART I - ANIMALS OBSERVED. Historical evidence relating to the distribution and abundance of ungulates in the Foothills region from 1792 to 1863. Number of occasions on which large animals were reported to have been seen by early explorers. To make the table more readable, dashes were used instead of zeros for species that were not reported.

Observer ¹	Date	Trip Length (days)	Size of party	Number of ungulates and other large animals observed											Grizzly Bear	Black Bear	Bear ²
				Elk	Bison	Deer	Goat	Bighorn Sheep	Moose	Caribou	Wolf	Cougar					
1. Peter Fidler 12/30-1/2	1792-93	4	30-50	-	1	-	-	-	-	-	-	-	-	-	-	-	
2. David Thompson a. 10/11-10/14	1800 ³	4	8	-	1	-	-	-	-	-	-	-	-	-	-	-	
b. 11/29-12/1	1800	4	3+	-	-	-	-	1	-	-	-	-	-	-	-	-	
c. 6/6-6/11	1801	6	11	1	4	-	-	1	2	-	-	-	-	-	-	-	
d. 5/10-5/16	1807	7	9+	3	4	-	-	-	-	-	-	-	-	-	-	-	
e. 6/24-6/26	1808	3	6+	1	2	-	-	-	-	-	-	-	-	-	-	-	
f. 10/4-10/20	1808	19	6+	4	3	1	-	-	-	-	-	-	-	-	-	-	
g. 6/22-6/23	1809	2	8+	1	-	-	-	-	-	-	-	-	-	-	-	-	
h. 7/22-7/30	1809	9	6+	1	3	3	-	-	-	-	-	-	-	-	-	-	
i. 6/20-6/22	1810	3	8-11	2	1	1	-	1	-	-	-	-	-	-	-	-	
j. 10/29-12/29	1810	62	24	2	14	1	-	1	1	-	-	-	-	1	-	-	
k. 5/14-5/16	1812	3	4	1	-	-	-	-	-	-	-	-	-	-	-	-	
3. Alexander Henry a. 2/3-2/4	1811	2	8	-	-	1	-	-	-	-	-	-	-	-	-	-	
b. 2/12-2/13	1811	2	8	-	-	-	-	-	-	-	-	-	-	-	-	-	
4. Gabriel Franchère 5/25-5/28	1814	4	10	1	-	-	-	-	1	-	-	-	-	-	-	-	
5. George Simpson a. 4/28-4/29	1825	2	12+	1	-	-	-	-	1 ⁴	-	-	-	-	-	-	-	
b. 7/31-8/1	1841	2	12+	-	1	-	-	-	-	-	-	-	-	-	-	-	
6. David Douglas 5/5-5/7	1827	3	9+	-	-	-	-	-	1	-	-	-	-	-	-	-	
7. Edward Ermatinger 9/23-10/1	1828	9	49	-	-	-	-	-	-	-	-	-	-	-	-	-	
8. James Hector a. 8/6-8/7	1858	2	5	-	-	1	-	-	-	-	-	-	-	-	1	-	
b. 9/28-10/2	1858	5	5	-	-	-	-	-	-	-	-	-	-	-	-	-	
c. 12/10-12/14	1858	5	4	-	1	2 ⁵	-	-	-	-	-	-	-	-	-	-	
d. 1/21-1/30	1859	10	4	-	-	-	-	-	-	-	-	-	-	-	-	-	
e. 2/20-2/25	1859	6	4	-	-	-	-	-	-	-	-	-	-	-	-	-	
f. 8/15-8/16	1859	2	9	-	-	1	-	-	-	-	-	-	-	-	-	-	
9. John Palliser 8/10-8/17	1858	8	6	1	-	2	-	-	-	-	-	-	-	-	-	-	
10. James Carnegie a. 8/25-9/1	1859	7	11	-	-	-	-	-	1	-	-	-	-	-	-	-	
b. 10/1-10/5	1859	5	11	-	-	19	-	-	-	-	1	-	-	-	-	-	
11. W.B. Cheadle 6/17-6/28	1863	12	6	-	-	-	-	-	1	-	-	-	-	-	-	-	
Total	1792-1863	212	Varied	19	35	32+	-	4	8	-	1	-	-	1	1	-	

¹ See Table 2.3 for citations.

² Species not reported in original journals.

³ Thompson wrote: "Buffalo, Red Deer, Moose & small Deer are also Plenty and Grizzly Bears but too many."

⁴ On April 29 Simpson wrote: "Saw about 50 Moose & Red Deer, but time was too valuable to amuse ourselves in hunting."

⁵ On December 11 Hector stated that "The Virginian [white-tailed] deer is very abundant in this district, and we are continually starting them..." and again on December 13 he noted that "we started band after band of deer, just as if we were passing through a deer park. This is the only time that I have ever seen game in such plenty in the country, excepting of course buffalo herds."

Explorers of the Foothills region did not make frequent reference to animal sign. This may be due to the fact that ungulates were apparently being seen and killed at a far greater frequency than in the Rocky Mountains or Columbia Valley. Table 2.2 does indicate, however, that sign of bison and moose were each recorded on four occasions and wolf twice. Bear sign of undetermined species was noted twice and grizzly bear sign once. There were only four references to a lack of game or food and, in all cases, these were recorded in the northern half of the Foothills region between the North Saskatchewan and Athabasca Rivers. No reference to lack of game was made in the southern half of the Foothills.

Table 2.3 presents the total number of animals killed by explorers in the Foothills. These figures support those found in the observations table. A total of 43 bison were killed compared to 24+ deer and 19 elk. Nine moose, five bighorn sheep, one grizzly, and one black bear were also taken.

Rocky Mountains

Wildlife observations in the Rocky Mountains are presented in Tables 2.4, 2.5, and 2.6. These tables summarize the journals of twenty-six expeditions that spent a total of 369 days traveling in this region

between 1792 and 1872. Bighorn sheep was by far the most frequently observed large animal with 69 sightings. Bison were observed on 39 occasions, moose 27, and mountain goat 23. As for elk, one of the most numerous and frequently seen ungulates in the Rockies today, only 12 observations are recorded by early explorers. This is a figure equal to the total number of grizzly and black bear sightings. Other large animal observations included deer 7 times, caribou 4, wolf 3, and cougar 2.

TABLE 2.2. FOOTHILLS: PART II - ANIMAL SIGN. Historical evidence relating to the distribution and abundance of ungulates in the Foothills region from 1792 to 1863. Number of occasions on which animal sign was reported to have been seen, heard or referenced by early explorers. To make the table more readable, dashes were used instead of zeros for species that were not reported.

Observer ¹	Date	Number of occasions on which animal sign was seen, heard or referenced											Number of occasions on which Natives were seen or sign observed or referenced		Reference to lack of game or lack of food.
		Elk	Bison	Deer	Goat	Bighorn Sheep	Moose	Caribou	Wolf	Cougar	Grizzly Bear	Black Bear	Seen	Sign	
1. Peter Fidler	12/30-1/2	1792-93	-	-	-	-	-	-	-	-	-	-	-	1	-
2. David Thompson															
a. 10/11-10/14	1800	-	-	-	-	-	-	-	-	-	-	-	3	-	-
b. 11/29-12/1	1800	-	1	-	-	-	-	-	-	-	-	-	-	-	-
c. 6/6-6/11	1801	-	-	-	-	-	-	-	-	-	1	-	-	-	-
d. 5/10-5/16	1807	-	-	-	-	-	-	-	-	-	-	-	1	-	-
e. 6/24-6/26	1808	-	-	-	-	-	-	-	-	-	-	-	-	-	-
f. 10/4-10/20	1808	-	-	-	-	-	-	-	-	-	-	-	-	-	-
g. 6/22-6/23	1809	-	-	-	-	-	-	-	-	-	-	-	-	-	-
h. 7/22-7/30	1809	-	-	-	-	-	-	-	-	-	-	-	-	-	-
i. 6/20-6/22	1810	-	-	-	-	-	-	-	-	-	-	-	-	-	-
j. 10/29-12/29	1810	-	1	-	-	-	1	-	-	-	-	-	1	-	-
k. 5/14-5/16	1812	-	-	-	-	-	-	-	-	-	-	-	-	-	-
3. Alexander Henry															
a. 2/3-2/4	1811	-	-	-	-	-	-	-	1	-	-	-	-	-	-
b. 2/12-2/13	1811	-	-	-	-	-	-	-	1	-	-	-	-	-	-
4. Gabriel Franchère															
5/25-5/28	1814	-	-	-	-	-	-	-	-	-	-	-	-	-	-
5. George Simpson															
a. 4/28-4/29	1825	-	-	-	-	-	-	-	-	-	-	-	-	-	-
b. 7/31-8/1	1841	-	1	-	-	-	-	-	-	-	-	-	-	1	-
6. David Douglas															
5/5-5/7	1827	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7. Edward Ermatinger															
9/23-10/1	1828	-	-	-	-	-	-	-	-	-	-	-	1	-	-
8. James Hector															
a. 8/6-8/7	1858	-	-	-	-	-	-	-	-	-	-	-	2	-	-
b. 9/28-10/2	1858	1	-	-	-	-	-	-	-	-	-	-	-	1	-
c. 12/10-12/14	1858	-	-	-	-	-	-	-	-	-	-	-	-	-	-
d. 1/21-1/30	1859	-	-	-	-	-	-	-	-	-	-	-	1	2	-
e. 2/20-2/25	1859	-	-	-	-	-	-	-	-	-	-	-	-	-	-
f. 8/15-8/16	1859	-	-	-	-	-	-	-	-	-	-	-	-	-	-
9. John Palliser															
8/10-8/17	1858	-	-	-	-	-	-	-	-	-	-	-	-	1	-
10. James Carnegie															
a. 8/25-9/1	1859	-	-	-	-	-	1	-	-	-	-	-	-	1	-
b. 10/1-10/5	1859	-	1	-	-	-	-	-	-	-	-	-	-	-	-
11. W.B. Cheadle															
6/17-6/28	1863	-	-	-	-	-	2	-	-	-	-	-	2	-	-
Total	1792-1863	1	4	-	-	-	4	-	2	-	1	-	2	10	6+

¹ See Table 2.3 for Citations.

² Species not reported in original journals.

TABLE 2.3. FOOTHILLS: PART III - ANIMALS KILLED. Historical evidence relating to the distribution and abundance of ungulates in the Foothills region from 1792 to 1863. Number of ungulates and other large animals reported to have been killed by early explorers. To make the table more readable, dashes were used instead of zeros for species that were not reported.

Observer	Date	Number of ungulates and other large animals killed											Reference
		Elk	Bison	Deer	Goat	Bighorn Sheep	Moose	Caribou	Wolf	Cougar	Grizzly Bear	Black Bear	
1. Peter Fidler 12/30-1/2	1792-93	-	1	-	-	-	-	-	-	-	-	-	Fidler 1991: 42-54
2. David Thompson a. 10/11-10/14	1800	-	1	-	-	-	-	-	-	-	-	-	Thompson 1800
b. 11/29-12/1	1800	-	-	-	-	4	-	-	-	-	-	-	Thompson 1800
c. 6/6-6/11	1801	-	6	-	-	-	3	-	-	-	-	-	Dempsey 1965:3-6
d. 5/10-5/16	1807	2	4	-	-	-	-	-	-	-	-	-	Thompson 1807
e. 6/24-6/26	1808	-	1	-	-	-	-	-	-	-	-	-	Thompson 1808
f. 10/4-10/20	1808	10	8	1	-	-	-	-	-	-	-	-	Thompson 1808
g. 6/22-6/23	1809	1	-	-	-	-	-	-	-	-	-	-	Thompson 1809
h. 7/22-7/30	1809	-	1	2	-	-	-	-	-	-	-	-	Thompson 1809
i. 6/20-6/22	1810	2	1	-	-	-	-	-	-	-	-	-	Thompson 1810
j. 10/29-12/29	1810	3	18	1	-	1	2	-	-	-	1	-	Thompson 1810
k. 5/14-5/16	1812	-	-	-	-	-	-	-	-	-	-	-	Thompson 1812
3. Alexander Henry a. 2/3-2/4	1811	-	-	-	-	-	-	-	-	-	-	-	Coues 1965: 676-678
b. 2/12-2/13	1811	-	-	-	-	-	-	-	-	-	-	-	Coues 1965: 698-699
4. Gabriel Franchère 5/25-5/28	1814	1	-	-	-	-	2	-	-	-	-	-	Franchère 1969: 163-165
5. George Simpson a. 4/28-4/29	1825	-	-	-	-	-	1	-	-	-	-	-	Merk 1931:148
b. 7/31-8/1	1841	-	-	-	-	-	-	-	-	-	-	-	Simpson 1841
6. David Douglas 5/5-5/7	1827	-	-	-	-	-	-	-	-	-	-	-	Douglas 1959: 262-263
7. Edward Ermatinger 9/23-10/1	1828	-	-	-	-	-	-	-	-	-	-	-	Ermatinger 1912: 106-108
8. James Hector a. 8/6-8/7	1858	-	-	-	-	-	-	-	-	-	-	1	Spry 1968: 287-289
b. 9/28-10/2	1858	-	-	-	-	-	-	-	-	-	-	-	Spry 1968: 336-337
c. 12/10-12/14	1858	-	2	1 ²	-	-	-	-	-	-	-	-	Spry 1968: 354-357
d. 1/21-1/30	1859	-	-	-	-	-	-	-	-	-	-	-	Spry 1968: 334-368
e. 2/20-2/25	1859	-	-	-	-	-	-	-	-	-	-	-	Spry 1968: 382-384
f. 8/15-8/16	1859	-	-	-	-	-	-	-	-	-	-	-	Spry 1968: 433-435
9. John Palliser 8/10-8/17	1858	-	-	2	-	-	-	-	-	-	-	-	Spry 1968: 264-268
10. James Carnegie a. 8/25-9/1	1859	-	-	-	-	-	1	-	-	-	-	-	Southesk 1969: 175-190
b. 10/1-10/5	1859	-	-	17	-	-	-	-	-	-	-	-	Southesk 1969: 254-264
11. W.B. Cheadle 6/17-6/28	1863	-	-	-	-	-	-	-	-	-	-	-	Cheadle 1971: 153-160
Total	1792-1863	19	43	24	-	5	9	-	-	-	1	1	

¹ Species not reported in original journals.

² Hector stated that "Virginian deer is very abundant in this district..." and "...there is one killed nearly every day by some of us."

TABLE 2.4. ROCKY MOUNTAINS: PART I - ANIMALS OBSERVED. Historical evidence relating to the distribution and abundance of ungulates in the Rocky Mountain region from 1792 to 1872. Number of occasions on which large animals were reported to have been seen by early explorers. To make the table more readable, dashes were used instead of zeros for species that were not reported.

Observer ¹	Date	Trip Length (days)	Size of party	Number of ungulates and other large animals observed											
				Elk	Bison	Deer	Goat	Bighorn Sheep	Moose	Caribou	Wolf	Cougar	Grizzly Bear	Black Bear	Beaver ²
1. Peter Fidler	12/31-1/1	1792-93	1	43+	-	-	-	-	-	-	-	-	-	-	-
2. David Thompson															
a. 6/12-6/14	1801	3	11	-	1	-	-	1 ³	-	-	-	-	-	-	-
b. 5/17-6/30	1807	45	9+	2	13	-	1	3	-	-	-	-	-	2	-
c. 6/18-6/23	1808	5	6+	2	-	-	-	2	-	-	-	-	-	1	-
d. 10/21-10/31	1808	9	6+	-	5	-	2	1	-	-	-	-	-	-	-
e. 6/10-6/21	1809	12	6+	2	2	-	-	3	-	-	-	-	-	-	-
f. 7/31-8/13	1809	11	6+	-	3	-	-	3	-	-	-	-	-	-	-
g. 6/12-6/19	1810	3	8-11	-	1	-	-	-	-	-	-	-	-	-	-
h. 12/30-1/19	1810-11	21	13	-	3	-	-	2	3	-	-	-	-	-	-
i. 5/6-5/13	1812	8	3	-	1	-	-	2	-	-	-	-	-	-	-
3. Alexander Henry	2/5-2/12	1811	8	8	8	-	2	10	-	-	2	-	-	-	-
4. Gabriel Franchère	5/12-5/24	1814	13	10	1	-	-	-	-	-	-	-	-	-	-
5. George Simpson															
a. 10/10-10/19	1824	10	12	-	-	-	1	1	-	-	-	-	-	-	-
b. 4/22-4/28	1825	7	12+	-	-	-	-	-	-	-	-	-	-	-	-
c. 8/2-8/7	1841	6	12+	1	-	-	1	1	-	-	-	-	-	-	-
6. David Douglas	4/28-5/5	1827	8	9	-	-	-	2	-	-	-	-	-	-	-
7. Edward Ermattinger	9/23-10/1	1828	10	49	-	-	-	-	2	-	-	-	1	-	-
8. Henry J. Warre	7/24-7/30	1845	7	16	1	-	1	-	1	-	-	-	1	-	-
9. James Hector															
a. 8/11-9/27	1858	48	5	3	-	2	4	10	14	-	-	2	-	1	1
b. 1/31-2/19	1859	20	4	-	-	-	1	4	-	1	1	-	-	-	-
c. 8/17-9/16	1859	31	9	1	-	3	3	6	5	-	-	-	-	1	-
10. John Palliser	8/18-8/28	1858	11	1	1	-	2	1	-	-	-	-	1	-	-
11. James Carnegie	9-2-9/30	1859	29	11	-	-	-	5	16	2	-	-	2	-	-
12. W.B. Cheadle	6/29-7/17	1863	19	6	-	-	1	2	-	-	-	-	-	-	-
13. Walter Moberly															
a. 10/10-10/23	1871	14	4+	-	-	-	-	-	-	-	-	-	-	-	-
b. 8/28-9/6	1872	10	4	-	-	-	-	-	-	3	-	-	1	-	-
Total	1792-1872	369	Varied	12	39	7	23	69	27	4	3	2	6	5	1

¹ See Table 2.6 for citations.

² Species not reported in original journals.

³ Thompson referred to sheep as goats, so it is likely that "three Mountain Goats" killed were sheep. After 1807, however, he referred to these animals by their correct names.

TABLE 2.5. ROCKY MOUNTAINS: PART II - ANIMAL SIGN. Historical evidence relating to the distribution and abundance of ungulates in the Rocky Mountain region from 1792 to 1872. Number of occasions on which animal sign was reported to have been seen, heard or referenced by early explorers. To make the table more readable, dashes were used instead of zeros for species that were not reported.

Number of occasions on which animal sign was seen, heard or referenced													Number of occasions on which Natives were seen or sign observed or referenced		Reference to lack of game or lack of food	
Observer ¹	Date	Elk	Bison	Deer	Goat	Bighorn Sheep	Moose	Caribou	Wolf	Cougar	Grizzly Bear	Black Bear	Bear ²	Seen	Sign	
1. Peter Fidler 12/31-1/1	1792-93	-	-	-	-	1	-	-	-	-	-	-	-	1	-	-
2. David Thompson a. 6/12-6/14	1801	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
b. 5/17-6/30	1807	1	1	-	-	-	2	-	-	-	-	-	-	1	-	5
c. 6/18-6/23	1808	-	1	-	-	-	-	-	-	-	-	-	-	-	-	1
d. 10/21-10/31	1808	-	2	-	-	-	-	-	-	-	-	-	-	-	-	-
e. 6/10-6/21	1809	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
f. 7/31-8/13	1809	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
g. 6/17-6-19	1810	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
h. 12/30-1/19	1810-11	1	3	-	-	1	1	-	-	-	1	-	-	-	-	-
i. 5/6-5/13	1812	-	-	-	-	-	1	-	-	-	1	-	-	-	-	-
3. Alexander Henry 2/5-2/12	1811	-	6	-	1	3	-	-	1	-	-	-	-	-	1	1
4. Gabriel Franchère 5/25-5/28	1814	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
5. George Simpson a. 10/10-10/19	1824	-	1	1	1	1	-	-	-	-	-	-	-	-	-	3
b. 4/22-4/28	1825	-	-	-	-	-	-	-	-	-	-	-	-	1	-	1
c. 8/2-8/7	1841	1	1	-	2	2	1	-	1	-	-	-	1	-	-	3
6. David Douglas 4/28-5/5	1827	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
7. Edward Ermattinger 9/23-10/1	1828	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
8. Henry J. Warre 7/24-7/30	1845	-	-	-	1	1	-	-	-	-	-	-	-	-	-	-
9. James Hector a. 8/11-9/27	1858	3	1	2	2	1	2	-	-	1	-	-	1	1	2	2
b. 1/31-2/19	1859	-	-	-	-	-	-	1	1	-	-	-	-	-	-	1
c. 8/17-9/16	1859	2	1	2	-	-	2	-	-	1	-	-	3	-	-	-
10. John Palliser 8/18-8/28	1858	-	-	-	-	-	-	-	-	-	1	-	-	-	2	-
11. James Carnegie 9/2-9/30	1859	-	-	-	-	-	1	-	-	-	-	-	2	1	-	-
12. W.B. Cheadle 6/29-7/17	1863	-	-	-	-	1	-	-	-	-	-	-	-	1	2	-
13. Walter Moberly a. 10/10-10-23	1871	3	2 ⁴	1	-	1	-	2	-	-	1	-	1	-	1	-
b. 8/28-9/6	1872	-	-	-	-	-	-	3	-	-	1	-	-	-	1	-
Total	1792-1872	11	12	6	7	12	10	6	3	2	5	-	8	5	10	17

¹ See Table 2.6 for citations

² Species not reported in original journals.

³ Simpson commented that, after crossing the Miette River, "The country...appears well stocked with animals."

⁴ Moberly noted that all bison sign was old. "In bye gone years these animals must have been plentiful here as I saw a good many of their skulls & innumerable places they had hollowed out in the soft ground to lie in."

TABLE 2.6. ROCKY MOUNTAINS: PART III - ANIMALS KILLED. Historical evidence relating to the distribution and abundance of ungulates in the Rocky Mountain region from 1792 to 1872. Number of ungulates and other large animals reported to have been killed by early explorers. To make the table more readable, dashes were used instead of zeros for species that were not reported.

Observer	Date	Number of ungulates and other large animals killed											Reference
		Elk	Bison	Deer	Goat	Bighorn Sheep	Moose	Caribou	Wolf	Cougar	Grizzly Bear	Black Bear	
1. Peter Fidler	1792-93	-	-	-	-	-	-	-	-	-	-	-	Fidler 1991: 44-53
2. David Thompson													
a. 6/12-6/14	1801	-	-	-	-	3 ²	-	-	-	-	-	-	Thompson 1801
b. 5/17-6/30	1807	2	12	-	-	2	-	-	-	-	-	2	Thompson 1807
c. 6/18-6/23	1808	-	4	-	-	1	-	-	-	-	-	-	Thompson 1808
d. 10/21-10/31	1808	-	-	-	3	1	-	-	-	-	-	-	Thompson 1808
e. 6/10-6/21	1809	2	3	-	-	14	-	-	-	-	-	-	Thompson 1809
f. 7/31-8/13	1809	-	2	-	-	2	-	-	-	-	-	-	Thompson 1809
g. 6/17-6/19	1810	-	1	-	-	-	-	-	-	-	-	-	Thompson 1810
h. 12/30-1/19	1810-11	-	3	-	-	3	4	-	-	-	-	-	Thompson 1810-11
i. 5/6-5/13	1812	-	-	-	-	4	-	-	-	-	-	-	Thompson 1812
3. Alexander Henry													
2/5-2/12	1811	-	8	-	-	7	-	-	1	-	-	-	Coues 1965: 679-698
4. Gabriel Franchère													
5/12-5/24	1814	-	-	-	-	-	-	-	-	-	-	-	Franchère 1969: 158-163
5. George Simpson													
a. 10/10-10/19	1824	-	-	-	2	2	-	-	-	-	-	-	Merk 1931: 29-36
b. 4/22-4/28	1825	-	-	-	-	-	-	-	-	-	-	-	Merk 1931: 143-148
c. 8/2-8/7	1841	1	-	-	-	-	-	-	-	-	-	-	Simpson 1841
6. David Douglas													
4/28-5/5	1827	-	-	-	-	2	-	-	-	-	-	-	Douglas 1959: 255-262
7. Edward Ermattinger													
10/1-10/10	1828	-	-	-	-	-	3	-	-	-	1	-	Ermatinger 1912: 108-110
8. Henry J. Warre													
7/24-7/30	1845	-	1	-	-	-	1	-	-	-	-	-	Warre 1845
9. James Hector													
a. 8/11-9/27	1858	1	-	1	2	20	13	-	-	-	-	-	Spry 1968: 289-335
b. 1/31-2/19	1859	-	-	-	-	3	-	-	4 ³	-	-	-	Spry 1968: 368-382
c. 8/17-9/16	1859	1	-	3	6	7	2	-	-	-	-	-	Spry 1968: 435-453
10. John Palliser													
8/18-8/28	1858	2	-	2	-	-	-	-	-	-	-	-	Spry 1968: 269-279
11. James Carnegie													
9/2-9/30	1859	-	-	-	2	32	3	-	-	-	-	-	Southesk 1969: 190-251
12. W.B. Cheadle													
6/29-7/17	1863	-	-	-	2	10	-	-	-	-	-	-	Cheadle 1971: 160-181
13. Walter Moberly													
a. 10/10-10/23	1871	-	-	-	-	-	-	-	-	-	-	-	Moberly 1871
b. 8/28-9/6	1872	-	-	-	-	-	-	4	-	-	-	-	Moberly 1872
Total	1792-1872	9	34	6	17	113	26	4	5	-	1	2	

¹ Species not reported in original journals.

² Thompson referred to sheep as goats the previous autumn, so it is likely that "three Mountain Goats" killed were sheep. After 1807, however, he referred to these animals by their correct names.

³ Hector wrote that the Jasper House factor baited and killed four wolves with strychnine.

Animal sign observations for the Rocky Mountains are summarized in Table 2.5. Elk sign was observed on only 11 occasions, nearly equal to moose at 10. Bison sign was recorded on 19 occasions and bighorn sheep on 12. Although bighorn sheep were by far the most frequently seen and killed ungulate in the Rocky Mountains, their sign was seldom recorded. As bighorns were usually not tracked like other ungulates, it is understandable why sign of these animals would not be mentioned as frequently as one might otherwise expect.

The most revealing statistics on the relative abundance of ungulates in the Rocky Mountains, however, are found in Table 2.6 -- the record of animals actually killed. As previously indicated, bighorn sheep lead the tally with 113 animals. Bison were second with 34 kills, followed by moose at 26, and mountain goat at 17. Elk placed a distant fifth with only 8 animals killed. Considering that on many of the 369 days these early parties were traveling through the Rockies, two or more hunters were sent out in search of food, and that much of the hunting took place in montane valleys where elk are now the most common ungulate, the total of only eight animals killed is revealing and suggests that elk were not as common ca. 1800-1870 as they are today. Other animals killed by early explorers in the Rocky Mountains included 6 deer (both mule and white-tailed), 5 wolves, 4 caribou, 2 black bear, and one grizzly.

While these sighting and kill rates appear to indicate that at least some game species were once relatively common in the Canadian Rockies, such may not have been the case. Early explorers, for instance, made 17 references to a general lack of game while they were in the mountains, and aside from occasional groups of bighorn sheep, large herds of ungulates were not encountered in the Canadian Rockies ca. 1800-1870. There certainly is no evidence that there were game animals, and especially elk, standing behind every tree, as some people have suggested (Millar 1915; Bryne 1968; Nelson 1969a, 1969b, 1970; Morgantini 1995). Moreover, of the wildlife sightings and kills reported in Tables 2.4 and 2.6, a large percentage occurred in one area -- Kootenay Plains. Compared to the rest of the Canadian Rockies, early explorers reported killing elk 5.2 times more frequently once they reached the Kootenay Plains -- one elk killed per 56.2 days in other areas of the mountains versus one elk killed per 10.7 days on Kootenay Plains. Bison were killed 2.3 times more frequently on Kootenay Plains (12.0 vs. 5.3 days per kill), while bighorn sheep were killed 4.2 times more frequently (4.2 vs. 1.0 days per kill). No deer or mountain goats, and only one moose, however, were killed on Kootenay Plains.

Columbia Valley

The Columbia Valley recorded the fewest number of expeditions and explorer-days of the three regions analyzed in this study. Our survey uncovered journals of only eleven parties which spent a total of 161 days within the Rocky Mountain Trench. These journals encompass a period starting in 1807 and ending in 1859. Table 2.7 indicates that the large mammal most frequently seen in the Columbia was deer with 14 observations. Elk was the second with 7. The remainder of sightings were divided between bighorn sheep 2, moose 2, mountain goat 1, wolf 1, and black bear 1.

Tracks and other sign of large animals were also seldom reported in the Columbia, as indicated in Table 2.8. Sign of deer was noted on 5 occasions, moose 4, elk 4, and bear once. The only elk sign recorded after 1811 was by James Hector who passed a large pile of antlers on his way south from the mouth of the Blaeberry River in 1859. He suggested antlers had been stacked there for many years, but noted that none were from recent kills. References to a general lack of game were made on 9 occasions, a rate which is 21% higher per expedition-day than that recorded in the Rocky Mountains.

TABLE 2.7. COLUMBIA VALLEY: PART I - ANIMALS OBSERVED. Historical evidence relating to the distribution and abundance of ungulates in the Columbia Valley from 1807 to 1859. Number of occasions on which large animals were reported to have been seen by early explorers. To make the table more readable, dashes were used instead of zeros for species that were not reported.

Number of ungulates and other large animals observed																
Observer ¹	Date	Length of trip (days)	Size of party	Elk	Bison	Deer	Goat	Bighorn Sheep	Moose	Caribou	Wolf	Cougar	Grizzly Bear	Black Bear	Bear ²	
1. David Thompson																
a. 7/1-7/19	1807	19	9+	1	-	8	-	-	-	-	-	-	-	-	-	
b. 6/5-6/17	1808	13	6+	1	-	1	-	-	-	-	-	-	-	-	-	
c. 11/1-11/13	1808	13	6+	-	-	-	-	-	-	-	-	-	-	-	-	
d. 4/27-6/9	1809	44	8+	2	-	3	1	-	-	-	1	-	-	-	-	
e. 8/14-8/20	1809	7	8+	1	-	1	-	1	-	-	-	-	-	-	-	
f. 6/8-6/16	1810	9	8-11+	-	-	-	-	-	-	-	-	-	-	-	-	
g. 4/17-5/14	1811	28	4	2	-	1	-	-	-	-	-	-	-	-	-	
h. 9/18-9/23	1811	6	8	-	-	-	-	-	2	-	-	-	-	-	-	
2. George Simpson																
8/7-8/9	1841	3	12+	-	-	-	-	-	-	-	-	-	-	-	-	
3. Henry J. Warre																
7/30-8/1	1845	3	16	-	-	-	-	1	-	-	-	-	-	-	-	
4. James Hector																
9/17-10/2	1859	16	9	-	-	-	-	-	-	-	-	-	-	1	-	
Total	1807-1859	161	Varied	7	-	14	1	2	2	-	1	-	-	1	-	

¹ See Table 2.9 for citations.

² Species not reported in original journals.

TABLE 2.8. COLUMBIA VALLEY: PART II - ANIMAL SIGN. Historical evidence relating to the distribution and abundance of ungulates in the Columbia Valley from 1807 to 1859. Number of occasions on which animal sign was reported to have been seen, heard or referenced by early explorers. To make the table more readable, dashes were used instead of zeros for species that were not reported.

Observer ¹	Date	Number of occasions on which animal sign was seen, heard or referenced												Number of occasions on which Natives were seen or sign observed or referenced		Reference to lack of game or lack of food
		Elk	Bison	Deer	Goat	Bighorn Sheep	Moose	Caribou	Wolf	Cougar	Grizzly Bear	Black Bear	Bear ²	Seen	Sign	
1. David Thompson																
a. 7/1-7/19	1807	1	-	2	-	-	-	-	-	-	-	-	-	2	-	2
b. 6/5-6/17	1808	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
c. 11/1-11/13	1808	-	-	1	-	-	-	-	-	-	-	-	-	-	-	2
d. 4/27-6/9	1809	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1
e. 8/14-8/20	1809	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
f. 6/8-6/16	1810	1	-	1	-	-	-	-	-	-	-	-	-	1	-	2
g. 4/17-5/14	1811	2	-	-	-	-	-	-	-	-	-	-	-	1	-	1
h. 9/18-9/23	1811	-	-	-	-	-	3	-	-	-	-	-	-	-	-	3
2. George Simpson																
8/7-8/9	1841	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-
3. Henry J. Warre																
7/30-8/1	1845	-	-	1	-	-	1	-	-	-	-	-	1	-	1	-
4. James Hector																
9/17-10/2	1859	1 ⁴	-	1	-	-	-	-	-	-	-	-	-	3	1	-
Total	1807-1859	5	-	6	-	-	4	-	-	-	-	-	1	7	3	9

¹ See Table 2.9 for citations

² Species not reported in original journals.

³ An exploration of the Canoe River following the Rocky Mountain Trench north 50 miles from the Big Bend of the Columbia River. Thompson wrote in his *Narrative* (Glover, p. 324) that "Moose Deer and Beaver were plentiful" in this valley.

⁴ Hector indicated that this was old sign, writing that: "Elk or wapiti must at one time have been very numerous in this district, as we saw a great many antlers lying on the ground, and sometimes the Indians had piled them in heaps of 50 or 60 together. . . We have not seen a single track of an elk yet in the valley, and but only a few of the smaller deer."

TABLE 2.9. COLUMBIA VALLEY: PART III - ANIMALS KILLED. Historical evidence relating to the distribution and abundance of ungulates in the Columbia Valley from 1807 to 1859. Number of ungulates and other large animals reported to have been killed by early explorers. To make the table more readable, dashes were used instead of zeros for species that were not reported.

Observer	Date	Number of ungulates and other large animals killed											Reference
		Elk	Bison	Deer	Goat	Bighorn Sheep	Moose	Caribou	Wolf	Cougar	Grizzly Bear	Black Bear	
1. David Thompson													
a. 7/1-7/19	1807	1	-	7	-	-	-	-	-	-	-	-	Thompson 1807
b. 6/5-6/17	1808	1	-	1	-	-	-	-	-	-	-	-	Thompson 1808
c. 11/1-11/13	1808	-	-	-	-	-	-	-	-	-	-	-	Thompson 1808
d. 4/27-6/9	1809	1	-	3	2	-	-	-	1	-	-	-	Thompson 1809
e. 8/14-8/20	1809	1	-	1	-	3	-	-	-	-	-	-	Thompson 1809
f. 6/8-6/16	1810	-	-	-	-	-	-	-	-	-	-	-	Thompson 1810
g. 4/17-5/14	1811	3	-	1	-	-	-	-	-	-	-	-	White 1950: 139-165
h. 9/18-9/23	1811	-	-	-	-	-	1	-	-	-	-	-	Thompson 1811
2. George Simpson													
8/7-8/9	1841	-	-	-	-	-	-	-	-	-	-	-	Simpson 1841
3. Henry J. Warre													
7/30-8/1	1845	-	-	-	-	-	-	-	-	-	-	-	Warre 1845
4. James Hector													
9/17-10/2	1859	-	-	-	-	-	-	-	-	-	-	1	Spry 1968: 453-461
Total	1807-1859	7	-	13	2	3	1	-	1	-	-	1	

¹ Species not reported in original journals

Table 2.9 indicates that deer were the most frequently killed animal with a total of 13, all taken by David Thompson south of the mouth of the Blaeberry River between 1807 and 1811. Elk kills totaled 7, again all by David Thompson and his men prior to 1812. Other recorded kills include 3 bighorn sheep, 2 mountain goats, 1 moose, 1 wolf, and 1 black bear. It should be noted that all moose observations and kills were recorded in the Canoe Valley north of the Big Bend on the Columbia.

JUDGING THE VALIDITY OF EARLY REPORTS

Most ecologists, who have used written records to estimate the early abundance of wildlife, have made little or no attempt to judge the validity of their historical source materials (e.g., Murie 1940; Byrne 1968; Nelson 1969a, 1969b, 1970; Gruell 1973; Houston 1982; Morgantini 1995). But as Forman and Russell (1983:5) asked "If we read something written today, do we automatically believe it? If we read something written a long time ago ... do we believe it?" They noted that "Too often the answer to the last questions is 'yes', simply because information is scarce and the statement is old [emphasis in original]." Historians, however, have developed standard source-evaluation techniques that can be used to gauge the validity of historical statements regarding the 1792-1872 distribution and abundance of ungulates in the Central Canadian Rockies Ecosystem (Rusco 1976, Price 1980, Forman and Russell 1983, Black-Rogers 1986). These include (1) first or second-hand observations and the credibility of the observer, (2) purpose or possible bias of the statements, (3) author's knowledge of the subject, and (4) context of the statement including negative information.

(1) First or second-hand observations. Did the author of a statement personally make the observation reported, or was it learned second- or third-hand? Was it written at the time of the event or was it written long after the fact based solely on memory? Was the observer credible? And do the statements appear to be within reason?

Except as noted in the text, we relied primarily on first-person historical accounts and only those are included in our summary Tables 2.1-2.9. To the best of our knowledge, other first-person journals of comparable quality are not known to exist for the Canadian Rockies. There are other narrative accounts of early exploration, but these were not included in our analysis because historians have determined that narrative accounts are not as accurate as first-person journals written at the time of the event (White 1991:613-632). White (1991:618) noted that daily journals kept by early western travelers often differ from their latter narrative accounts because the narratives were written to conform with accepted social myths. Unlike journals, which were usually written for personal use, narratives were written for publication and had to conform to accepted social traditions if they were to be widely read and financially successful. During the 1800's, the myth that the West was a "Garden of Eden" teeming with wildlife but overrun with hostile "savages" colored most narratives (White 1991:613-632).

All of the historical accounts found in Tables 2.1-2.9 appear to have been written by the observer at the time of the event or shortly thereafter. Several, however, do contain some second-hand information relating to the early abundance of elk and other ungulates. When Hector (Spry 1968) was camped near the head of the Pipestone River, for instance, he included a description of how two years earlier one of his native hunters had killed bison in that location. This and comparable accounts are clearly second-hand information and are not as reliable as if the writers had actually seen the animals themselves. Similarly, Rylatt's (1991) narrative cited above is not as reliable as are David Thompson's journals.

Of the more than 20 historical accounts summarized in Tables 2.1-2.9, all appear to have been written by credible observers, and none appear to have exaggerated what they saw or how many animals they found, except perhaps Simpson (see below). We did not encounter instances of wild exaggeration in these journals as has been reported in other historical studies (Kay 1990:277-278, Kay in press a).

(2) Purpose or possible bias of the statement. "Did the author of the statement have a special interest or bias which may have colored the statement?" (Forman and Russell 1983:6). Or did the author color his entire journal?

Since most of the journals we used were not written with an intent to publish, and as noted previously many have not been published to this day, there appears to have been little incentive for these people to have biased their chronicles. Only, George Simpson (1841, Merk 1931) may have had a reason to be overly optimistic about how much game his fur brigades could expect to find in the Canadian Rockies. After all, he was in the business of promoting the fur trade, and local food supplies were exceedingly important for they lowered costs and increased profits. During the height of the fur trade, the Hudson's Bay Company maintained posts on the Canadian prairies whose primary purpose was to secure dried meat and pemmican to provision posts further north and west where game was not abundant.

There is another source of bias in all of these journals, though, that is much more difficult to address. The procedures we used to compile our summary tables assume that animals were seen, killed, and recorded in proportion to their historical abundance. This may or may not be an appropriate assumption. Rare animals or highly prized game animals, such as elk, may have been recorded more often than common species. It is well known that people have a tendency to more frequently write down events which are of importance or interest to them (Rusco 1976). So, we suspect that a higher proportion of elk sightings, sign, and kills were recorded by early visitors to the Central Canadian Rockies than were similar data on other animals, because elk were probably more important to them than were the smaller ungulates. There certainly is no indication that elk would have gone under-reported or unreported if they had actually been encountered by early explorers (Kay 1990).

(3) Author's knowledge of the subject. Although few early explorers of the Central Canadian Rockies had any formal zoological training, we assume that all could tell the various ungulate species apart on sight. It would, though, be more difficult to distinguish between their sign. Could early explorers, for instance, tell deer tracks from bighorn sheep tracks? Or elk, from moose, from caribou tracks? Or black bear from grizzly tracks? Or wolf, coyote, and mountain lion tracks apart? There simply is no way to tell. It would even be more difficult to positively identify animal calls, such as the howls of wolves and coyotes or the screams of mountain lions. So, observations recorded in Tables 2.1, 2.4, and 2.7 (actual sightings) and Tables 2.3, 2.6, and 2.9 (animals killed) are more reliable than those based on other information (Tables 2.2, 2.5, and 2.8).

(4) Negative information and the context of early statements. When early explorers reported little or no game does that mean they actually saw few animals, or that they simply did not bother to write down a description of all the animals which were seen? Is negative information data? Murie (1940:2) contended that "negative evidence must yield to positive evidence because failure to report game does not disprove its abundance." While Gruell (1973:10) claimed that "the failure to mention sightings of elk in early reports was not in itself positive evidence that they were not plentiful in the mountains." Morgantini (1995:27) also argued that "when ... reports fail to mention the presence of elk or when they indicate a general scarcity of game animals, no clear conclusion can be made." Although positive statements are preferable to silence, we submit that negative information can be just as important. We also maintain that what people do not say is, at times, even more important than what they record. For instance, negative information avoids the problems of exaggerations and misleading statements discussed above (Price 1980).

There are two ways to check the validity of the negative information contained in the historical source materials for the Canadian Rockies. First, if people recorded wildlife sightings or kills before entering the mountains, but not while they were in the Rockies, that strongly suggests they were careful observers whose lack of record really means they saw little game (Kay 1990). This certainly is true of the journals used in this study. While David Thompson, for instance, recorded relatively little game in the Rockies, and less still in the Columbian Trench, his journals contain numerous accounts regarding the abundance of game on the Canadian prairies (Tyrrell 1916, Coues 1965). The same is true of other explorers. Accounts of seeing and

killing game on the prairies were common but those entries declined precipitously when parties entered the mountains or passed into the Columbia Valley.

Second, the majority of early journals exhibit the same general pattern. That their writers were removed in time and space, yet reported similar ungulate sighting and kill rates, would imply that those were valid patterns, not aberrant occurrences (Kay 1990). For instance, Canada's early explorers generally reported more game in the Foothills than in the Rockies, and less still west of the cordillera in the Columbian Trench. Furthermore, without exception, all parties who visited Kootenay Plains reported more game there than at any other place in the Canadian Rockies (see above).

WHY DID EARLY EXPLORERS SEE SO LITTLE GAME?

At least six reasons, other than an out-right scarcity of animals, have been advanced to explain why early explorers saw relatively little game and so few elk in the Canadian Rockies. These include (1) Large, noisy parties chased all the game out of the country or drove the animals into hiding, in advance of their passing. (2) Game in summer was primarily at higher elevations away from the most frequently traveled routes. That is to say, people traveling through winter ranges in summer would not be expected to see game. (3) Hunting drove game away from established trails and posts such as Jasper House. (4) It was more difficult to see and kill game in the heavily wooded mountains than on the plains where reports of game were common. (5) Fur brigades traveled fast and light and did not have time to hunt. (6) Fire and disease decimate game populations ca. 1850 (Spry 1968:326, Morgantini 1995:25).

(1) As noted in the journal synopses, some early visitors to the Canadian Rockies suggested that their large, noisy parties scared off game before it could be seen. While this no doubt was true to some degree, we do not believe it can be cited as a major reason relatively so little game was seen or killed in the mountains. First, if anything, parties on the plains were larger than those in the Rockies, and as noted, parties on the prairie had little trouble procuring game. Second, many parties split into smaller groups to explore the Rockies and several sent out hunters ahead of their line of march. Most of those smaller groups were no more successful at seeing or killing game than were the larger parties. As already noted, many hunters searched diligently for days yet saw and killed very little. Finally, although elk are very sensitive to hunting disturbance associated with motor vehicles and modern high-powered rifles (see Chapter 6), there is little evidence that elk simply hid from early explorers, or that if they had, they would have been successful. Besides, of the ungulate species found in the Canadian Rockies ca. 1800-1870, elk were one of the easiest to hunt (Frison 1978, 1991). That is to say if elk were as common in the past as they are today, there is no logical reason why early explorers would not have seen and killed a great many elk.

(2) *The argument that early explorers saw little game in the Canadian Rockies because all the animals summered at higher elevations away from traveled routes is based on the assumption that even in the absence of human disturbance, elk would summer there to secure better forage or to avoid insects. This assumption, though, appears to be without merit. When Wyoming's Grand Teton National Park was expanded to its present size in the 1950s, no elk summered on the valley floor. Since then, a summering herd of 3,000 to 4,000 elk has built up in that area (Boyce 1989). A summer elk herd has also become established on the National Elk Refuge at even lower elevation in Wyoming's Jackson Hole (Boyce 1989). That herd would have continued to grow except the Wyoming Game and Fish Department and the National Elk Refuge set special hunting seasons to eliminate those animals because they did not want elk summering on the winter range (Boyce 1989).*

Summering elk herds have also become established on Yellowstone National Park's northern winter range. Several hundred elk now summer on Mt. Everts, Brunsen Peak, and around Mammoth (Kay 1990).

In Montana, summering elk herds have become established on several winter ranges owned by the Montana Department of Fish, Wildlife and Parks. Those herds would also have expanded beyond their present numbers, except that Montana set special hunting seasons to eliminate them because the state does not want elk summering on its winter ranges such as the Sun River Game Range (Kay 1990). The same is true in the Canadian Rockies. Today, several hundred elk summer in Banff's Bow Valley (Woods 1988, 1991), on the Ya Ha Tinda (Skjongsberg 1993, Morgantini 1995), and in Jasper's Athabasca Valley (Dekker 1985a).

In addition, elk do not "need" to forage at higher elevations to meet their nutritional requirements. Lewis and Clark (1893), Maximilian (1966), and other early explorers repeatedly saw and killed large numbers of elk on the Great Plains, as did Palliser (1969), David Thompson (Tyrrell 1916), Southesk (1969), and others on the Canadian prairies. In the hottest, driest part of Washington State's Columbia Basin, a resident elk herd not only increased at near the theoretical maximum rate for that species, but bulls grew huge record-book antlers indicative of excellent nutritional conditions (McCorquodale et al. 1986, 1988, 1989a, 1989b; McCorquodale 1987a, 1987b, 1991, 1993, 1995). This herd occupies a grass-sagebrush (*Artemisia* sp.) range with no tree cover except for a few small riparian areas. If elk can summer there, they surely could summer on any winter range in the Canadian Rockies.

Furthermore, as noted above, several parties traveled through the Athabasca Valley in late fall or early winter when snow and cold temperatures would have forced ungulates onto low-elevation ranges, yet they still failed to observe any elk. So even when early explorers traversed what are now major elk wintering areas during winter, they did not report seeing the concentrations of animals that are common today. On many of these winter crossings, the explorers also complained of a lack of food, making it doubtful that they would have failed to report or somehow have overlooked elk if the latter had been present in any numbers.

(3) Some have suggested that early visitors to the Canadian Rockies saw relatively little game because fur-trade associated hunting had killed-off all the animals or at least had driven them away from the most traveled routes. First, since explorers killed relatively few ungulates, other than bighorn sheep, it appears doubtful that this could have had a major influence on ungulate distribution or abundance. It is clear, though, that David Thompson, the first European known to have traversed the North Saskatchewan, Athabasca, and the Columbia Valleys, reported seeing and killing more ungulates, and especially bison, than later parties. Similarly, it is apparent that the establishment of posts, such as Jasper House in the Athabasca Valley, placed additional pressure on game resources. Nevertheless, we do not believe there was enough fur-trade hunting pressure, in and of itself, to have killed out elk and other ungulates, except perhaps for bison and possibly moose (see below).

As will be discussed more fully in Chapters 4, 5, and 6, there was more ungulate winter range in the Canadian Rockies ca. 1800 than there is today due to a high-frequency of low-intensity fires which maintained open grassland communities at the expense of forests (Van Egmond 1990). The frequent burning would also have enhanced forage production and quality (Bailey 1986). So if food was the only thing that limited herbivore numbers, ungulate populations ca. 1800 should have been two or three times higher than what they were in the 1950s-1960s when wolves were absent (Peck 1980, 1988; Van Egmond 1990; Peck and Peek 1991). That is to say, the major winter ranges in the Bow, Athabasca, and North Saskatchewan Valleys could each have supported around 10,000 ungulates. Since even the earliest explorers did not report anywhere near these numbers of animals, this suggests that some factor other than food was already limiting those populations. Wolf predation and aboriginal hunting are two factors that could have kept ungulate numbers well below carrying capacity of the range ca. 1800. This will be addressed in Chapter 7, but for now, while fur-trade induced hunting may have contributed to declining ungulate populations, there is no evidence that it alone killed-off all the game and especially not elk. Besides, there is no evidence that the fur trade had any significant impact on Banff's Bow Valley, and game populations and elk numbers were just as low there ca. 1840 as they were in other, more traveled, areas of the Canadian Rockies. Moreover, despite repeated hunting and kills on Kootenay Plains, that is the one area where all parties continued to report game throughout the 1800s (see above).

(4) It has also been postulated that early explorers reported more game on the plains than in the Canadian Rockies because game was easier to see and kill where there was no forest cover. While ungulates certainly are more visible in the open than in the timber, two lines of evidence suggest that this was probably not an overriding consideration. First, even in the mountains most ungulates feed in openings where they can be easily seen from opposing hillsides or mountain tops, especially using binoculars or telescopes that were often carried by early explorers. Second, repeat photographs show that forests in the Canadian Rockies have both grown-up and thickened-up since the late 1800s due to human suppression of forest fires and the elimination of aboriginal burning (Van Egmond 1990; see Chapters 4 and 5). In reviewing early photographs (see Figures 4.1-4.12), one is struck by how open much of the country was when the Canadian Rockies were first explored, especially lower montane valleys where most explorers traveled. So, animals hidden from view by dense forests, would be a greater concern today than in the past.

It must also be remembered that early explorers traveled by foot or on horseback which allowed them ample opportunities to look for game. They did not speed by at 100 km per hour as many tourists do today. Since early explorers were living off the land, or at least tried to, they also had more incentive to find game than visitors today. For those accustomed to motorized travel, it is surprising how much more can be observed on foot or horseback.

(5) As noted in the journal synopses, many explorers traveled relatively quickly (for that day and age, but not by modern standards) through the Canadian Rockies which could possibly explain why they saw few elk or other ungulates. We believe, however, that rapid travel itineraries were often mandated by a lack of game, not the cause of reduced game sightings. It is clear from journal entries that many parties would have stopped to rest except that a lack of food forced them to continue. After a section of country was known to hold little game, and therefore offered little chance of substance, then it was logical for fur brigades to push on as rapidly as possible to reach the next supply point, such as Kootenay Plains or Jasper House or even Fort Edmonton.

(6) Hector (Spry 1968:326, Morgantini 1995:25) suggested that a combination of large forest fires and disease decimated game herds in the Rocky Mountains ca. 1850. As explained earlier, however, forest fires by creating an abundance of high quality forage, generally are beneficial to ungulates, and there is no evidence that disease had a significant impact on ungulate populations anywhere in western North America ca. 1800-1870.

SUMMARY AND CONCLUSIONS

Despite the difficulties of dealing objectively with written historical materials, we believe continuous-time analyses of early first-person journals support the following general conclusions relating to the ca. 1800-1870 distribution and abundance of ungulates in the Central Canadian Rockies Ecosystem.

1. Bighorn sheep were the most frequently seen and killed ungulate in the Canadian Rockies. Bison was next, followed by moose, mountain goats, elk, and deer. Elk did not dominate the ungulate community in the past as they do today.

2. The earliest explorers to the Athabasca and North Saskatchewan Valleys generally saw and killed bison, or at least observed recent sign. Later parties reported old buffalo skulls, but few actually saw bison or fresh sign.

3. Game was more frequently observed in the Foothills than in the main Canadian Rockies, and even fewer animals were reported in the Columbia Valley.

4. Within the mountains, game was more frequently seen and killed on Kootenay Plains than in any other area.

5. The first explorers who visited an area in the mountains usually reported more animals than parties that followed.

6. Even the earliest game populations, however, were not what would have been expected if food had been the major factor limiting ungulate numbers. No one encountered huge herds of game. The other possible limiting factors, carnivore predation and aboriginal hunting, are discussed in Chapter 7.

7. The earliest explorers encountered few Native Americans or signs of native people. Despite a presence in the Canadian Rockies dating back over 10,000 years (see Chapter 3), apparently there was little year-round or seasonal use of the mountains by aboriginal groups ca. 1800. This may have been the result of European disease epidemics that reduced native populations or it could have been caused by intertribal warfare. During the early 1800s, for instance, the Piegan clearly kept the Kootenay west of the mountains. While Peter Filder noted that Piegan and Kootenay traded horses on the Oldman River during the winter of 1792-1793, David Thompson's journals make it clear that during the early 1800s, Piegan were keeping the Kootenay west of the Rockies by force of arms (Dempsey 1965, Belyea 1994). This may have created a tribal boundary or buffer zone where human predation was reduced allowing game numbers to have increased, at least temporarily (Hickerson 1965, Mech 1977, Steffian 1991, Kay 1994). Prior to expansion of Piegan influence during the 1700s, Kootenay may have permanently occupied the Canadian Rockies and even the Alberta Foothills (Smith 1984, Langemann 1995).

8. Later parties, however, generally observed more native peoples, though, encounter rates were still low. Apparently, various native groups moved into the Athabasca Valley to service the fur trade or to be near trading posts, such as Jasper House and La Rocque's Mountain House. The Stoney apparently moved into the Rockies from the north only after the 1837-1838 smallpox epidemic decimated Piegan and other members of the Blackfoot confederation.

9. Hunting to supply fur-trade posts no doubt contributed to the decline and suppression of ungulate populations in the Athabasca Valley. This could not have been an important factor in the Bow Valley, though, because Europeans first entered that area in 1841, and because fur posts were never established in what is now Banff National Park.

10. Wolves and other predators were encountered in the Canadian Rockies, and they too preyed on ungulates. There are several accounts of wolves attacking horses during winter in the Athabasca Valley.

11. There is no evidence that elk were common anywhere in the Canadian Rockies or the Columbia Valley ca. 1800-1870. Even the earliest explorers, such as David Thompson, did not encounter large herds of elk. Between 1792 and 1872, 26 expeditions spent 369 party-days in the mountains, yet they only saw elk 12 times and only 8 animals were killed. There can be little doubt that elk numbers during the 1800s were much lower than they are today. There is no historical evidence that large herds of elk occupied the Bow and Athabasca Valleys until the mid-1900s.

This conclusion, moreover, is supported by comparison of the Yellowstone and Central Canadian Rockies Ecosystems. Twenty-one different expeditions spent 765 days in the Yellowstone Ecosystem between 1835 and 1876, and reported seeing elk once every 18 party days, today there are over 100,000 elk in that ecosystem (Kay 1990). Photographic evidence of aspen and other woody forage species also show that Yellowstone's elk population was very low ca. 1770-1870 (Chadde and Kay 1991, Kay and Wagner 1994, Kay 1995b). Clearly, Yellowstone's elk were no where near as abundant in the past as they are today.

(Kay 1990). In the Canadian Rockies, though, the historical elk sighting rate was even lower than in Yellowstone. On average between 1792 and 1872, travelers in the Canadian Rockies observed elk only once every 31 days. In Yellowstone, the historical elk kill rate was once every 21 days, while in the Canadian Rockies it was much less, one elk killed per 46 days. If historically elk were not abundant in Yellowstone, which they were not, then they were even less common in the Canadian Rockies. Other studies based on historical accounts have found that elk were rarely seen by early explorers throughout the Intermountain West (Koch 1941, Rawley 1985, Davis 1986).

Recently, though, Morgantini (1995) questioned these interpretations and instead relied on Millar's (1915) report of abundant elk in the Canadian Rockies ca. 1870. Millar (1915:31-33), however, based his account on second-hand information and the presence of elk antlers on ranges where that animal did not exist during Millar's travels in the Rockies. As elk antlers are resistant to weathering and can last a very long time, a large number of old elk antlers does not necessarily imply that elk were "enormously abundant" (Millar 1915:31) in earlier days. Over 10 years, for instance, 100 wintering bull elk would shed 2,000 antlers, but clearly that does not mean that thousands of elk were present in the past.

Moreover, a careful reading of Millar's (1915) narrative supports our more detailed analysis of the historical record. Millar, for instance, never claimed that the Canadian Rockies were prime elk habitat. "It will be noted that the favourite habitat of elk, unfortunately, is the type of country that is most valuable for stock range, and it is practically impossible to consider the retention of elk on the open foothills or plains which form its natural habitat" (Millar 1915:32). "In Alberta the principal range of the elk seems to have originally been the high plains ..." (Millar 1915:31 – see Chapter 3 for additional discussion of elk as a plains animal). Millar (1915:31) also noted that the last place elk were found in the Central Canadian Rockies in any numbers was on and near Kootenay Plains which, as described above, is consistent with earlier historical observations.

Millar (1915:18-20) also had this to say about the lack of game in the Canadian Rockies. "None of the other agencies of destruction [wolves, severe winters], however, ... can in any way compare with the depredations on big game for which the Stoney Indians are responsible ... Not only do these Indians kill game vastly in excess of the legal restrictions, and to the great detriment of the game supply of the region, but they also exercise no restraint whatever in the matter of age or sex. I have associated with hunting parties of Stoney Indians on a number of occasions, and find that the confining of game killing to males alone is a thing absolutely incomprehensible to a Stoney." This is consistent with recent studies which found Native Americans had a preference for prime-age females (Kay 1994, 1995a; and see Chapter 7).

The one time Millar (1915:35) did observe fair numbers of game, mostly mule deer, he noted that,

This abundance in this particular region [Red Deer Valley, Clearwater River, Ram Creek, and Brazeau Valley] is easily explained by the fact that it has until the last few years been the most remote portion of the mountains as far as white hunters are concerned, and that it is a sort of neutral belt between the hunting grounds of the Stonies on the south and the Crees on the north so that moose and deer have undoubtedly been forced into this narrow belt of country as a result of the activities of both the Crees and the Stonies, and have more or less concentrated in this locality.

That is to say, Millar was describing a tribal-territory buffer zone like those we discussed earlier and which are a common phenomenon associated with native hunting (Kay 1994, 1995a, in press b) – this and other prey refugia are discussed at greater length in our summary chapter.

CHAPTER 3

ARCHAEOLOGICAL EVIDENCE

INTRODUCTION

Although detailed cultural sequences have yet to be developed, the Canadian Rockies contain a record of human activity that dates to the end of the Wisconsin glaciation over 10,000 years ago. Depressions discovered along the Bow River near Banff townsite and in the Red Deer Valley are thought to represent the cultural pit-house tradition of Interior Salish and Kootenay peoples, who utilized the region from an undetermined time in the past till just prior to European contact ca. 250 BP (years before present) (Bernard et al. 1995, Langemann 1995). During the late 1700s and early 1800s, Piegan were the dominant people on the Alberta plains and foothills and they may have been responsible for forcing the Kootenay and Salish west of the divide (Kidd 1984).

Stoney (Assiniboine) and Cree migrated west across the Canadian prairies during the mid-1700s and scattered bands were living along the foothills when European fur traders arrived in the 1790's. For the most part, however, the Stoney and Cree stayed above the North Saskatchewan to avoid conflict with the Piegan. Only after the 1836-38 smallpox epidemic decimated the Piegan did Stoney and Cree move south into the Bow Valley (Bernard et al. 1995). So, although native peoples have occupied the Canadian Rockies for thousands of years, cultural affiliations changed over time. Nevertheless, those people left an archaeological record that can be used to gauge the relative abundance ungulates at various points in the past (Kay 1990, 1994, 1995a).

Before proceeding with a discussion of archaeologically recovered ungulate remains, though, it is important to note that zooarchaeologists use two measures to quantify faunal remains per taxon. These include the minimum number of individuals (MNI) and the number of identified specimens (NISP) (Grayson 1984). "Briefly defined, the minimum number of individuals is that number of individuals which are necessary to account for all of the skeletal elements ... of a particular species found in the site" (Olson 1983:21). Calculation of MNI depends on the unit used to aggregate the faunal remains. For instance, the entire sample of faunal material from one site can be treated as a single aggregate, or the faunal materials can be grouped by natural stratigraphic units, or the faunal materials can first be separated by stratum and then subdivided by units within each stratum (Grayson 1984). The faunal remains can also be separated into an animal's right and left sides, as well as into young and old animals. All of these factors tend to increase MNI. Grayson (1984:37) demonstrated that $MNI \text{ of } 10 \text{ cm units} > MNI \text{ per stratum} > MNI \text{ per site}$.

The number of identified specimens (NISP) is simply the total number of bones or bone fragments that have been identified for an individual taxon from the total site. Grayson (1984:20-26) and Olson (1983:21) listed a total of 11 different criticisms that have been directed toward NISP counts, though MNI data also contain several biases. Since these problems have been widely discussed in the archaeological literature (Ringrose 1993), it is only necessary to note the following. First, as total sample size (NISP) increases (i.e., more bones are excavated and identified at a site), the minimum number of individual animals per taxon (MNI) and the number of represented taxa increase (Grayson 1981, 1984; Lyman 1982). That is MNI has been shown to be a function of NISP. Second, MNI tends to over-represent rare animals. Third, Marshall and Pilgram (1993:261) noted that "MNI may be a less representative descriptor of relative element frequency than NISP in highly fragmented assemblages" such as those commonly found in the Canadian Rockies (see below).

Grayson (1978, 1981, 1984), Lyman (1982), and others have recommended that analysts calculate and interpret NISP and MNI values independently and then compare those results. Because of the biases inherent within MNI and NISP calculations, though, it may be best to use ordinal scales of relative abundance instead of actual percentages (Lyman 1982:360, Ringrose 1993). If ordinal scales ranked MNI and NISP species abundances similarly, then that would suggest the pattern was robust and ecologically significant. Accordingly, in the results and discussion which follow, both MNI and NISP data are provided when the original site reports contained that information.

We will first present a detailed discussion of ungulate faunal remains recovered from archaeological sites in Banff, Jasper, Kootenay, and Yoho National Parks. Next, we will present a more generalized analysis of faunal remains from archaeological sites in the Alberta Foothills and the Columbia Trench. We will then address the question of why elk are so rarely recovered from archaeological sites in the Canadian Rockies before closing with a discussion of bone grease processing. Our original report (Kay et al. 1994) should be consulted if detailed site by site listings of ungulate faunal remains are required.

BANFF NATIONAL PARK

As of 1988, 346 prehistoric sites had been recorded in Banff National Park, mostly in the Bow and Red Deer Valleys (Archaeological Research Services Unit 1989a:78). The distribution of known sites, though, is largely a reflection of the level of investigation, for a detailed systematic survey of the entire park has not been completed. The large number of sites recorded in the Bow Valley reflects the level of recent human developments along the Bow River corridor, and archaeological mitigation mandated by Federal and Provincial statutes. "Although enhanced as a result of a number of inventory and excavation projects conducted over the past decade, the prehistoric record of Banff Park is skeletal and interpretations must be considered tentative" (Archaeological Research Services Unit 1989a:35). "Archaeological investigations in Banff National Park are at a very basic level" (Archaeological Research Services Unit 1989a:9). Few sites have been excavated, and of those, only small areas have been unearthed. "The greater part of [the archaeological] evidence derives from excavation of some 30 occupation levels at 11 prehistoric sites in the Bow Valley" near the Vermilion Lakes (Archaeological Research Services Unit 1989a:35). Although only six sites have produced significant amounts of faunal remains, they are all located in areas of the Bow Valley where elk now concentrate in winter and summer (Woods 1991).

(1) Vermilion Lakes (EhPv-8) is a multicomponent site with over 10,000 years of cultural history represented within 2 m of stratified sediments. The site is situated at the foot of an alluvial fan on the north shore of Vermilion Lakes west of Banff townsite. The site includes two localities (153R, 502R) separated by 100 m. Temporal control is provided by 26 radiocarbon dates on organic material associated with cultural activity and time diagnostic stone tools. The site was excavated by Parks Canada during the early 1980s as mitigation when the Trans-Canada Highway was twinned. This is the oldest archaeological site that has been excavated in Banff National Park, and one of the oldest in Canada (Fedje and White 1988, Fedje et al. 1995). It is also the site in the Canadian Rockies with the best temporal control, especially for the earliest or oldest levels. A total of 3,424 bone or bone fragments were recovered, but only 196 (6%) could be identified to species (Tables 3.1 to 3.3). Of the 170 identified ungulate bones, 165 (97%) were from bighorn sheep, bison 3 (2%), and deer 2 (1%). No elk, moose, or caribou bones were identified though some of the unidentified large-ungulate bone fragments may have been from those species.

(2) The Christensen Site (360R) is located in the Bow Valley some 10 km west of Banff townsite. The site was excavated by the University of Calgary in 1991 as part of a program developed by Parks Canada to stabilize erosion threatening the area (Gorham et al. 1992). Although the site contained stratified cultural deposits dating to ca. 8000 BP, temporal control was poor, so it was not possible to assign the

uneearthed ungulate remains to specific time periods. Nevertheless, a total of 38,343 bone fragments were recovered,

Table 3.1. Ungulate remains recovered from the Vermilion Lake sites (153R, 502R; EhPv-8) in Banff National Park. NISP = Number of identified specimens and MNI = Minimum number of individuals; see text.

Occupation	Date	Total number of bones recovered	Number of bones identified to species	Percent of total bones identified to species	Bighorn		Bison		Deer ¹	
					NISP	MNI	NISP	MNI	NISP	MNI
9	10,700-10,300 BP	333	26	8%	24	4	-	-	-	-
8	10,100-10,000 BP	2,047	110	5%	85	5	2	1	-	-
7	ca 10,000 BP	797	50	6%	49	6	-	-	-	-
6a	ca 9650 BP	141	4	3%	4	3	-	-	-	-
5	8500-8000 BP	3	0	0%	-	-	-	-	-	-
1-4	8000-100 BP	63	6	10%	3	1	1	1	2	1
Total		3,424	196	6%	165	19	3	2	2	1

¹Includes both white-tailed and mule deer.

Table 3.2. Ungulate remains recovered from archaeological sites in Banff National Park.
Part 1: Number of identified specimens.

Site	Date	Number of identified specimens (NISP)						Reference
		Elk	Bison	Deer ¹	Bighorn	Moose	Goat	
Vermilion Lakes (153R, 502R)	10,700-100 BP	-	3	2	165	-	-	Fedje&White 1988
Christensen 1992(360R)	8000-100 BP	25	173	1	18	-	-	Gorham et al.
Echo Creek (515R)	1500-100 BP	14	65	8	31	2	-	Francis 1991
Second Lake (162R)	9500-1900 BP	2	17	26	6	-	2	Fedje 1986
Norquay (156R)	9000-2500 BP	-	4	-	-	-	-	Fedje 1988
Eclipse (62R)	10,000-200 BP	-	2	-	-	-	-	Fedje 1988
Total		41	264	37	220	2	2	
Percent of total (NISP = 566)		7%	47%	7%	39%	<1%	<1%	
Rank		3	1	4	2	5	5	

¹Includes both white-tailed and mule deer.

Table 3.3. Ungulate remains recovered from archaeological sites in Banff National Park.
Part 2: Minimum number of individuals.

Site	Total number of bones recovered	Number of bones identified to species	Percent of total bones identified to species	Minimum number of individuals (MNI)				
				Elk	Bison	Deer ¹	Bighorn	Moose
Goat								
Vermilion Lakes (153R, 502R)	3,424	196	6%	-	2	1	19	-
Christensen (360R)	38,343	270	1%	1	6	1	2	-
Echo Creek (515R)	15,326	206	1%	4	15	2	5	1
Second Lake (162R)	4,998	66	1%	1	7	5	3	-
Norquay (156R)	3,481	4	<1%	-	2	-	-	-
Eclipse (62R)	727	3	<1%	-	1	-	-	-
Total	66,299	745	1%	5	33	9	29	1
Percent of total (MNI = 78)				6%	42%	12%	37%	1%
Rank				4	1	3	2	5

¹Includes both white-tailed and mule deer.

but only 270 (1%) could be identified to species (Table 3.3). Of that total, 173 (64%) were identified as bison, 25 (9%) as elk, 19 (7%) as bighorn sheep, and one as deer.

(3) The Echo Creek Site (515R; EhPv-78) is located on the floodplain of Echo Creek at the northeastern edge of the Vermilion Lakes wetland north of Banff townsite. Most of the site was destroyed when the Norquay Road was widened during twinning of the Trans-Canada Highway. The site was excavated by Parks Canada in the early 1980s and the oldest strata dated to 1500 BP (Francis 1991). Although nine different components were identified, temporal control was poor. Most of the faunal remains were unearthed in component 3 which dates to ca. 700 BP. A total of 15,326 bone fragments were recovered, but only 206 (1%) could be identified to species. Of the 120 identified ungulate bones, 65 (54%) were from bison, 31 (26%) from bighorn sheep, 14 (12%) from elk, 8 (7%) from deer, and 2 (2%) from moose (Tables 3.2 and 3.3).

(4) The Second Lake Site (162R) was excavated in 1985 by Parks Canada as mitigation associated with twinning the Trans-Canada Highway. The site is situated between the second and third Vermilion Lakes west of Banff townsite (Fedje 1986). Although the oldest date at this large site was ca. 9500 BP, all faunal remains unearthed during excavation dated between 3600 and 1900 BP. Of the 53 identified ungulate bones, 26 (49%) were from deer, 17 (32%) from bison, 6 (11%) from bighorn sheep, and 2 (4%) each from elk and mountain goat (Table 3.2).

(5) The Norquay Site (156R) is located approximately 200 m east of the Norquay Interchange on the Trans-Canada Highway north of Banff townsite. Much of the site was lost to highway construction during 1958. The site was excavated in 1986 by Parks Canada to mitigate disturbance associated with the Trans-Canada Highway (Fedje 1988). The site dated from 9000 to 2500 BP, but temporal control was poor. Only a small portion of the site was systematically excavated, and only four of 3,481 bone fragments were identified to species. The only ungulate positively identified was bison (Tables 3.2 and 3.3).

(6) The Eclipse Site (62R) is situated on the north side of the Trans-Canada Highway approximately 1 km east of the Minnewanka interchange. The area was excavated by Parks Canada in 1986 because the game-proof fence north of the highway was to be installed across the site (Fedje 1988). Excavations were limited in extent, but produced evidence of prehistoric occupation dating from 100 BP to over 10,000 BP. Of 727 bone fragments that were recovered, only three could be identified to species. Bison was the only ungulate positively identified (Tables 3.2 and 3.3).

In summary, the faunal remains recovered from archaeological sites in the Bow Valley indicate that bison and bighorn sheep were the most common ungulates comprising over 85% of the ungulate bones unearthed (Table 3.4). Elk and deer were equally represented, but each accounted for only 7% of the ungulate bones identified. Only two moose and two mountain goat bones were recorded. This is different than present conditions. Although a small bison herd has been maintained in a viewing paddock north of Banff townsite since 1897, no free-ranging bison have occurred in the park for over 150 years. Elk now dominate Banff's ungulate community (51%) while that species only accounted for 7% of the ungulate remains recovered from archaeological sites. If we remove bison from these calculations, archaeologically, bighorn sheep then become the most common ungulate (73%) and elk still are rarer (14%) than they are today (Table 3.4). No matter how the data are analyzed, elk were relatively less abundant in the past, than they are in the Bow Valley today.

Table 3.4. Comparison of the relative abundance of ungulates wintering in the Bow Valley portion of Banff National Park during the 1980s with the relative abundance of ungulate remains recovered for archaeological sites in the same area.

Data set	Species percentage of total					
	Elk	Bison	Deer	Bighorn	Moose	Goat
1980s population estimates*	51	0	15	26	0	3
Archaeological sites (NISP)	7	47	7	39	<1	<1
Archaeological sites (NISP - Bison)	14	0	12	73	1	1

*Personal communication, Cliff White, Banff Warden Staff, 1993; also see Skjonsberg (1993).

JASPER NATIONAL PARK

As of March 1988, 200 prehistoric sites had been recorded in Jasper National Park. "Archaeological investigations in Jasper National Park are at a very basic level. At the majority of sites, investigations have been limited to basic site location and recording" (Archaeological Research Services Unit 1989b:8). Moreover, "it is likely that only a limited percentage of prehistoric sites have been discovered because of archaeological visibility biases imposed by geological processes, decay from natural elements, and the inherent preservation qualities of the prehistoric record" (Archaeological Research Services Unit 1989b:9). Known archaeological sites within the park are relatively small, and quantities of associated faunal remains and cultural artifacts tend to be quite limited. "Sites with dense, stratified artifact horizons typically used by archaeologists to construct cultural sequences are not presently known for Jasper National Park" (Archaeological Research Services Unit 1989b:33).

The earliest dated evidence of human occupation in the general vicinity of Jasper National Park has been found in the Athabasca Valley near Brule Lake, some 10 km east of the park boundary (Ball 1986). That site dated to 8700 BP, but native peoples probably occupied Jasper for the last 10,000 or so years. Because less than 40 square meters of archaeological sites has been excavated (Archaeological Research Services Unit 1989b:34), Jasper's archaeology is less well known than that of Banff. Moreover, all sites excavated in Jasper have been in either the Athabasca or Miette River Valleys.

(1) The Track Site (198R; FhQ1-6) is located along the Canadian Pacific Railway in the lower Athabasca Valley approximately 2.5 km inside Jasper's east boundary (Pickard 1987). The area is known for its minimal snow cover, grassland vegetation, and large numbers of wintering ungulates. The site was excavated during the early 1980s by Parks Canada as mitigation associated with twinning the Canadian Pacific Railway.

In 1983 and 1986, approximately 26 m² of the site was excavated. Cultural deposits dated from 3500 to 200 BP. Faunal remains were extremely fragmentary and most specimens were corroded, making species identification all but impossible. Both small- and large-sized ungulates were present. The small-sized ungulate bones were attributed primarily to bighorn sheep, while the larger-sized ungulate bones were thought to be either elk or bison. Three elk antler fragments were identified (Pickard 1987:127). Of the remaining 817 bone fragments recovered, only two could be identified to species, and both were from bighorn sheep (Pickard 1987:135-137).

(2) Devona Cave (239R; FhQm-1) is situated on the northwest side of the Athabasca River at the base of the Bosche Range near the east boundary of Jasper National Park. Only three square meters have been excavated with cultural deposits dating to 4300 BP. The faunal remains were extremely fragmentary, and of the 165 pieces recovered, only two could be identified to species, both were small mammals. Several bones were identified as small ungulate and were attributed to either bighorn sheep or mountain goat (Head 1987). No bones of larger-sized ungulates, such as elk, moose, or bison, were unearthed.

(3) Site 317R (FhQm-40) is located on the south side of the Athabasca River approximately 10 km east of Jasper townsite. Less than one square meter of the site was test excavated in 1987 and a total of 309 bone fragments were recovered, but none could be identified to species. Small ungulates, either bighorn sheep, mountain goats, or deer, were present, but bones from larger-sized ungulates were not unearthed. The site has not been dated (Head 1987).

(4) The most extensive excavations in Jasper National Park have occurred at Jasper House, a trading post used by the Hudson's Bay Company between ca. 1830 and 1884 (Pickard 1985, Pickard and

D'Amour 1987). This historic site was excavated by Parks Canada in 1985, 1986, and 1987. A total of 35,209 faunal remains were recovered, and 3,412 (10%) were identified to species. The faunal remains from Jasper House were generally in a good state of preservation, as attested to by the large number of fish, bird, and juvenile animal bones that were recovered. Although bones from Jasper House were subjected to human butchering and some carnivore gnawing, probably from domestic dogs, many apparently were not subject to the degree of bone grease processing common at archaeological sites (see below). This, the site's recent age, and excellent preservation probably explain why a greater proportion (10%) of the faunal remains from Jasper House were identified to species than commonly occurs at archaeological sites (1%) in the Canadian Rockies.

Of the 1,382 identified ungulate bones, 656 (47%) were from bighorn sheep, 441 (32%) from moose, 181 (13%) from elk, 101 (7%) from mule deer, 2 from caribou, and 1 from bison (Table 3.5). This does not imply, however, that ungulates were common. According to historical accounts and post journals (see Chapter 2), in winter the threat of starvation was never absent even though one or more hunters were engaged to supply the establishment with meat. In 1846, Father Pierre-Jean De Smet recorded that the 54 residents of Jasper House consumed the following animals during one 26-day period: 12 moose, 2 caribou, 30 bighorn sheep, 2 porcupines, 210 snowshoe hares (Lepus americanus), 1 beaver, 1 muskrat (Ondatra zibethica), 163 assorted birds, and approximately 1,000 whitefish (Pickard and D'Amour 1987:163). Father De Smet noted that the people had left Jasper House and set up camp on a nearby lake to take advantage of the fisheries, because they could not procure enough ungulates to meet their food requirements.

It is interesting to note that the archaeological record and early historical accounts (see Chapter 2) agree as to the relative abundance of ungulate species found near Jasper House during the mid-1800s. Both rank bighorn sheep as the most common ungulate, followed by moose. Elk, the most abundant ungulate today, were seldom mentioned in post journals, and this is also reflected in that species' low ranking in the archaeological record.

Table 3.5. Ungulate remains recovered from Jasper House (23OR) in Jasper National Park. Jasper House was operated by the Hudson's Bay Company ca. 1830-1884. From Pickard and D'Amour 1987:318-319.

Measurement	Ungulate species						Total
	Elk	Bison	Mule Deer	Bighorn	Moose	Caribou	
NISP	181	1	101	656	441	2	1,382
Percent	13%	<1%	7%	47%	32%	<1%	
Rank	3	6	4	1	2	5	
MNI	11	1	9	31	16	2	70
Percent	16%	1%	13%	44%	23%	3%	
Rank	3	6	4	1	2	5	

KOOTENAY NATIONAL PARK

There have been fewer archaeological investigations in Kootenay National Park than in either Banff or Jasper. A total of only 51 prehistoric sites were recorded as of March 31, 1989 (Archaeological Research Services Unit 1989c:9). The low number of known sites is probably more a reflection of the level of archaeological work that has been conducted and low site visibility due to the more forested habitats, than it is of past human occupation. No sites have been excavated in Kootenay National Park and the few test pits have only produced small quantities of mostly unidentifiable bone (Archaeological Research Services Unit 1989c). Thus, there are no archaeologically recovered ungulate remains to report for Kootenay National Park.

YOHO NATIONAL PARK

Very little archaeological work has been done in Yoho National Park (Archaeological Research Services Unit 1993). No sites have been excavated and no faunal remains are available (Perry 1987, Sumpter and Perry 1987).

ALBERTA'S EASTERN SLOPES

Archaeologists have divided Alberta's Eastern Slopes into five regions along major river drainages (McCullough and Fedirchuk 1986, Ronaghan 1986). From south to north these include: (1) Oldman, (2) Bow-Red Deer, (3) North Saskatchewan, (4) Athabasca, and (5) Smoky. As defined, the Continental Divide is the western boundary of Alberta's Eastern Slopes while the eastern boundary is the eastern limit of the Foothills Ecosystem (McCullough and Fedirchuk 1986). Along its length, the Eastern Slopes constitute a transition zone between the Rocky Mountains to the west and the plains to the east. For this analysis, the western limit of the Eastern Slopes is further defined as the eastern boundary of Banff and Jasper National Parks. That is the archaeological data reported for Banff and Jasper (see above) will not be repeated here.

"As of 1983, 3,314 prehistoric sites had been recorded in the Eastern Slopes of Alberta" (Ronaghan 1986:285). The vast majority of those sites, however, were identified only on the basis of brief surficial examinations. Of those sites, 86% were recorded in the Oldman and Bow River basins (Ronaghan 1986:285), and archaeological excavations have been concentrated there as well. Few major excavations have been undertaken in the Red Deer, North Saskatchewan, Athabasca, or Smoky River drainages.

This is a reflection, primarily, of site visibility and development activity. The foothills in the Oldman and Bow areas are less timbered than the valleys further north, and the southern areas have also seen the highest levels of recent human activity. According to Federal and Provincial statutes, since the mid-1970s all development projects must include a survey of archaeological resources, and salvage excavations are mandated to mitigate any archaeological sites that may be lost during construction. So the areas with the highest levels of development have had more archaeological study and, correspondingly, their prehistory is better known (Reeves 1986, Ronaghan 1986).

Oldman Drainage Basin

Most of the archaeological excavations in the Oldman River basin have occurred either in Waterton National Park or the Crowsnest Pass region. In both areas, plains grasslands extend directly into the Rocky Mountains which, in the past, provided easy access for ungulates, such as bison, once common on the Canadian prairies (Driver 1978, 1982, 1985, 1993). This is reflected in the ungulate remains unearthed at archaeological sites which are dominated by bison (Table 3.6).

Even at sites in the mountainous part of this drainage, few elk have been unearthed. Reeves and Dormarr (1970) reported on the Gap Site (DIPo-20) where the Oldman River passes through the Livingstone Range north of Crowsnest Pass. They identified four occupational levels dating between 8000 BP and 6000 BP. The only ungulate identified was bison (NISP=23).

Brulotte (1981, 1983) investigated archaeological sites along Racehorse Creek which joins the Oldman River near Livingstone Gap in the Front Range of the Rockies. Brulotte (1981) surveyed the entire Racehorse drainage from its confluence with the Oldman River to its headwaters along the Continental Divide. He then test excavated two sites; DIPo-4 – the Daisy Creek site, and DkPp-11 – the Racetrack Creek Rockshelter. At the Daisy Creek site, Brulotte (1983) unearthed 1,770 bone fragments of which 20 were identified as bison. No other identifiable ungulate remains were recovered. At the Racetrack Creek Rockshelter, he recovered 28,867 bone and tooth fragments. Deer, elk, and bighorn sheep were identified but NISP data were not provided. Based only on teeth counts, Brulotte identified a MNI of four bighorn sheep, three deer, and one elk. Neither site was dated.

Table 3.6 Ungulate remains recovered from Alberta eastslope archaeological sites. See Kay et al. (1994) for detailed site by site data.

Drainage	Number of identified specimens (NISP)						Minimum number of individuals					
	Elk	Bison	Deer*	Bighorn	Moose	Goat	Elk	Bison	Deer*	Bighorn	Moose	Goat
Oldman												
Waterton N.P.	5	606	18	4	-	-	4	51	4	4	1	-
Crowsnest Pass	132	6509	75	113	3	2	47	401	36	34	2	1
Bow -- Red Deer	4	248	18	15	13	2	3	21	6	2	4	-
Total	141	7363	111	132	16	4	54	473	46	40	7	1
Percent	2%	95%	1%	2%	<1%	<1%	9%	76%	7%	6%	1%	<1%
Rank	2	1	4	3	5	6	2	1	3	4	5	6

*Includes both mule and white-tailed deer.

Bow-Red Deer Drainage Basin

Although excavations have been limited in size and scope, and the recovered faunal remains highly fragmented, the following conclusions can be drawn for archaeological sites in the Bow-Red Deer Drainage Basin. First, bison was the most common ungulate unearthed at all sites, and that species accounted for 83% of total NISP (Table 3.6). Deer were ranked second, bighorn sheep third, moose fourth, elk fifth, and mountain goat sixth. Only four bones were identified as elk and they accounted for only 1% of total NISP. Only mountain goat was reported less frequently than elk.

Of particular interest is the Ya Ha Tinda - James Pass region where at least 2,000 elk now winter (Morgantini 1995). It appears that prehistoric use of the Ya Ha Tinda and its associated grasslands (see Figure 4.9) has, "indeed, been intense throughout the Holocene" (Ronaghan 1993). During the summer of 1991, a brief inventory program was conducted in the James Pass area as part of the Provincial Museum of Alberta's First Man Project. In what has been termed the James Pass Meadow Complex (EkPu-3-9), bison bones dating to at least 10,000 BP were unearthed (Ronaghan 1993). No other ungulates were identified. In 1993, the Provincial Museum conducted additional excavations in James Pass and Parks Canada began excavations on the Ya Ha Tinda, but those reports are not yet available. Ronaghan (pers. comm. 1994) excavated 15 m² on the south-facing slopes above James Pass Meadow during 1993 and recovered over 10,000 stone artifacts dating between 10,000 BP and 3000 BP. Only small amounts of bone were recovered and most of the identifiable remains were bison. No elk bones were unearthed. So, while elk dominate the present ungulate community, elk have rarely been found in archaeological sites. Instead, bison dominate archaeologically recovered faunal remains.

North Saskatchewan Drainage Basin

As part of the Provincial Museum of Alberta's First Man Project, Ronaghan and Beaudoin (1988) searched for archaeological sites along the North Fork of the Saskatchewan River from Nordegg Bridge upstream to Banff National Park including Kootenay Plains (see Figures 4.10 and 4.11). Ronaghan and Beaudoin (1988:43), however, did not find any sites of early Holocene or late Wisconsinan age, and they also failed to locate many sites of more recent age. They noted, however, that the best habitation areas in the valley, and all the known large archaeological sites, were inundated by Lake Abraham when Bighorn Dam was constructed. Although pre-dam test excavations were conducted on a number of Middle to Late Prehistoric sites, only a few faunal remains were recovered and bison was the only ungulate identified (Brian Reeves, pers. comm. 1993).

Athabasca Drainage Basin

At least 35 archaeological sites have been recorded between Jasper National Park and the town of Hinton (Ball 1986). Cultural artifacts suggest that native peoples used the area for at least the last 9,000 years, but no sites have been excavated. Hall (1976), though, excavated the Whitehorse Creek Rockshelter (FfQi-1) just upstream from the confluence of Whitehorse Creek and the McLeod River. That site dated to 3750 BP and while a few bone fragments were recovered, none could be identified to species.

Numerous archaeological investigations have also been conducted in the areas impacted by the Gregg River and Luscar Sterco coal projects. Due to acidic soils, poor preservation, and the highly fractured

nature of the bone, however, few faunal remains were recovered, and fewer still were identified to species (Calder and Reeves 1977, Reeves 1980, Light 1985). At FqQe-11 along the Lovett River, 22 bone fragments were recovered, and moose and bighorn sheep/mountain goat were identified (Light 1985:16). Because of these factors, relatively little is known about prehistoric human subsistence patterns in the Athabasca drainage.

Smoky Drainage Basin

At least 36 prehistoric sites have been recorded in the Smoky River area (Brink and Dawe 1986). Several sites were test excavated and yielded a total of 1,577 bone fragments, but only a few could be identified to species. Neither NISP or MNI data have been presented, but elk and moose were identified (Brink and Dawe 1986: 176-177). At the Grand Cache Lake site (FIQs-30), occupied between 5600 BP and 200 BP, approximately 23,441 pieces of bone were recovered, however, not a single bone measured more than 5 cm in any dimension due to prehistoric bone grease processing. Only 19 bones could be identified to species and caribou was the only ungulate positively identified. Excavations at the Smoky site (GaQs-1) suggest that area was used by native peoples dating back to 4500 BP. A total of 8,406 bones was recovered, but all were highly fragmented due to cultural processing. Only 19 could be identified to species, and although neither NISP or MNI data were reported, elk, moose, and bighorn sheep were identified (Brink 1974, 1975; Brink and Dawe 1986:232).

A characteristic of all these prehistoric sites is the poor condition of the bone, due to cultural activities like bone grease processing (see below), and poor preservation caused by acidic soils. With few exceptions, the condition of the faunal material reduces species identification to near zero, hindering ecological interpretations.

BRITISH COLUMBIA

The Rocky Mountain Trench, a long flat-bottomed depression, extends from Flathead Lake in Montana, through British Columbia, into the Yukon. It separates the Rocky Mountains on the east, including Banff, Jasper, Kootenay, and Yoho National Parks, from the remainder of the Canadian Cordillera to the west. In British Columbia, the Kootenay, Columbia, and Canoe Rivers drain the Rocky Mountain Trench which parallels the mountains that form the Continental Divide on the east. The upper Columbia and lower Kootenay's grasslands are flanked by forested slopes (see Figure 4.12), while the Canoe River is more heavily timbered. Early fur traders repeatedly traveled through the Canoe, Columbia, and Kootenay Valleys to reach company posts in Washington, Idaho, Montana, and southern British Columbia (see Chapter 2). Unfortunately, few archaeological sites have been excavated in this portion of British Columbia, and fewer still have yielded identifiable ungulate remains.

Much of the Canoe River has now been inundated by waters behind Mica Dam, and little is known about that region's archaeology. Mica Dam also flooded the Columbia River from below its confluence with the Canoe River upstream to near Golden. Over 200 archaeological sites, however, have been identified along the Columbia River from Golden upstream to Canal Flats (Sneed 1979). While another 100 archaeological sites have been identified to the south along the Kootenay River and its tributaries, including that section of the Kootenay now flooded by Montana's Libby Dam (Choquette 1971, 1972a, 1972b, 1974, 1981).

Site EdQa-8, located on a high glaciolacustrine terrace on the northeast end of Windermere Lake near Invermere, was excavated in 1986 (Bussey 1986). EdQa-8 was identified as a temporary camp or food processing site that was occupied at least twice around 2400 BP. The majority of the faunal remains

recovered from EdQa-8 were unidentifiable. "They represent the smashed remains of bones that were probably boiled to extract the marrow/grease" (Bussey 1986:78). Nevertheless, some tooth fragments were identified as elk and a few bones were identified as deer (Tables 3.7 and 3.8). McKenzie (1976a, 1976b) reported on two sites, EcQa-1 and EcPx-5, along the east shore of Windermere Lake. Neither site was dated and no bones were recovered from EcQa-1. Of 423 small bone fragments unearthed at EcPx-5 during 1975, only a single deer carpal was identified to species (McKenzie 1976a:28). An additional, but unidentified, number of bone fragments were recovered in 1976 and "apart from phalanges of deer, no complete bone was recovered" (McKenzie 1976b:30). Two broken mandibles were unearthed, one from a bighorn sheep and another from a mule deer. "The bones ... had apparently been pounded into small fragments, perhaps to obtain fat and marrow [i.e., bone grease processing]" (Tables 3.7 and 3.8).

Mohs (1981) and Yip (1982) reported on site EbPw-1 on the southeast side of Columbia Lake. Mohs (1981) dated the site between 5000 BP and 100 BP and unearthed 10,143 bone fragments but none could be identified to species due to the highly fragmented nature of the recovered material. Yip (1982) unearthed an additional 7,026 bone fragments of which five were identified as deer and one as caribou. Again, the rest could not be identified because they had been so highly fragmented, most likely during bone grease processing (Tables 3.7 and 3.8).

Further south down the Kootenay Valley, the Wild Horse River site (DjPv-14) was excavated in 1975 by Blake (1975, 1981). DjPv-14 is situated near the confluence of the Wild Horse and Kootenay Rivers near historic Fort Steele. Blake did not date the site but believed it was at least 3,000 years old. The site lies near the historic Dewdney Trail which was heavily used by Europeans beginning in the 1860s. Of the prehistoric material, 666 bone fragments were recovered, but only 23 could be identified to species. Deer comprised 83% of the total while elk accounted for 17% (Tables 3.7 and 3.8). The site was also excavated by Choquette (1985a) in 1984. Unlike Blake, Choquette believed DjPv-14 was at least 8,000 years old. Choquette (1985a) recovered 30,189 bone fragments but was able to identify only 13 to species (Tables 3.7 and 3.8). Twelve of the identified bone fragments were from bison, suggesting that at one time bison may have occupied the Rocky Mountain Trench.

Choquette (1981, 1985b) also conducted archaeological surveys and test excavations in Top-Of-The-World Provincial Park where major chert quarries and workshop complexes have been discovered above 2,100 m in the Van Nostrand Range. Top-Of-The-World chert has been recovered from archaeological sites throughout the Southern Canadian Rockies, and apparently was highly prized by Native Americans who used it to make projectile points, knives, and other implements. Top-Of-The-World chert "is superior to obsidian because it is less prone to shatter, thereby keeping a sharp cutting edge for a longer period of time" (Choquette 1981:27). Although the alpine meadowlands surrounding the quarry sites may have also been used by prehistoric peoples, limited test excavations have not recovered any identifiable ungulate remains.

Table 3.7. Ungulate remains recovered from archaeological sites in British Columbia.
Part 1: Number of identified specimens.

Site	Date	Number of identified specimens (NISP)						Reference
		Elk	Bison	Deer ¹	Bighorn	Moose	Goat	
EdQa-27 1993	2000-100 BP	-	-	1	-	-	-	Choquette
EdQa-8	2400 BP	*	-	*	-	-	-	Bussey 1986
EcPx-5 1976a	*	-	-	2	1	-	-	McKenzie 1976b
EbPw-1	5000-100 BP	-	-	5	-	-	-	Mohs 1981 Yip 1982
Wild Horse River (DjPv-14)	3000-100 BP	4	-	19	-	-	-	Blake 1981
Wild Horse River 1985a (DjPv-14)	9000-100 BP	1	12	1	-	-	-	Choquette
DgQi-2	4000-200 BP	-	-	3	-	-	-	Bussey 1981
DgQi-3	4000-200 BP	4	-	714	-	-	-	Bussey 1981
Total		8	12	745	1	-	-	
Percent of total (NISP = 766)		1%	2%	97%	<1%	-	-	
Rank		3	2	1	4	-	-	

*Data were not presented in site report.

¹Includes both white-tailed and mule deer.

Table 3.8. Ungulate remains recovered from archaeological sites in British Columbia.
Part 2: Minimum number of individuals.

Site Goat	Total number of bones recovered	Number of bones identified to species	Percent of total bones identified to species	Minimum number of individuals (MNI)				
				Elk	Bison	Deer ¹	Bighorn	Moose
EdQa-27	52	1	2%	-	-	1	-	-
EdQa-8	*	*	*	*	-	*	-	-
EcPx-5	*	*	*	-	-	2	1	-
EbPw-1	17,169	6	<1%	-	-	*	-	-
Wild Horse River (DjPv-14)	666	23	3%	*	-	*	-	-
Wild Horse River (DjPv-14)	30,189	12	<1%	-	*	*	-	-
DgQi-2	3,015	3	<1%	-	-	1	-	-
DgQi-3	31,752	728	2%	1	-	7	-	-
Total	82,843	774	<1%	1	*	11	1	-
Percent of total (MNI = 14)				7%	-	86%	7%	-
Rank				2	4	1	2	-

*Data were not presented in site report.

¹Includes both white-tailed and mule deer.

DhPt-9 is situated near the Kootenay River approximately 2 km above its confluence with the Elk River and dates to around 5000 BP (Choquette 1971, 1972b, 1981). "Faunal remains in the lower levels were predominantly deer, while upper level samples included a considerable quantity of [bighorn] sheep, elk, and bison -- remains of the latter providing conclusive evidence of the prehistoric presence of bison west of the Continental Divide in intermontane British Columbia" (Choquette 1981:28). Unfortunately, neither MNI or NISP data were reported.

Choquette (1971, 1974) also surveyed and test excavated archaeological sites along the Kootenay River before they were inundated by the waters of Libby Dam. He reported finding deer bones, but comprehensive site reports are lacking. To the south in Montana, another 80 archaeological sites were recorded along the Kootenay River before they were flooded by Libby Dam. Of 1,455 ungulate bones recovered and identified at those sites, 1,431 (98%) were deer while 24 (2%) were elk, and only one was from bighorn sheep (Kay 1990:447).

At two archaeological sites along the Pend D'Oreille River in the lower Columbia system, DgQi-2 and DgQi-3, deer and elk were the only identified ungulates. Deer comprised 99% of the total while elk accounted for only 1% (Tables 3.7 and 3.8). Of 34,767 bones unearthed, only 731 could be identified to species because they had been highly fragmented, most likely by aboriginal bone grease processing (Bussey 1981).

So in summarizing archaeological sites excavated in British Columbia's southern Rocky Mountain Trench, the vast majority of identified ungulate faunal remains have been those of deer (Tables 3.7 and 3.8). Elk bones have been recovered from a few sites, but in very low numbers. Bison remains have been unearthed at two sites along the Kootenay River, suggesting that bison at one time may have extended their range west of the Continental Divide. As noted earlier, bison were common in Alberta's Crowsnest Pass and just to the west in British Columbia at sites DjPp-1 and DjPp-2 (Loveseth et al. 1979, Kennedy et al. 1982, Ronahgan et al. 1982). Bison could simply have continued down Elk River to the Kootenay Valley, though that has yet to be demonstrated.

SUMMARY

Contrary to conditions prevailing in the Canadian Rockies today, where ungulate communities are dominated by elk, archaeologically recovered ungulate remains are predominately from smaller ungulates, like bighorn sheep and deer, or from bison. Even in the Bow Valley portion of Banff National Park, bison and bighorn sheep were the ungulates most commonly unearthed, not elk which dominate that ecosystem today. A similar pattern has been observed throughout the western United States. In Yellowstone National Park, Wyoming's Jackson Hole, Idaho's Middle Fork of the Salmon River, and Oregon's Blue Mountains, elk dominate present ungulate communities comprising up to 80% or more of total ungulate numbers, yet elk bones are seldom recovered from archaeological sites in those areas (Wright 1984; Frison 1978, 1991; Kay 1987, 1990, 1992, 1994; Walker 1987; Akenson 1992). Of over 52,000 ungulate bones identified at nearly 200 Intermountain archaeological sites, elk comprised only 3%. Instead, bighorn sheep or deer were the most frequently unearthed ungulates (Kay 1990).

WHY ARE ELK SO RARE IN ARCHAEOLOGICAL SITES?

At least six explanations can be advanced to account for the scarcity of elk in the archaeological record. These include: (1) Native Americans could not kill elk; (2) Native Americans chose not to kill elk; (3) elk were killed but their bones were not brought back to human habitation sites inferring a transportation problem; (4) elk were killed and their bones transported to areas of human use (i.e., today's archaeological sites), but they did not survive the ravages of time – this would be a differential preservation or taphonomic problem; (5) special elk processing sites exist, but have never been excavated by archaeologists, thus skewing the available archaeological record; or (6) elk were a plains animals and, hence, were not present in the mountains for Native Americans to hunt or kill.

Native Americans Could Not Kill Elk

Although often not explicitly stated, the idea that prehistoric humans lived a brutish existence underlies most out-of-hand dismissals of Native Americans as important ecological factors. Native Americans are invariably characterized as possessing a "primitive" technology that made killing large ungulates extremely difficult. Native Americans have usually been delegated to the role of poor, starving savages who had to spend most of their time searching for something to eat (McCabe 1982:65, 87; McCabe and McCabe 1984:37, 39).

Unbeknown to most ecologists, though, anthropologists abandoned this stereotype of "primitive" people over 25 years ago with the publication of Lee's (1968) research on the !Kung and the subsequent Man the Hunter Conference (Lee and DeVore 1968). Lee demonstrated that the !Kung spent relatively little time in the quest for food despite living in one of the most inhospitable environments on Earth, Africa's Kalihari Desert. Lee showed that those "primitive" people had more leisure time than the average person living in today's "most advanced" western civilizations. Sahlin's (1972) even went so far as to call hunter-gatherers "the original affluent society." While more recent studies have shown that Lee's original estimates for !Kung work effort were too low, nevertheless the !Kung and most other present-day hunter-gatherers usually spend less time provisioning themselves than modern man, and they certainly do not live a hand-to-mouth existence (Hawkes and O'Connell 1981, Hawkes et al. 1985, Hawkes 1987, and others).

Unlike carnivorous predators that must physically close with their prey and thereby risk injury at each predation event, humans kill at a distance. About 8,000 to 10,000 years ago, the spear was superseded by the atlatl or spearthrower which had a much greater effective range (Grant 1980:20). The atlatl, in turn, was replaced by the more efficient bow and arrow between 1,000 and 2,000 BP (Blitz 1988). This new weapon was an improvement over the atlatl for it killed at longer ranges, was more accurate, achieved higher projectile velocities, and had superior penetrating power. In addition, arrows could be launched while the hunter remained crouched in his blind, whereas the atlatl had to be hurled from the standing position (Grant 1980).

The bows used by Native Americans were extremely powerful and could drive arrows completely through mature bison at ranges under 10 m. Saxton Pope (1923:368-369) compared the penetration of arrowheads by shooting identical arrows with steel or obsidian points from the same bow at a deer-hide-covered box filled with bovine liver to simulate animal tissue. To his surprise, he found that although the arrows were "identical in weight, feathering, and size of head, yet the steelheads, even when sharpened to a keen cutting edge, do not approach the penetration of obsidian by twenty-five percent." When flaked to its optimum, obsidian can be 500 times sharper than a modern razor blade (Silsby 1994:278).

Laubin and Laubin (1980) and others (Hamm 1989, 1992, 1993, 1994) constructed bows using techniques and materials once common throughout North America. They found that the relatively short, 1-1.2 m, sinew-backed bows of the Plains and Intermountain tribes were far superior to any bows developed in the history of world archery, except for Turkish composite bows of 1450 to 1570 A.D. They concluded that the sinew glued to the back of the bow was the key to these bows' marvelous elasticity and limb speed which imparted high velocity to the arrows and enhanced the arrows' penetration power. A Native American equipped with such a bow and arrows could kill the largest of North American ungulates at distances approaching 50 m or more. Native Americans certainly possessed the technology to kill all species, age classes, and condition classes of ungulates at will (Kay 1994).

Moreover, Native Americans used snowshoes to hunt or run down ungulates during winter (Anell 1969). Often they killed the exhausted animals with little more than handaxes or spears (McCabe 1982). Native peoples also used dogs to hunt ungulates, a technique so effective that it is now banned throughout Canada and the western United States. Not only did Native Americans hunt cooperatively, but they also built extensive networks of brush driveways, traps, and corrals to capture ungulates, even bison (Kay 1994).

So a review of the available evidence suggests that Native Americans could kill elk. Aboriginal technology was more than sufficient to kill all ungulate species for the last 10,000 or so years (Frison 1978, 1987, 1989a, 1989b, 1991). As discussed above, bison remains occur more frequently in archaeological sites than those of elk. Since Native Americans could kill bison, which are at least twice as large as elk, there is no logical reason to assume that aboriginal peoples were physically unable to kill elk. Based on analysis of elk behavior and Native American hunting techniques, Frison (1978:274, 1991:261) concluded that elk were "not difficult to hunt." In fact, Frison contends that elk were one of the easiest ungulates for Native Americans to kill (Kay 1990:335). There can be little doubt that prior to European contact, Native Americans possessed the physical, cultural, and social attributes to be effective predators of all ungulate species (Kay 1994, 1995a, in press b).

Native Americans Chose Not To Kill Elk

Optimal-foraging theory represents an attempt to develop a set of models general enough to apply to a broad range of animal species yet rigorous and precise enough to explain detailed behavior of each individual forager. The theory assumes that foraging behavior evolved by natural selection to respond to changing conditions in a way that maximizes each forager's individual survival and reproductive success. Optimal-foraging theory represents an attempt to specify a general set of decision rules for predators based on cost-benefit considerations that are in turn deducible from first principles of adaptation via natural selection (Stephens and Krebs 1986).

Originally developed by biologists to study non-human animals (Pyke et al. 1977, Stephens and Krebs 1986), optimal-foraging models have been used by anthropologists to examine human foraging (Winterhalder 1981a, 1981b; Smith 1983; Smith and Winterhalder 1992). Optimal-foraging models have been used to study a variety of hunter-gatherer societies, as well as to better understand the archaeological record (Yesner 1981, Simms 1984, Bettinger 1987).

Not only do all cultures have a stated preference for large mammals, but optimal-foraging studies have shown that ungulates are the highest ranked diet items. This means that ungulates will be taken in preference to other available resources, such as fish, small animals, or vegetal foods, and that ungulates will be pursued even when those species are rare (Kay 1994). To the optimizing hunter, the decision to pursue a prey item rests only on a consideration of the cost, benefits, and alternatives, not the long-term health of the prey population (Webster and Webster 1984:282, Smith and Winterhalder 1992).

Not only is meat an ideal source of protein but animal fats may be of critical importance (Speth 1983, 1987; Speth and Spielmann 1983). Anecdotal support for the importance of lipids can be found in statements about the desirability of fat animals that have been expressed by all hunter-gatherers. There also appear to be valid physiological reasons why animal fats are universally preferred by hunter-gatherers and other humans (Hayden 1981:395, Speth and Spielmann 1983, Abrams 1987, Lieberman 1987). Meat is so highly desired by some societies that its low availability often intensifies social disharmony (Baksh 1985, Good 1987).

Contrary to the notion that Native American diets were primarily meat (McCabe and McCabe 1984:28), anthropologists have long noted that those peoples should more appropriately be called gatherer-hunters since, except for the Inuit and perhaps Plains tribes, vegetal foods and fish comprised 80% to 90% of their diets (Lee 1968, 1979, 1984; and others). Native Americans, however, preferred meat when it was available (Webster 1985:44). Vegetal foods were a poor second choice even though they may be highly nutritious (Gould 1982:77).

Native Americans throughout western Canada, and especially those living in the mountains, consumed considerable quantities of fish, small animals, berries, roots, and other vegetal resources (Chamberlain 1892; Teit 1906, 1908, 1909; Goodard 1916; Turney-High 1941; Smith 1984; Driver 1988; and others). By prey-switching to a diet of fish or vegetal foods, Native American populations could have continued to grow despite the increasing scarcity of their preferred ungulate foods and the diminishing returns of the hunt. Although diminishing returns apparently act as a homeostatic mechanism to control populations of some predators, little such control has operated in the case of man (Cohen 1977:187).

Since vegetal foods and small mammals are lower-ranked diet items than ungulates, the high relative abundance of those foods in prehistoric diets indicates that few ungulates were available to those people (Bayham 1979, Smith 1983, Simms 1984, Smith and Winterhalder 1992). Under these conditions, there is no evidence to support the notion that prehistoric peoples in the Canadian Rockies choose not to kill elk. In fact, elk were a highly preferred diet item wherever they occurred (Smith 1984:103). Lewis and Clark (1893:725-794), for instance, reported that elk were highly prized by Native Americans as a supplement to their regular diets of fish and vegetal foods.

While the demonstrated lack of elk in archaeological sites may at first appear to suggest that native hunting was unimportant in keeping elk numbers low (see Chapter 1), in fact, the opposite is true. Optimal-foraging theory predicts that high-ranked items, like elk, are more susceptible to overexploitation than low-ranked items. According to optimal-foraging models, high-ranked items will seldom appear in the diet if they are being overexploited (Stevens and Krebs 1986). So, ungulate species unearthed from archaeological sites with the lowest frequency, such as moose and elk, were probably subjected to extreme overexploitation (Kay 1994, 1995a).

A Transportation Problem

This hypothesis assumes that Native Americans killed elk, but did not bring bones from those animals back to human habitation sites (i.e., today's archaeological sites). White (1952, 1953a, 1953b, 1954) was the first to note that the bones of any one ungulate species found in archaeological sites did not match the proportion of bones in the live animal. That is to say, certain bones appeared in archaeological contexts less frequently than would be expected if entire ungulates had been brought to the sites. White noted that, in general, "anatomical parts with comparatively large amounts of meat (e.g. femurs) are more likely to be transported than those with comparatively small amounts of meat (e.g. feet)" (Metcalf and Jones 1988). "This phenomenon was later formalized as the 'Schlepp Effect,' defined as 'the larger the animal killed and the farther from the point of consumption it is killed, the fewer of its bones will be schlepped back to camp,

village or other area" (Lyman 1987a:255). When faced with carrying portions of a large ungulate back to a distant campsite, aboriginal hunters tended to leave behind the lower-quality bones in favor of transporting meat (Binford 1978, 1981).

This consideration notwithstanding, it is unlikely that transportation costs precluded Native Americans from carrying elk bones to prehistoric sites in Banff National Park and throughout the Canadian Rockies for at least three reasons. First, many archaeological sites are found in close proximity to known elk wintering areas such that the "ditching" of bones would probably not have been an overriding consideration (Metcalf and Barlow 1992). Second, as discussed above, bison outnumber elk in most archaeological sites. Since bison are at least twice as large as elk, aboriginal hunters would probably not have "ditched" elk bones but brought bones back from bison kills. Finally, studies of modern hunter-gatherers have shown that only the largest bull elk are within the size class of animals from which aboriginal hunters commonly fail to transport bones to habitation sites (O'Connell et al. 1988, 1990). So these lines of evidence suggest that the lack of elk in Banff's archaeological sites cannot be attributed to the fact that hunters killed elk but failed to carry those animal's bones back to their campsites.

Differential Preservation or a Taphonomic Problem

This hypothesis assumes that Native Americans killed elk and brought them to human habitation sites, but for some reason, elk bones were more susceptible to the ravages of time than the same bones from other ungulates. This would be what archaeologists call a taphonomic or differential preservation problem. Based on extensive experimentation and bone measurements, it has been shown that dense bones survive better than light bones, bones of large animals generally survive better than the same bones of smaller animals, and bones of older animals have a higher probability of survival than the same bones from younger individuals (Lyman 1987a, 1987b). Since large, dense bones preserve better than small light bones, differential preservation should favor elk bones over those from mule deer or bighorn sheep, the exact opposite of the species-abundance patterns observed at archaeological sites in Banff National Park and throughout the Canadian Rockies. So it is unlikely that elk would be underrepresented in archaeological contexts because of differential preservation. Furthermore, based on butchering marks and breakage patterns, there is no evidence that aboriginal peoples treated elk bones differently from those of other ungulates.

It has been suggested, however, that the degree of butchering may affect preservation and subsequent species identification.

... A particular bone may be large and dense, and therefore a good candidate for preservation as a whole bone, but the larger bones are also more likely to be fragmented during butchering and bone grease preparation, and thereby rendered more vulnerable to weathering. The bones of smaller animals, or smaller elements, may be less broken during butchering, and therefore less vulnerable to weathering. It is not enough to discuss the effects of weathering on whole bones, and say that since elk are more robust than sheep, they should preserve better. There is a cumulative effect here; the greater the degree of butchering, the more likely weathering is to remove them from the sample, even if they are large and robust animals to start with.

Secondly, the degree of fragmentation and the resulting weathering affects the identification. If you have a four cm piece of bighorn sheep bone, it is quite probably identifiable. A four cm piece of elk bone is much less likely to be identifiable ... [Gwyn Langemann, pers. comm. 1993].

While this may be a valid consideration, it does not appear to have skewed the archaeological record in favor of smaller ungulates to the detriment of larger species like elk. In addition to the NISP or MNI data reported above, most archaeological studies also listed otherwise unidentifiable faunal material as being from either small ungulates; such as deer, bighorn sheep, mountain goat, antelope; or from large ungulates like elk, moose, or bison – in many cases this can be done quite easily based on bone thickness. If fragmentation made it less likely that elk remains would actually be identified to species than bones of smaller ungulates, then unidentified large ungulate remains should outnumber unidentified small ungulate remains. This pattern, though, is not observed in the archaeological record. In all cases except where bison is the most commonly identified ungulate, unidentified small ungulate remains greatly outnumber unidentified large ungulate remains. This suggests that differential preservation and taphonomic factors do not tend to remove elk from the archaeological record.

Elk Processing Sites Have Been Overlooked

The idea that special elk processing sites exist but have never been found or excavated by archaeologists, is also not supported by available evidence. Since a wide variety of archaeological sites, from temporary camps, to kills, to base camps, have been recorded in the Canadian Rockies and along Alberta's Eastern Slopes (Reeves 1986, Ronaghan 1986), it is doubtful that there would have been a bias against elk processing sites even if the latter existed. Special elk process sites are not known from the western United States (Kay 1990) and none of the professional archaeologists interviewed during the course of this study was aware of any special elk processing sites in Canada. So it is extremely unlikely that this factor has biased the available archaeological record to any significant extent.

Based on data which shows that elk have been more frequently unearthed in summer (6% of NISP), instead of winter (less than 1% of NISP), occupation sites in the Crowsnest Pass region of southwest Alberta (Driver 1985), it has been suggested that the archaeological faunal record in Banff National Park and other mountainous areas may be skewed because mostly lower-elevation, winter-occupation sites have been excavated. That is to say, if elk are more common in summer, in contrast to winter, occupation sites, and if only winter occupation sites have been excavated, this could possibly bias the archaeological record against elk.

... I suspect that the sample of sites we have excavated in any detail may well be biased to winter sites: repeatedly occupied sites on the south-facing grassy montane slopes of the major river valleys. The summer sites may be those farther back into the valleys, or farther up the slopes, that are less frequently occupied, and less visible, and more exposed and the bone more poorly preserved. So while it is not necessarily the case that archaeologists have not been discovering elk processing sites ... I think you could make a good case that we have not found many of these smaller specialized short term use sites, whatever their particular function may be. They are present in the site files ... but I think they are not present in the numbers that they ought to be, and they are certainly not excavated to anything like the extent that the large valley bottom sites are. [Gwyn Langemann, pers. comm. 1993].

Again, while this may be a valid concern, it does not appear to have biased the archaeological faunal record to any significant degree. First, this hypothesis assumes that few elk summer in low-elevation valleys. This is not true because relatively large numbers of elk summer in Banff's Bow Valley (Woods 1991) and on the Ya Ha Tinda (Morgantini 1995). The same is true in the Yellowstone Ecosystem and throughout the Intermountain West. Where winter ranges are protected from human disturbance, such as in national parks (Yellowstone and Grand Teton), wildlife refuges (Wyoming's National Elk Refuge), and state game ranges (like Sun River in Montana), large herds of elk now summer in low-elevation montane valleys (Kay 1990). In fact, there is no physiological need for elk to migrate to high-elevation summer ranges. After all, elk were relatively common on the Canadian prairies prior to European arrival (Glover 1962, Palliser 1969, Hind 1971).

Second, where high-elevation ranges commonly used by elk today have been searched for archaeological sites, either few archaeological sites have been found or the archaeological sites contain few or no elk remains (Frison 1978, 1991; Wright 1984; Kay 1990). At several sites, archaeologists have commented on the fact that although they frequently saw elk in or near their excavations, few, or no elk bones were found in those sites (Reid and Caulk 1986, Reid 1988). Instead, high-elevation archaeological sites in the Intermountain West contain mostly bighorn sheep or deer (Frison 1978, 1991; Wright 1984; Kay 1990). While it certainly would be interesting to excavate a sample of higher-elevation archaeological sites in the Canadian Rockies, there is no evidence that those sites would yield a plethora of elk bones. The apparent greater number of elk in summer occupation sites from Crowsnest Pass may simply be a methodological artifact for Driver (1985:120) noted that seasonality for some sites was inferred.

Elk Were a Plains Animal

Frison (1978, 1991) and Wright (1984) have speculated that elk were originally a plains animal which were driven into the mountains by advancing European civilization. Others contend that elk were found historically both on the plains and in the mountains and that settlement did not push elk into the mountains, but rather the herds on the plains were exterminated while those in the mountains were better able to survive (Koch 1941, Bryant and Maser 1982:23). Yet this does not explain why elk were rare in the mountains when they appear to be better adapted to that niche than either mule deer or bighorn sheep which outnumber elk in archaeological sites.

Numerous studies conducted in the Canadian Rockies and throughout the Intermountain West have documented that on montane winter ranges, elk outcompete and dominate mule deer and bighorn sheep (Case 1938; Cliff 1939; Cowan 1944, 1947a; Flook 1964; Stelfox 1971, 1974, 1976; Olmsted 1979). Elk have a larger diet breadth than mule deer or bighorn sheep (Kufeld 1973, Nelson and Legee 1982, Collins and Urness 1983, Jenkins and Wright 1988) and elk can digest their diets more efficiently than can mule deer (Nelson and Legee 1982, Baker and Hansen 1985). Elk can also digest the diets of mule deer more effectively than can mule deer (Collins and Urness 1983). Because elk have a larger mass-to-surface-area ratio than either deer or bighorn sheep, they are better able to withstand cold temperatures and high winds (Moen and Jacobsen 1974, Beall 1976, Grace and Easterbee 1979, Moen 1982).

Furthermore, because of their larger size, elk are better able to cope with deep snow than either deer or bighorn sheep (Telfer and Kelsall 1984, Dailey and Hobbs 1989). Elk expend less energy moving through a given depth of snow than deer or bighorn sheep (Parker et al. 1984, Dailey and Hobbs 1989). Besides, if elk do so well in the Canadian Rockies today, why were they not there in the past, especially since elk are superior competitors over either deer or bighorn sheep which outnumber elk in archaeological sites? A few elk were present in the Banff Ecosystem for the last several thousand years, but what kept the elk population from expanding? It certainly was not interspecific competition. So the hypothesis that elk were not present in the mountains simply because they were a plains animal is not supported by available ecological data.

If large numbers of elk inhabited the Banff Ecosystem for the last several thousand years, as they do today, then those animals should have been killed and transported to habitation sites in equally large numbers by Native Americans. Elk bones should have accumulated in those sites and elk should dominate the archaeologically recovered ungulate remains. That they do not can only mean that large numbers of resource-limited elk did not inhabit the Banff Ecosystem until recent times (Kay 1994, 1995a).

BONE GREASE PROCESSING

Most of the bone recovered from archaeological sites in the Canadian Rockies, along Alberta's Eastern Slopes, and in the Columbia Trench is highly fragmented due to processing by the native peoples who left those cultural deposits. The same is true throughout the western United States (Kay 1990). In Banff National Park, for instance, 66,299 pieces of bone were recovered from six archaeological sites, but most were so highly fragmented that only 745 (1%) could be identified to species (Table 3.3). When archaeologists refer to bones recovered from intermountain sites, they more properly are referring to bone fragments because most of the bones have been broken into pieces less than 3 cm in any dimension (see Figure 3.1). This fragmentation has been attributed to bone grease processing by aboriginal peoples.

Prior to European influences, native inhabitants often produced bone grease in the following manner, although other methods were also used (Leechman 1951; Vehick 1977; Binford 1978, 1981). First, a hole was dug in the ground and lined with a green hide, hair side down. Second, bones were smashed into small pieces using anvil and hammer stones. Third, the hide-lined hole was filled with water and the broken bones added. Fourth, rocks were heated in an adjacent fire and placed in the water using green sticks until the water approached a boil. The water was kept simmering rather than being allowed to boil violently, as that rendered the oil and grease from the bone fragments and caused it to accumulate on the surface. The grease was then skimmed off and placed in storage vessels.

Bone grease processing is extremely labor intensive and calculations suggest that it may even have been done at a net loss of energy. That is to say, it took more energy or calories to produce than the aboriginal peoples obtained when they consumed the bone grease. This suggests that native peoples may have been experiencing a period of nutritional stress, or at least that critical animal fats (see above) were in short supply (Binford 1978, 1981; Olson 1983; Schalk and Mierendorf 1983; Potter 1995) which, in turn, indicates that ungulates were not abundant (Broughton 1994a, 1994b, 1995; Potter 1995). On the Canadian and United States prairies where large herds of bison and other ungulates were encountered at historical contact (Lewis and Clark 1893, Hendry 1907, Tyrrell 1916, Glover 1962, Palliser 1969, Lamb 1970, Hind 1971), ungulate bones unearthed in archaeological sites are not highly fragmented like they are in the foothills and mountains (Frison 1978, 1991; Reeves 1983a, 1983b). So the fact that bone grease processing was the norm in montane environments, suggests that large herds of ungulates were not common in the Canadian Rockies prior to the arrival of Europeans and modern wildlife management. As noted in Chapter 2, the first Europeans to explore the Canadian Rockies encountered few ungulates, especially elk.



Figure 3.1. An example of ungulate bones typically unearthed at archaeological sites in the Canadian Rockies. Shown are bones recovered from the Vermilion Lakes site in Banff National Park (Fedje and White 1988, Fedje et al. 1995). The upper bone is either a deer or bighorn sheep acetabulum (the part of the pelvis where the femur is attached) and was unearthed at a depth of 192 cm (153R-13B-lot 15), while the lower bone fragments were recovered from the 100-110 cm level (153R-14F-lot 11). Not surprisingly, none of the lower bone fragments could be identified to species. This fragmentation was mostly likely the result of aboriginal bone grease processing, not other taphonomic factors, and explains why the vast majority of the bones commonly recovered from Rocky Mountain archaeological sites can not be identified to species. Faunal remains curated by the Archaeology Branch, Parks Canada Western Regional Office, Calgary, AB. Photo in August 1993 by Charles Kay (No. 3709-16A).

CHAPTER 4

REPEAT PHOTOGRAPHS

INTRODUCTION

Perhaps the best measure of success in preserving national parks unimpaired for future generations, and one easily judged by all, lies not in detailed scientific studies, but rather in the simplicity of the photograph. After all, it was photography that stimulated the original establishment of Canada's national parks. By framing scenes of spectacular grandeur, photographs aroused the interest and support of the Canadian public (Pole 1991, Woodward 1993).

Building the Canadian Pacific Railway across the continent during the 1870s and 1880s coincided with advancements in the camera and the rise of photography as both a hobby and a profession (Pole 1991, Woodward 1993). The Canadian Pacific had as early as 1871 contracted the Montreal firm of William Notman and Son to produce views along the railroad. In 1884, the younger Notman, William McFarlane, toured the Canadian Pacific taking a series of photographs as far west as the end of the line, including scenes of construction in Kicking Horse Pass across the Continental Divide. In 1887, William Van Horne, general manager of the Canadian Pacific Railway, had Notman's pictures incorporated into an advertising booklet, "The New Highway to the East," designed to draw passengers to the railway (Hart 1983). Grand panoramas and the encouragement of the railroad, which by 1887 even provided a photographer's car complete with a darkroom, attracted early camera buffs to the Canadian Rockies (Hart 1983).

The popularity of the camera came at a most fortuitous time for it stimulated legislative protection in western North America. In the United States, early journalists submitting articles describing the marvels of Yellowstone were rejected by editors with such comments as "champion liar" or "thank you but we do not print fiction." It was not until William Henry Jackson's impressive photographic images of landscapes, waterfalls, and geysers were published that Americans realized the uniqueness of Yellowstone and set it aside as the world's first national park in 1872 (Hayden 1872, 1873; Haines 1974, 1977; Chambers 1988).

We are not only indebted to these early photographers for helping establish our national parks, but their work provides a benchmark to judge ecological integrity. Prior to building the Canadian Pacific Railway, Banff's Bow Valley had not been changed, to any measurable degree, by Europeans (Byrne 1968). Hostile plains tribes had forced fur traders to cross the mountains by more northerly routes (see Chapter 2), and mineral-poor rock had not drawn a rush of prospectors as happened further west in British Columbia. So, the earliest photographs depict a landscape relatively untouched by the hand of modern man. This is significant for it was one of the first times in Canadian history that the camera caught up to the advancing frontier. Even in Jasper National Park, the fur trade had been firmly established for decades before the first photographer arrived in 1872 (see Chapter 2).

As part of his duties in Banff National Park, Warden Cliff White has sought to commemorate a century of landscape preservation and photography in the Central Canadian Rockies by retaking historical photographs from the same locations. These repeat photosets allow not only an appreciation of the historical scene, but also an evaluation of the changes that have occurred during a century of park management. Over the past 15 years, Cliff White has compiled approximately 200 repeat photosets of areas in Banff National Park, including low-elevation montane zones, lower and upper subalpine settings, and windswept alpine ridges. Since our terms of reference concerned primarily the Bow Valley and similar montane habitats where ungulates now winter, we selected a series of 12 repeat photographs from Mr. White's work that depict montane scenes and which are representative of his entire collection. Included are eight photosets from the

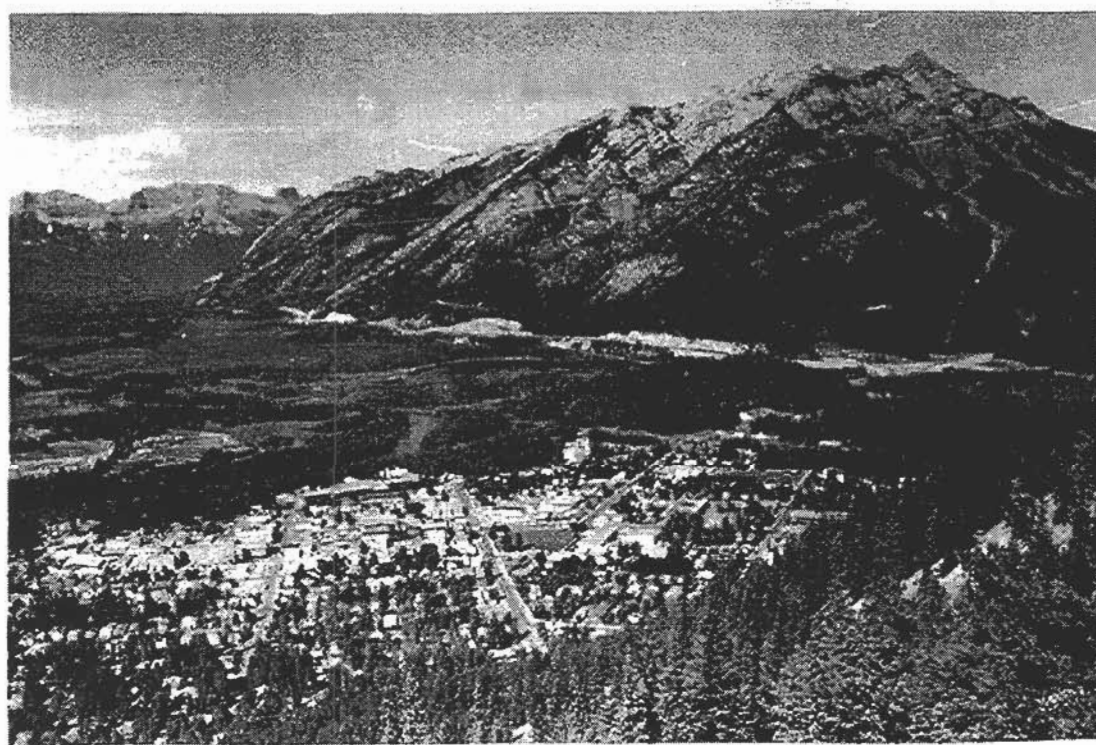
Bow Valley, one from the Ya Ha Tinda, two from the North Saskatchewan, and one taken in the Columbia Trench.

PAIRED PHOTOGRAPHS

Figure 4.1. Mount Norquay and Banff townsite viewed northwest from Tunnel Mountain in 1902 and 1984. (a) The southern slopes of Mount Norquay burned in ca. 1850, 1866, 1881, and 1889. The frequent, but low intensity fires maintained montane grasslands, aspen communities, and shrubfields. Conifers were present, primarily, on upper rocky slopes where a lack of fine fuels prevented the spread of fire. Conifers on the lower slopes were mostly Douglas-fir, whose thick bark allowed those trees to survive repeated low-intensity ground fires. There is no evidence of large-scale crown fires. The valley bottom, with many open areas, young-age forests, and scattered older trees along the Bow River also suggests a history of frequent, but low-intensity fires. Photo by the Detroit Photographic, Co. courtesy Whyte Museum of the Canadian Rockies (NA66-1804a). (b) That same area photographed 82 years later. With the removal of aboriginal peoples and the institution of Canada's fire suppression program, this area has not burned since the 1890s. In contrast to earlier conditions, thick stands of conifers now dominate Mount Norquay and the Bow Valley. Grasslands and aspen have declined markedly as have open Douglas-fir forests. The growth of coniferous forest and the accumulation of fuels has set the state for large-scale high-intensity crown fires. Part of Mount Norquay was prescribed burned by Parks Canada in 1992 (see Chapter 6). Photo by Cliff White (BNP-84D-10).



a.



b.

Figure 4.2. Banff townsite and the Bow Valley viewed northeast from Sulphur Mountain in 1898 and 1981. (a) Depicted are montane grasslands, aspen communities, and open forests all indicative of high-frequency low-intensity fires. Before 1890, fires were common but the scattered patches of coniferous forests suggest that large-scale crown fires were the exception. In fact, frequent burning and the early successional vegetative mosaic which resulted, probably prevented severe firestorms, like those seen in Yellowstone during the summer of 1988. Photo by George Paris courtesy Whyte Museum of the Canadian Rockies (NG5-97). (b) That same scene photographed 83 years later. The Bow Valley has not burned since the earlier photo. In the absence of fire, grassland and aspen communities have declined, and the coniferous forests have both grown-up and thickened-up. Under extreme burning conditions, the area would now support large-scale high-intensity crown fires. Foraging areas available to elk and other ungulates have declined approximately 90% since the 1890s (Van Egmond 1990). Photo by Bruno Engler (BNP-FM-24).



a.



b.

Figure 4.3. Cascade Mountain viewed north from the Bow Valley in 1886 and 1981. (a) The lower southern exposures show the effects of frequent burning and are mostly grasslands, shrubs, and regenerating aspen stands. Mid-slope forests also show the effects of fire but to a lesser extent, being somewhat protected by rocks and cliffs. Forests on the upper slopes, though, show little impact of fire as large areas of bare rock prevented low-intensity ground fires from spreading into those zones. Shown is the Woodworth cabin built in 1883, one of the first buildings in Banff National Park. Photo by A. Falmer courtesy Whyte Museum of the Canadian Rockies (NA71-3530). (b) That same scene 95 years later. With exclusion of fire, vegetative change on the lower slopes has been dramatic. Aspen trees have reached maturity only to be replaced by more shade-tolerant conifers, while aside from the lower meadow, grasslands and shrubfields have declined. This area is now heavily used by elk which also prevents aspen regeneration and limits shrub growth. Mid-slope forests have thickened, to a limited degree, while those on the upper slopes show little change. Photo by Bruno Engler (BNP-81A-1).



a.



b.

Figure 4.4. Hoodoos near Banff townsite viewed southeast in 1890 and 1981. (a) The south-facing grassy slopes above the Bow River; the open, widely-scattered, mature Douglas-fir; and the dead snags suggest that low-intensity ground fires were common prior to establishment of Banff National Park. There is no evidence, however, of recent crown fires as would be the case if the Bow Valley was heavily forested only to have been ravaged by fires associated with early railroad construction and European settlement (c.f. Byrne 1968; Nelson 1969b, 1970; Nelson et al. 1972). That is, the open nature of the vegetation depicted in the earliest photos is not an artifact of European making, but instead is representative of conditions that existed in the Bow Valley before Europeans arrived. Studies indicate that light ground fires swept this area in 1845, 1851, 1860, 1867, and 1876. Photo by George Paris courtesy Whyte Museum of the Canadian Rockies (WMCR-NG5-22). (b) That same area 91 years later. With the exclusion of fire, conifers have increased markedly, replacing what was once a grassland-shrub community, and reducing its value as big game winter range and wildlife habitat (Van Egmond 1990). The change has been dramatic and is ongoing. The forest has grown to such an extent that, under the right conditions, it would now support a stand-replacing crown fire, something that could not have happened 100 years ago. Photo by Bruno Engler (BNP-81A-18).

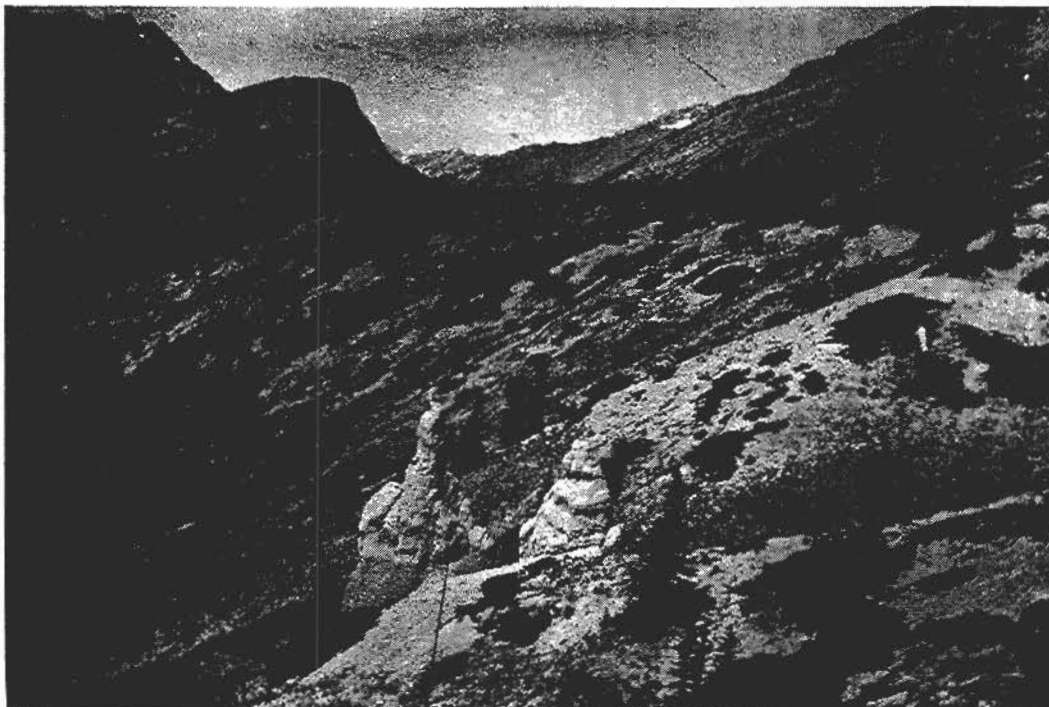


a.



b.

Figure 4.5. Banff's Hoodoos viewed northwest in 1894 and 1985. (a) Again, the grassland communities, limited conifers, and dead snags suggest that the area burned at frequent intervals prior to establishment of Banff National Park. As seen in other early photos, there is no evidence of recent crown fires, indicating that Banff's forests were not burned-off by early European settlers and railroad builders (c.f. Byrne 1968; Nelson 1969b, 1970; Nelson et al. 1972). Photo by the Vaux Family courtesy Whyte Museum of the Canadian Rockies (WMCR-NA-80-49). (b) Despite the fact that these south-facing slopes are among the driest in Banff National Park, with 95 years of fire suppression, conifers have increased dramatically. In time, conifers may completely dominate the site, further reducing its value as big game winter range and wildlife habitat (Van Egmond 1990). Photo by Cliff White (BNP-85C-12).



a.



b.

Figure 4.6. Banff's Bow Valley viewed north above the Hoodoos in 1889 and 1985. (a) Light ground fires swept this area in ca. 1840, 1867, 1871, 1876, and 1886. The short interval between fires prevented the growth of most conifers, and maintained the area as grasslands, shrubs, and regenerating aspen. There is no evidence of recent large-scale crown fires as would be the case if Banff's forests were destroyed by European set fires when the park was first settled (c.f. Byrne 1968; Nelson 1969b, 1970; Nelson et al. 1972). The photographer is unknown but the photo is courtesy Whyte Museum of the Canadian Rockies (WMCR-NA66-2346). (b) That same scene 96 years later. Since fire has been excluded from the Bow Valley, the number of conifers on this site has increased dramatically. In fact, this repeat photo had to be taken by climbing into the top of a tree as the original ground level photopoint is now blocked by conifers. What was once a grassland-shrub community is now a coniferous forest capable of supporting large-scale crown fires. The fire regime has changed from high-frequency, low-intensity ground fires to infrequent, but high-intensity crown fires, completely changing plant and animal communities. Photo by B. Low (BNP-85K-14).



a.



b.

Figure 4.7. Viewed west up the Bow Valley in 1914 and 1983. (a) Many of the widely scattered conifers have had their lower branches removed by light ground fires. That plus the open grasslands, shrubfields, and regenerating aspen suggest that this area experienced a history of frequent low-intensity fires during the 1800s. Shown is what was then the main park road and which now is Highway 1A. Mount Cory is on the right. This photograph was taken as evidence in a bighorn sheep poaching case. The dashed lines mark the route of the poachers, and the location of the dead sheep. Photo by the Banff Warden Service in 1914 courtesy of Whyte Museum of the Canadian Rockies (PD49-1-23). (b) That same scene after 69 years of fire suppression. Aspen trees have matured only to be replaced by conifers, and except for the driest south-facing hillside, grasslands and shrubs have markedly declined only to be replaced by conifers. Under the right burning conditions, the lower valley would now support stand-replacing crown fires. The value of this area as winter range for elk and other ungulates has significantly declined. Photo by Cliff White in 1983 (BNP-83-C-12, 15, 18).

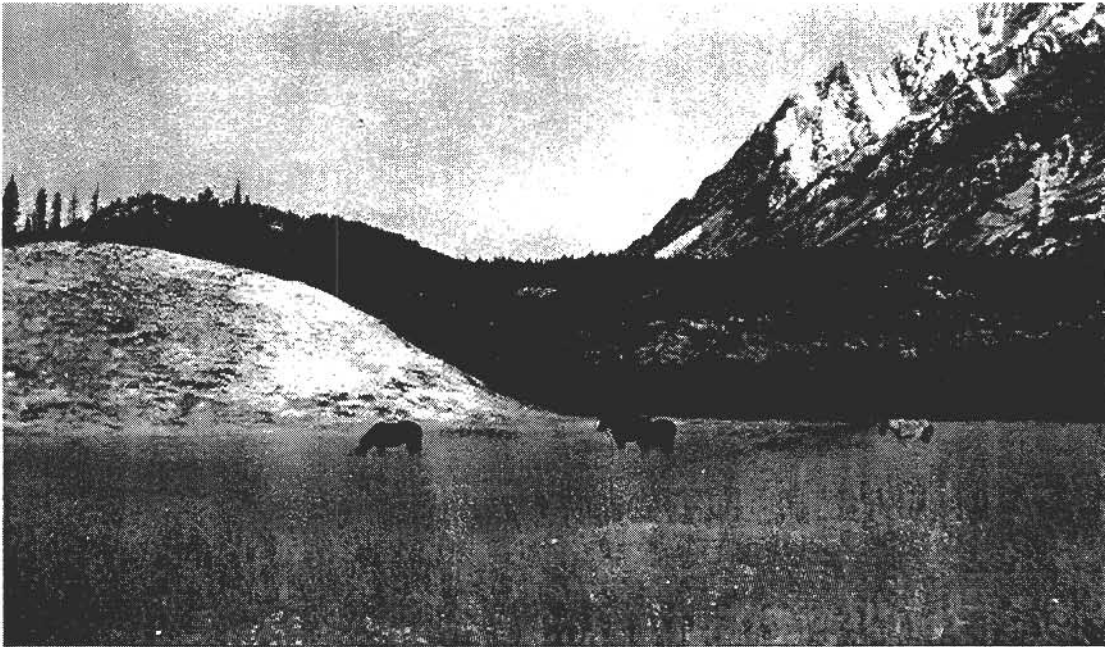


a.

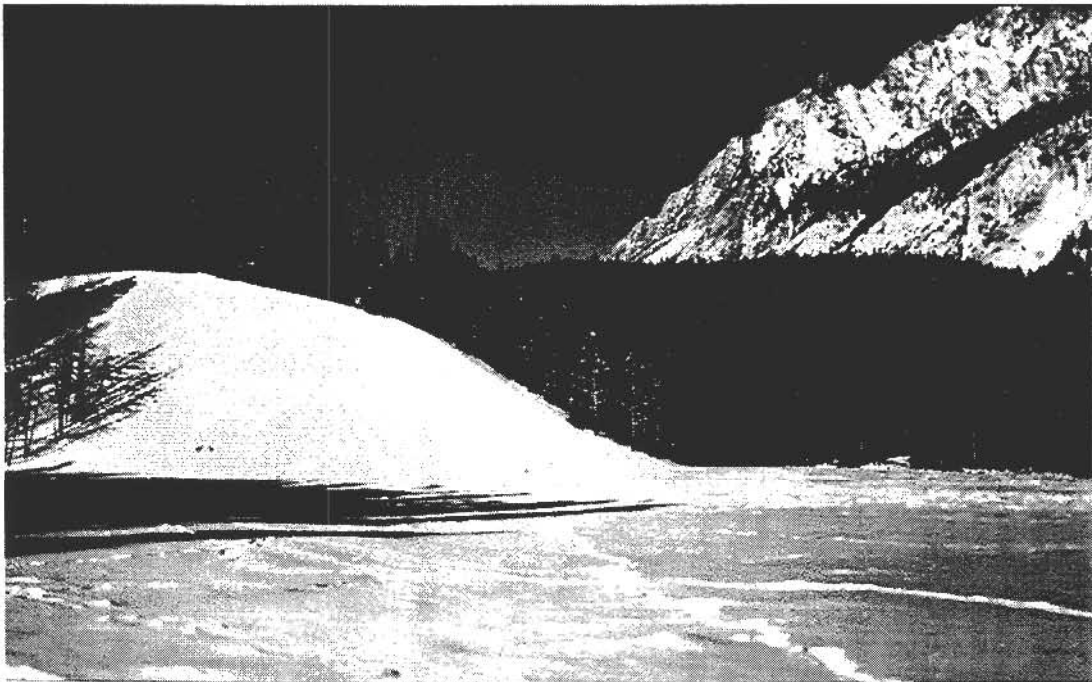


b.

Figure 4.8. Hillsdale Meadows west of Banff townsite in ca. 1907 and 1986. (a) Aspen communities were widespread, and both mature aspen trees and regenerating aspen saplings had not been browsed by ungulates. Conifers showed the effects of frequent low-intensity ground fires as many of the larger Douglas-firs had their lower branches removed by fire. Photo by Elliott Barnes courtesy Whyte Museum of the Canadian Rockies (WMCR-NA65-386). (b) That same scene after 79 years of fire exclusion. Most of the aspen matured only to be replaced by more shade-tolerant conifers. Today, this area is heavily used by elk, primarily during winter, and aspen show extensive bark damage and repeated browsing of suckers. Unlike the earlier photo, ungulate browsing now prevents aspen regeneration. After a control burn conducted by Parks Canada near here in 1985, aspen produced abundant root suckers, but elk browsing prevented any of those plants from growing more than 1 m in height and, thus, kept the stands from regenerating (see Chapter 6). Photo by Cliff White (BNP-86Q-15).



a.



b.

Figure 4.9. The Ya Ha Tinda viewed north in 1937 and 1986. (a) The Ya Ha Tinda, situated on the Red Deer River, was once part of Banff National Park but was excluded when Banff's boundaries were redrawn in 1930 (Byrne 1968). The Ya Ha Tinda, however, is still owned by Parks Canada and serves as a horse ranch, primarily for wintering animals. The area also supports a wintering population of 2,000± elk that summer in Banff National Park (Morgantini 1995). There is no commercial development in this drainage, and unlike Banff's Bow Valley there is no railroad or highway. Nevertheless, the area still showed the effects of frequent fire prior to park establishment. The shrubfield and old snags on the north-facing hillside in the foreground attest to Ya Ha Tinda's fire history. Photographs by Banff Warden Service courtesy Whyte Museum of the Canadian Rockies (WMCR-465-15 and WMCR-465-16). (b) After nearly 50 years of fire suppression, the conifers in the foreground have increased markedly. The trees are now so dense and tall, that the repeat photograph had to be taken with the aid of a helicopter as the original ground level photopoint is now blocked by conifers. White spruce (*Picea glauca*) and shrub birch (*Betula glandulosa* and *B. pumila*) have invaded Ya Ha Tinda's grasslands shown in the distance. Aspen is still common, but stands show evidence of repeated elk browsing and bark damage, and are regenerating only where elk use is limited by hunting pressure (see Chapter 6). Unlike Banff National Park, sport hunting and native subsistence hunting are both permitted on the Ya Ha Tinda. Photos by Cliff White (BNP-8601-5 and BNP-8601-9).



a.



b.

Figure 4.10. Viewed south over Kootenay Plains in 1907 and 1993. (a) A road was not built up the North Saskatchewan until ca. 1940 and before then this area had not seen the early development that took place in Banff's Bow Valley. Nevertheless, the distant mountain slopes, the steep hillsides above the North Saskatchewan River, and Kootenay Plains themselves all reflect a history of frequent low-intensity fires. There is little evidence to support the notion that stand replacing crown fires were common or that the area was originally covered by climax forests until burned by Europeans (c.f. Byrne 1968; Nelson 1969b, 1970; Nelson et al. 1972). Photo by Elliott Barnes courtesy Whyte Museum of the Canadian Rockies (WMCR-NG9-5). (b) After 86 years of fire suppression, though, forests on the distant mountain slopes have increased markedly as have conifers on the hillsides above the North Saskatchewan River. In the absence of fire, conifers have even invaded Kootenay Plains and, in time, may eliminate those montane grasslands. Aspen has also increased markedly. Few elk winter in this area as it is open to regulated sport hunting and native subsistence hunting. Unlike aspen in Banff National Park, aspen on Kootenay Plains has successfully regenerated, even in the absence of fire (see Chapter 6). Photo by Charles Kay (No. 3617-5).



a.



b.

Figure 4.11. Viewed southeast over Kootenay Plains in 1907 and 1993. (a) This photograph was taken approximately 1 km west of the area depicted in Figure 4.10., and like that previous photo, this picture shows relatively few trees on the mountain slopes, open hillsides above the North Saskatchewan River, and few conifers on Kootenay Plains. Photo by Elliott Barnes courtesy Whyte Museum of the Canadian Rockies (WMCR-NG9-64). (b) After 86 years of fire suppression, though, dense forests now dominate the distant mountain slopes while conifers have increased markedly on the hillsides overlooking the North Saskatchewan River. Conifers have also increased on Kootenay Plains. The photo point was originally on an open hillside slightly above the main grassland, but a dense coniferous forest now covers that area, so for this photograph, the camera had to be positioned off the hill and forward. Unless fires are again permitted to sweep across Kootenay Plains, in time, these unique montane grasslands will be replaced by advancing conifers. Photo by Charles Kay (No. 3617-11).



a.



b.

Figure 4.12. The Columbia River Valley viewed north from Swansed Peak in 1906 and 1990. (a) The valley floor and southwest-facing mountain slopes are predominately grasslands and open timber, suggestive of frequent low-intensity ground fires. Photo by H.W. Gleason courtesy Whyte Museum of the Canadian Rockies (WMCR-NA66-1140). (b) That same area 84 years later. In the absence of fire, conifers have increased markedly despite the dry environment (Kay 1996:24-28). What were once montane grasslands are now coniferous forests capable of supporting stand-replacing crown fires. If this trend continues, the remaining grasslands will eventually be lost. With increased forest cover, the value of this area as big game winter range and wildlife habitat has declined (Van Egmond 1990). Photo by Cliff White (BNP Photo No. 90-C-8/9).



a.



b.

SUMMARY AND CONCLUSIONS

Before 1885, the lower montane zones of Banff National Park and other montane areas in the Central Canadian Rockies were subject to frequent, but low-intensity fires. Dense stands of conifers were rare, and, accordingly, so were high-intensity crown fires. Although construction of the Canadian Pacific Railway and European settlement may have started fires in the Bow Valley, they did not destroy Banff's forests because there was no forest primeval (Tymstra 1991). Instead, European fires only replaced those once set by Native Americans (see Chapter 5). With the establishment of Banff National Park and government policies of fire exclusion, however, that changed.

Aspen, shrub, and montane grassland communities common during the 1800s were gradually replaced by conifers, and existing coniferous forests became more heavily stocked. This significantly reduced the foraging areas available to elk and other ungulates, especially during winter, and set the stage for large-scale stand-replacing crown fires; raging infernos that rarely occurred in the past. Thus, entire plant and animal communities have been altered by the exclusion of once common, but low-intensity ground fires.

Based on these repeat photographs, it is also apparent that aspen has declined markedly. Much of that decline is due to replacement of aspen stands by conifers in the absence of fire, but it is also due, in part, to repeated browsing by elk and other ungulates. Historical photographs show no evidence of ungulate browsing or elk bark damage on aspen, the exact opposite of present conditions. Today, burned aspen stands do not regenerate like they did in the past, because now all the new suckers are consumed by elk and other ungulates (see Chapter 6). This would indicate that few elk or other ungulates were found in Banff during the 1800s, and that today's elk population is not representative of earlier conditions. There are probably more elk in Banff National Park and the Central Canadian Rockies today than at any point in the recorded past (also see Chapters 2 and 3).

COMPARISON WITH OTHER AREAS

Yellowstone Ecosystem

Repeat photographs show a similar pattern in the Yellowstone Ecosystem (Gruell 1980a, 1980b; Houston 1982; Kay 1990). With the exclusion of fire, conifers invaded grasslands and aspen communities, and existing coniferous forests became much more densely stocked. Fire sensitive shrubs, like sagebrush (*Artemisia* spp.), also invaded many grasslands. Before the 1870s, lower montane valleys experienced a fire frequency of 25 years or less (Houston 1973, 1982), but many of those fires were started by native peoples, not lightning (Wright 1979; Kay 1990, 1995a; also see Chapter 5). Based on 81 repeat photosets, the area occupied by aspen on Yellowstone's northern range has declined approximately 95% since park establishment in 1872 (Kay 1990). Much of that decline, though, was due to repeated browsing by an unnaturally high elk population, in addition to successional replacement by conifers.

Repeat photosets of riparian communities (n=48) show that the area occupied by tall willows has also declined by around 95% since Yellowstone was designated the world's first national park. That decline,

however, was caused primarily by repeated ungulate browsing, not fire suppression, climatic change, normal plant succession, or other factors (Chadde and Kay 1988, 1991; Kay 1990; Kay and Chadde 1992; Patten 1991, 1993; Kay and Platts, in press).

Intermountain West

Repeat photographs compiled in Montana (Bureau of Land Management 1979a, 1979b, 1984; Gruell 1983), Wyoming (Wyoming State Historical Society 1976, Gruell 1980a, Johnson 1987), the Black Hills (Progulske 1974), Utah (Rogers 1982, U.S. Forest Service 1993a), Colorado (Baker 1987, Veblen and Lorenz 1991), Idaho (U.S. Forest Service 1993b), California (Heady and Zinke 1978, Vankat and Major 1978, Vale 1987, Gruell 1994), Oregon (Skovlin and Thomas 1995), and Arizona (Hastings and Turner 1980) show an identical pattern. Prior to European settlement, frequent low-intensity ground fires were the norm in lower montane zones. The coniferous forests that existed were very open and park-like, the result of repeated fires (Covington and Moore 1994, Fule and Covington 1995, Minnich et al. 1995, Touchan et al. 1995). Regenerating aspen was common and grassland communities generally lacked sagebrush. With fire exclusion, though, conifers and sagebrush have invaded grasslands, aspen has declined, and existing coniferous forests have become much more densely stocked – setting the stage for high-intensity crown fires.

As in the Canadian Rockies (c.f. Byrne 1968; Nelson 1969b, 1970; Nelson et al. 1972), some in the United States claim that what is seen in the earliest photos are the results of European-set fires, not a representation of how ecosystems looked and functioned in pre-Columbian times. The best evidence that this is not true, though, comes from the Black Hills of South Dakota which were not visited by Europeans because Sioux, Cheyenne, and Arapaho warriors kept trappers, miners, and settlers out by force of arms. That changed during the summer of 1874 when General Custer led a detachment of 1,200 soldiers through the Black Hills in violation of existing treaties that guaranteed those lands to native people as long as the grass grew and the streams flowed (Progulske 1974, Progulske and Shideler n.d.). While this expedition is historically of some note, it is also important from an ecological perspective because a landscape photographer, William H. Illingworth, accompanied Custer. There is no doubt that Illingworth's images depict the country as it looked prior to any direct European influence – that is before trappers, railroads, mining, and white settlement. One hundred years later, the scenes in Illingworth's pictures were rephotographed forming a set of 79 unique repeat photos (Progulske 1974).

The changes have been most dramatic. In 1874, Custer and his men took wagons or rode horses just about everywhere in the Black Hills because frequent ground fires had created an open park-like forest that permitted easy travel (Ludlow 1875, Frost 1979). Today, the area is very different. Where Custer once rode, you can now hardly walk. With the exclusion of fire, the coniferous forests have become much more densely stocked as young trees, no longer thinned by frequent fires, have now taken root (Progulske 1974, Progulske and Shideler n.d.). Grasslands and aspen have also declined markedly. So whether in the Black Hills or the Canadian Rockies, the pattern is the same. Vegetative mosaics of grasslands, aspen, shrubs, and open coniferous forests were once maintained by frequent, low-intensity fires, but 100 years of fire exclusion has favored the growth of dense coniferous forests creating conditions favorable for high-intensity crown fires (Covington and Moore 1994, and others). Wildlife habitats have also declined accordingly (Van Egmond 1990).

Early historical journals support this interpretation. Peter Fidler (1991) left the earliest written account of Alberta's Foothills and Rocky Mountains. He traveled with Piegan tribesmen from Fort Buckingham House, east of Edmonton, down past Red Deer and Calgary to the Oldman River, and returned in 1792-1793. Not only did Fidler recount numerous instances of aboriginal burning, but he also left a description of what he saw when he climbed Thunder Mountain on the Oldman River.

... small pines growing here from the bottom to the very top, but of a very stunted growth, but in different quantities according to its situation, a northern frontier is observable to produce the most wood and that of a more stout and healthy appearance than a southern aspect, in this direction very little is observed to grow. [Fidler 1991:47].

This same pattern, open south-facing hillsides with more timber on northern exposures, is evident in all the earliest photos of the Canadian Rockies (Figures 4.1-4.12). As will be discussed more fully in Chapter 5, because south-facing exposures are drier, they can support more frequent fires, and repeated aboriginal burning once kept those aspects clear of forests. With exclusion of native peoples and fire, however, that changed. Now dense coniferous forests blanket even south-facing slopes, a situation that did not exist prior to park establishment.

Others, however, claim that historical photographs are just snapshots-in-time that tell us nothing about how today's ecosystems should be managed. While no one believes that Parks Canada should "freeze" vegetation scenes based on early photographs, historical photos provide much more data than is commonly thought. The plant communities depicted in the earliest photographs owed their existence to a set of processes that existed for decades prior to when the photographs were originally taken. Thus, historical photographs provide information not only on vegetation states but also on the ecological processes that once structured those communities.

For instance, if aspen in a historical photo showed no evidence of browsing when they were photographed ca. 1870 and if those trees were 70 years old when they were originally photographed, this means that large numbers of elk and other ungulates did not inhabit that area from ca. 1800 to 1870 (Kay and Wagner 1994). Which, in turn, suggests that some factor besides food limited ungulate communities in earlier times (Kay 1994, 1995a, 1995b, in press b). Similarly, the open-forests, grasslands, and regenerating aspen communities depicted in early photographs all attest to a process of frequent low-intensity fires. Since many of the larger Douglas fir depicted in those open forests were 200 to 300 years old when first photographed, this implies that frequent burning was a well established process for hundreds of years. So, historical photographs provide data not only on states but also on long-term processes that once structured those ecosystems. Again, old photographs are not simply snapshots-in-time but windows to the past, and clearly key processes today are different than they were in earlier times.

CHAPTER 5

FIRE HISTORY AND ECOLOGY

INTRODUCTION

As noted earlier, fire plays a major role in structuring vegetation communities throughout western North America (Habeck and Mutch 1973; Tande 1979; Johnson and Fryer 1987; Agee 1993, 1994; Bernard et al. 1995; Risbrudt 1995). In this chapter, we review the factors influencing past and present wildland fire regimes in the Canadian Rockies. We focus on the hypothesis that changes in human land use practices account for most of the variation in burning patterns observed over time and space (White and Pengelly 1992).

Fire occurrence in a given area is a complex interaction of physical and biological forces (Figure 5.1). Ignition varies by source, location, and timing and may occur inside or adjacent to the area of concern. In the absence of suppression, fires usually go through smoldering phases of relative inactivity followed by active phases where the burning pattern is controlled by terrain, weather, and fuels. Active fires can spread into the area of concern from upwind or downslope depending on landscape level factors. Numerous fires over time create a fire regime for an area characterized by fire frequency (annual percent of the area burned), intensity (flame length), and severity (depth of burn). Distribution and variability of these elements in turn influence vegetation and hence fuel for subsequent fires.

Studies of historical fire regimes may be based on dendrochronology (tree-ring, stand-age, or fire-scar analysis), written records such as explorer diaries (see Chapter 2) and fire reports, historical photographs (see Chapter 4), or anthropology (interviews with native peoples). We will focus on fire regimes that have been described for the mountains of Wyoming, Montana, Idaho, Alberta, and British Columbia. For comparative analysis, that area will be divided into the eastslope of the Rockies located in Wyoming, Montana, and Alberta, and the area west of the Continental Divide in Montana, Idaho, and British Columbia (westslopes).

FIRE IGNITION

Ignition information from selected studies is summarized in Table 5.1. Actual ignition is rarely observed, and study periods sometimes are only a few years, so statistics from fire reports, historical accounts, or interviews must be interpreted with caution.

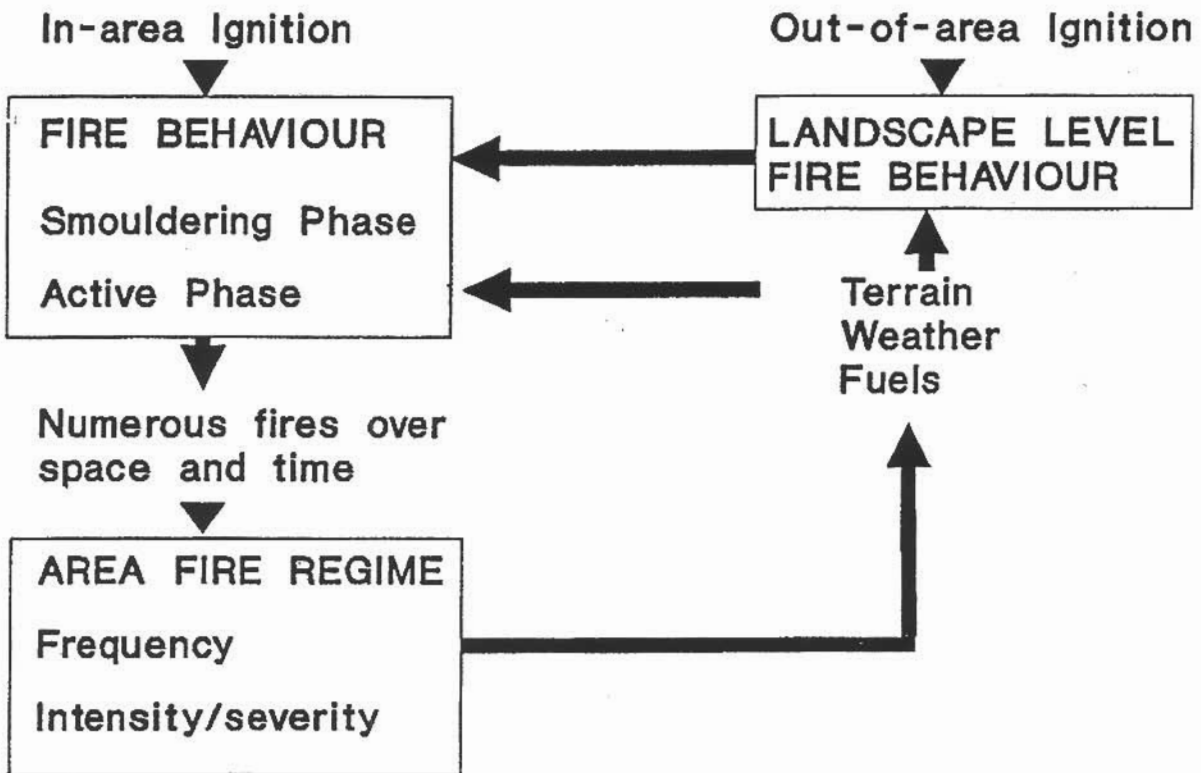


Figure 5.1. Factors influencing Rocky Mountain fire regimes.

Table 5.1 Ignition source, location, and timing of fires in the northern Rocky Mountains.

Area*	Type and period of analysis	Ignition source	Ignition location	Peak ignition timing	Reference
Jasper NP, AB	Number of fires from fire reports 1940-1986	15% lightning 85% human	-- mid-elevations -- -- valleys --	July-Aug. May	Arbor Wildland Management Services 1988
W. Montana	Interviews with elders on pre-ca. 1920 traditions	Flathead, Pend d'Oreille, Kootenai peoples	valleys and mid-elev. forests	Mostly spring or fall	Barrett and Arno 1982
East slopes Rocky Mtns., MT and WY	Number of fires from fire reports 1931-1945	59% lightning 41% human	-- mid-elev. -- -- valleys --	July-Aug Apr-Oct	Barrows 1951
West slopes Rocky Mtns., MT and WY	Number of fires from fire reports 1931-1945	79% lightning 21% human	-- mid elev. -- -- valleys --	July-Aug Apr-Oct	Barrows 1951
Kananaskis, AB	Number of fires from fire reports 1961-1982	17% lightning 83% human	- -	June-Aug Mar-Nov	Johnson and Larsen 1991
N. Alberta	Interviews with elders on pre-ca. 1940 traditions	Chipewyan, Slavery, Beaver, and Cree peoples	valleys meadows	Spring	Lewis 1982b
Bow Forest, AB	Number of fires from fire reports 1961-1970	30% lightning 70% human	- -	July-Aug May-Aug	Miyagawa 1974
Bow-Crow Forest, AB	Area burned from fire reports 1931-1983	22% lightning 13% human 65% unknown	- -	-	Delisle and Hall 1987
Yoho NP, BC	Number of fires from fire reports 1910-1988	35% lightning 41% human 24% unknown	-- mid-elevations -- -- valleys --	-	Tymstra 1988
Banff NP, AB	Number of fires >40 ha from fire reports 1880-1980	13% lightning 49% human 38% unknown	-- west side park -- -- valleys --	July-Aug Apr-Aug	White 1985a
Banff NP, AB	Area burned from fire reports 1880-1980	16% lightning 37% human 47% unknown	-- west side park -- -- valleys --	July-Aug Apr-Aug	White 1985a

*In addition, O'Brien (1969) noted that of 525 lightning fires reported in Glacier National Park, between 1910 and 1968, 90% occurred on the park's western slopes and 10% on the park's eastern slopes. Moreover, 80% of the lightning fires occurred in July or August.

Lightning Ignition

Studies of lightning have identified two types of discharges — a cold stroke that generally has an explosive effect, and a longer-lasting, higher-amperage hot stroke. Hot strokes are more likely to start fires than cold strokes. In the Canadian Rockies, only a small percentage of discharges actually cause ignition. Lightning starts more fires per unit area on the westslope of the Rockies (Barrows 1951, Masters 1990, Tymstra 1991) than on the eastslopes where humans are the predominant ignition source (Barrows 1951, White 1985a, Arbor Wildland Management Services 1988, Johnson and Larsen 1991, Heathcott and Wierzchowski 1996). For example, although Montana's Glacier National Park contains nearly equal areas of eastslope and westslope terrain, 95% of lightning fires occur west of the divide (O'Brien 1969, Finklin 1986).

Similarly, Figure 5.2 illustrates this pattern for a larger area of the southern Canadian Rockies. Yoho and Kootenay National Parks on the westslopes have over 10 times the occurrence of lightning fire per unit area than do Banff and Jasper National Parks east of the divide (Heathcott and Wierzchowski 1996).

Several hypotheses have been advanced to explain this effect. (1) Eastslopes may contain more grasslands which are less vulnerable to lightning ignition than westslope forests (Finklin 1986). (2) Eastslopes are generally at higher elevations, so the shorter cloud to ground distance may allow electrical energy to gradually dissipate with fewer high-energy lightning strikes (Alberta Forest Service 1987). (3) Lightning storms are commonly associated with upper pressure-ridge breakdowns and westerly winds over Alberta and British Columbia (Nimchuk 1983, Janz and Nimchuk 1985, Alberta Forest Service 1987). These air masses are unstable as they rise over the westslopes, causing frequent cloud build-up and lightning. As these weather disturbances descend the eastslopes, however, they are less prone to convective storms and lightning activity. (4) Eastslope lightning storms that occur during upslope or easterly winds usually coincide with high surface humidities and light rain, conditions unfavorable for ignition (Alberta Forest Service 1987).

Lightning ignitions are most common in July and August (see Figures 5.5 and 5.6) and tend to occur most frequently in mid-or-upper elevation forests (Keeley 1982; Fowler and Asleson 1984; Tymstra 1989:36-38; Johnson and Larson 1991:196; Van Wagtendonk 1991; Nash and Johnson 1993; Caprio and Swetnam 1995). Few lightning fires start at lower elevations or in valley bottoms, especially east of the divide (Keeley 1982, Fowler and Asleson 1984). Modern fire suppression cannot prevent lightning ignitions, but since the 1970s fire crews have responded to more lightning fires because automatic detection systems are better able to pinpoint lightning strikes. This permits rapid initial attack before natural extinguishment occurs or before the fires can spread (Pyne 1982, Pengelly 1993).

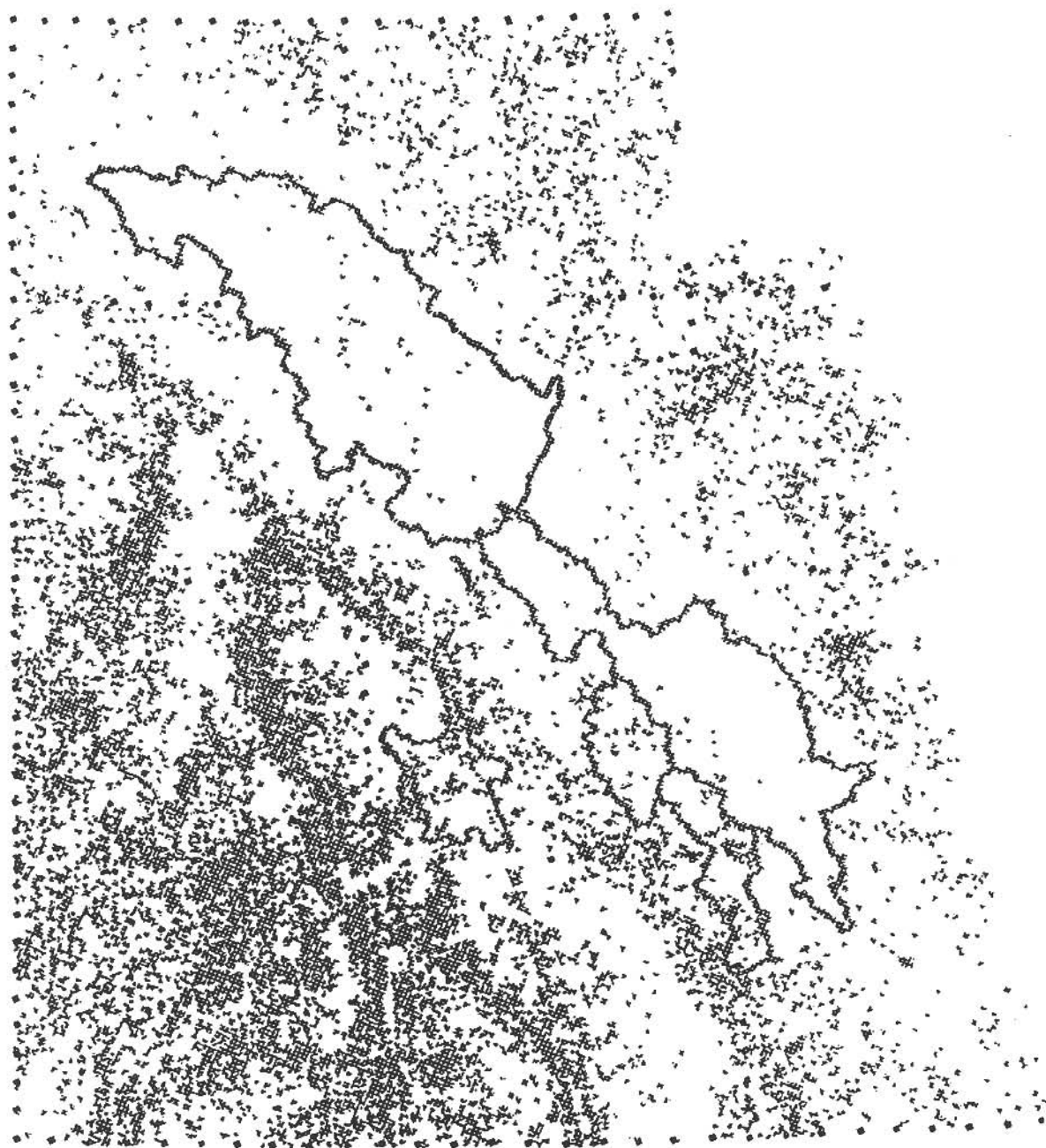


Figure 5.2 Spatial pattern of lightning-caused fires in the Canadian Rockies from 1961 to 1994.

Ignition by Native Peoples

Most ecosystems have a long history of human-ignited fire (Stewart 1956). Pyne (1993) observed that "anthropogenic fire is a ubiquitous technology that has been inserted into every conceivable place for every conceivable purpose." Eye-witness historical accounts (see Chapter 2) and anthropological investigations of native peoples inhabiting the northern Rocky Mountains, foothills, and adjacent plains provide consistent evidence that humans were a significant source of wildland fire ignition prior to modern fire suppression efforts (Arthur 1975; White 1975; Ferguson 1979; Barrett and Arno 1982; Lewis 1982, 1990b; Gruell 1985; Murphy 1985a; Boyd 1986; Reid 1987; Lewis and Ferguson 1988; Liberman 1990:90-91). Native Americans used fire to modify plant and animal communities for human benefit; that is fire was used as a land management tool (Kay 1995a). In California, native peoples had at least 70 different reasons for firing the vegetation (Lewis 1973, Timbrook et al. 1982). Even in northern Canada, where the vegetation is not as diverse, Native Americans still set fires for at least 17 reasons (Lewis 1977, 1980a, 1982b, 1985, 1990a; Ferguson 1979; Reid 1987; Lewis and Ferguson 1988). Native peoples commonly used fire —

(1) To enhance forage production — Native Americans burned to provide quality forage for favored big game species, and after European arrival, for domestic stock such as horses. They knew that moose, deer, bison, elk, and bighorn sheep are attracted to recent burns due to releases of nutrients and plant regrowth (Arthur 1975, Lewis 1982a). Hind (1971:Vol. 2-107) left one account of how Native Americans used fire on the Canadian Plains ca. 1850.

The ranges of the buffalo in the north-western prairies are still maintained with great exactness, and old hunters, if the plains have not been burnt, can generally tell the direction in which herds will be found at certain seasons of the year. If the plains have been extensively burned in the autumn, the search for the main herds during the following spring must depend on the course the fires have taken.

Similarly, an aboriginal informant explained why his people once burned bighorn sheep habitat in the Canadian Rockies (Lewis 1982b:44).

See, mountain [bighorn] sheep aren't like domestic sheep. Mountain sheep prefer only the tips of green grass; they don't like to graze an area more than once. When the burning stopped there were fewer grassy areas than before, so the sheep came back again and again...Maybe one sick animal, like one with lungworm would pass its sickness on to all the others. When we used to burn there was always plenty of fresh grass and they didn't have to do that [graze the same areas twice].

(2) To enhance furbearer habitat — Lewis (1982b) noted that Native Americans frequently fired sloughs and stream courses in northern Alberta to improve habitat for furbearers. This, no doubt, occurred more frequently with the advent of the fur trade, but it also was common in earlier times because native peoples needed furs for clothing and other uses.

(3) To herd wildlife during hunts — Native Americans sometimes used fire to drive game to waiting hunters (Anell 1969, Boyd 1986). Father Nicolas Point, who resided with native people in Montana for several years during the 1840s, illustrated his journals with numerous drawings and watercolors. One of which depicts Native Americans using fire to drive game to waiting hunters (Donnelly 1967:83).

(4) To maintain travel routes — Native informants told Barrett and Arno (1982) and Lewis (1982b) that they often used fire to keep trails cleared. This type of burning was most prevalent in montane stands of lodgepole pine, ponderosa pine (*Pinus ponderosa*), and Douglas-fir where frequent fires kept forests open and park-like, facilitating off-trail travel (Arno 1985, Steele et al. 1986).

(5) Other uses for fire – Natives set fires for a host of other purposes such as to increase plants used for food or medicine, to create stands of dried firewood, to signal nearby people, and to protect areas from high-intensity, lightning-caused fires during mid-summer (White 1975, Arno and Barrett 1982, Lewis 1982b, Boyd 1986, Reid 1987, Turner 1991, Gottesfeld 1994). They also used fire during war to burn off each others range or to flush enemies from hiding (Loscheider 1977).

Lewis (1982b) argued that native use of fire in northern Alberta was highly selective in time and place, while in northern Montana, Barrett and Arno (1982) described native burning as more opportunistic and random. Anthropologists, however, have shown that most aboriginal burning was purposeful and directed towards specific ends (Lewis 1973, Hallam 1975, White 1975, Boyd 1986, Reid 1987, Turner 1991; Pyne 1993, 1994, 1995a, 1995b; Gottesfeld 1994). Undoubtedly, fires were also started by accidental spread from the innumerable campfires natives used for cooking, heat, and light. In western Alberta during the winter of 1792-1793, Peter Fidler (1991) observed how escaped tribal campfires burned the countryside for days until extinguished by passing storms or lack of fuel. "As one authority who has made an extensive search of the literature notes, there is not a single reference to be found of native peoples anywhere in the world ever taking care to extinguish campfires" (Budiaksky 1995:107).

In the Rocky Mountains, Native Americans often burned meadows and montane zones because those areas were most favorable for human habitation. The largest and most extensive archeological sites are found in low-elevation, relatively dry valleys. Densely forested regions and upper elevations, particularly on the westslopes, have fewer archeological sites, and may have been somewhat less prone to aboriginal burning. Lewis (1980a, 1982b), Reid (1987), Barrett and Arno (1982), and White (1985a) all noted that natives frequently burned during spring (Table 5.1). Although middle and upper elevation areas may still be snow-covered at that time, montane and subalpine meadows are easily ignited. Fire intensities were relatively low, and the rapid green-up of vegetation after burning served aboriginal objectives by attracting ungulates. Aboriginal fires did burn middle and upper elevation valleys during summer either by spreading upwards from valleys fired earlier or by escaping from smouldering camp or cooking fires (Caprio and Swetnam 1995). In general though, native burning was concentrated in spring and fall when fire behavior was easier to predict and fires could more easily be controlled by natural features or weather (Barrett and Arno 1982, Reid 1987).

Ignition by Humans in the Recent Past

It is clear that European explorers, prospectors, railroad construction crews, and settlers were a significant source of fire in the Rocky Mountains during the late 1800s and early 1900s (Byrne 1968; White 1985a; Tymstra 1988, 1989). The pattern of those fires, however, may not have differed substantially from the pre-European period (Tymstra 1991). As discussed in Chapter 4, there is no evidence that European-set fires destroyed the forest primeval. Instead, early European-burning tended to maintain the ecosystem under pre-Columbian conditions. Besides, natives still used many valleys and early Europeans had similar subsistence needs for forage and wildlife. Stand-age analyses (see below) support this interpretation as there is no increase in annual area burned associated with European settlement (Tymstra 1991, Van Wagner 1995).

Modern Man

During the last 100 years, man has been the predominant ignition source on the eastslopes (Table 5.1). This may be due to a relatively higher human presence, or the lower occurrence of lightning compared

to other areas. Man-caused fires usually occur in heavily visited valley bottoms and tend to start during spring or fall when cured vegetation is easily ignited (Barrows 1951, White 1985a, Arbor Wildland Management Services 1988, Tymstra 1989:36-38). In most areas of the northern Rockies, modern fire prevention programs have reduced man-caused fires through education, fire-bans, and by providing receptacles for fires at campsites (Murphy 1985a, 1985b). The shift from steam to diesel-powered locomotives also sharply reduced the number of fires started by trains. In Banff National Park, for example, the ratio of human-caused to lightning fires greater than 40 ha dropped from 4 to 1 during the 1880-1930 period to a ratio of 1 to 1 from 1931 to 1980 (White 1985a).

FIRE BEHAVIOR

Fire behavior is controlled by weather, terrain, and fuels. These variables interact to create relatively long periods that support only smouldering fires interspaced with brief episodes favorable to rapid fire spread (Pyne 1982). In the presence of adequate ignition, the overriding factor that controls both active and smouldering phases is weather. Droughts occur when large blocking high pressure ridges prevent normal moisture-bearing low pressure systems from passing over the northern Rocky Mountains (Nimchuk 1983, Baker 1984, Fryer and Johnson 1988, Johnson and Wowchuk 1993, Bessie and Johnson 1995). Ordinating the years 1890 to 1990 for the Banff townsite weather station on the basis of spring (April 1 to June 30) and summer (July 1 to September 30) precipitation illustrates the link between precipitation and fire. Large fires tend to occur during the driest years. Before 1941, Banff National Park experienced fires greater than 40 ha in 12 out of the 13 years (92%) that had precipitation below threshold values. Over Banff's last century, drought years favourable for large fires occurred about twice per decade (White 1985a, Feunekes and Van Wagner 1995).

This record, moreover, can be extended back several hundred years by dendroclimatology because during drought years, trees produce smaller growth-rings (Schulman 1956, Stockton and Fritts 1973, Robertson and Josza 1988, Luckman 1992, Case and MacDonald 1995). Tande (1977) plotted fire years for Jasper National Park against tree-ring records of Douglas fir growing near Patricia Lake (Stockton and Fritts 1973). He found that 76% of the fires and 92% of the burned area occurred in years with below average tree growth. Since the large blocking high pressure systems that cause these droughts are often regional in extent, many areas of the Rocky Mountains experience fires in the same years (Johnson and Wowchuk 1993). For Jasper, Banff, Kootenay, Yoho, and the Kananaskis, large fires occurred in two or more of the areas in 1881, 1885, 1889, 1896, 1904, 1905, 1906, 1908, 1909, 1910, 1919, 1920, 1925, 1926, 1929, 1934, 1936, 1940, 1960, 1967, 1971, and 1985 (Tande 1977, White 1985a, Fryer and Johnson 1988, Masters 1990, Tymstra 1991).

Smouldering Phase (Ground Fire)

Despite thousands of lightning strikes and perhaps even more potential human ignitions, few ignite fuels for any length of time, and only a small percentage are ever detected before dying out on their own accord (Pyne 1982). Of those fires that do ignite, almost all have a high ratio of smouldering phase to active phase due to diurnal cycles of fuel moisture, humidity, and temperature unfavourable for active combustion and fire spread. In addition, lightning strikes in the Rocky Mountains usually accompany periods of rain which limits immediate active combustion (Alberta Forest Service 1987). Since today smouldering fires are, in general, immediately and easily suppressed, there are few studies of smouldering behavior. It is, however, recognized as a significant factor because holdover fires can become active if weather conditions change (Kourtz 1974, Pyne 1982, Flannigan and Wotten 1991, Pengelly 1993). The persistence of smouldering fires is dependent on the interaction of several factors.

(1) Fuel Type – Duff (loosely compacted decomposing organic matter), particularly under trees, and rotten wood in logs and snags is required to sustain smouldering fires (Kourtz 1967, 1974; Flannigan and Wotten 1991). These "heavier" fuels have long lag times compared to daily atmospheric relative humidity variations, and they do not recover moisture nor extinguish fire during nighttime cooling periods (Canadian Forestry Service 1987).

(2) Fuel Moisture – A low duff moisture content is usually required to sustain smouldering (Van Wagner 1972, Flannigan and Wotten 1991). In the Canadian Forest Fire Danger Rating System (CFFDRS), this roughly corresponds to a Duff Moisture Code (DMC) of greater than 20 (Canadian Forestry Service 1987).

(3) Time Since Ignition or Active Burning – Under marginal fuel moisture conditions, there is a rapid exponential decrease with time in the number of points that support smouldering fire (Kourtz 1974). During major drought periods, though, fires may smoulder for weeks or months (Pyne 1982). The 1988 Canyon Creek Fire in Montana's Scapegoat Wilderness ignited on June 25 and remained in a smouldering phase until July 19 when it began a series of active runs before reaching a final size of 100,000 ha (USDA Forest Service 1988).

(4) Number of Smouldering Locations – Once a fire becomes active, and grows in size, the number of sites that can support smouldering also increases, and they have a greater probability of persistence. In Yellowstone National Park, for instance, large mid-summer fires that are not suppressed will smoulder until late autumn snows, despite earlier periods of precipitation (Renkin and Despain 1992).

All control programs attempt to suppress fires while in a smouldering phase (Pyne 1982). Since fires in the Canadian Rockies often remain in a smouldering phase for days or weeks, even historical control efforts that relied on access only by horse, foot, or boat were still very effective in extinguishing these kinds of fires (Murphy 1985a, 1985b). By putting out smouldering fires, large scale fires were, and are, avoided during subsequent drying periods (Pyne 1982, Pengelly 1993).

Active Phase (Surface and Crown Fires)

Only a very small percentage of ignitions reach active burning phases where open flames burn surface or canopy vegetation. Active fires that blacken large areas can attain rates of spread exceeding 100 m/min and fireline intensities in excess of 100,000 kW/m (Anderson 1968, Fryer and Johnson 1988). Special combinations of weather, terrain, and fuels interact to transform smouldering fires into active ones. These include:

(1) Dry Fine Fuels – Unlike smouldering fires that depend on dry coarse fuels, active fires are sustained by fine (<25 cm diameter) surface fuels with a moisture contents below 15% (Canadian Forestry Service 1987). In low-elevation montane forests where snow melts early, fuels may dry out by April or May, and large active fires can occur during this period (Figure 5.3). In subalpine forests, fine fuels seldom dry enough to permit active fires before July and August.

(2) Low Relative Humidity and High Temperature – To achieve open flame, the relative humidity must be low (less than 30%), and the temperature must usually be greater than 20° C. Most active burning occurs during what are known as "Black Cross" conditions when the numeric value of the relative humidity is below the air temperature (e.g., 20% relative humidity and 25° C.). In the northern Rocky Mountains, Black Cross conditions occur infrequently, and only during the hottest part of dry days.

(3) Dry Large Fuels – Although this relationship is not fully understood, dry large fuels probably increase a fire's energy output accelerating its rate of spread through radiant and convective preheating of fuels (White 1985b).

(4) High Winds – In the northern Rockies, high summer winds generally occur when upper ridges of blocking high pressure are broken down by advancing low pressure systems. The winds created by this synoptic pattern are generally from the west or southwest. Large high-intensity burns usually correspond to the coincidence of a source of fire, high winds, and Black Cross conditions. Frontal passages during peak afternoon burning conditions have propelled several large fires through Banff National Park (Baker 1984) and the Kananaskis Valley (Fryer and Johnson 1988) that burned long elliptical patterns in an east to northeast direction. High winds also occur as downdrafts in advance of thunderstorms. Those downdrafts, however, are usually of short duration, contain cold air, and are often accompanied by rain (Alberta Forest Service 1987), so they generally do not generate fires as large as those associated with frontal winds. Five other synoptic patterns, however, can provide high-wind conditions necessary for large fires (Pengelly 1993). These include, short wave troughs, mid-western highs, Pacific highs, Canadian continental highs, and chinook winds (Shroeder and Buck 1970, Baker 1984).

(5) Steep Slope – Even in the absence of gradient atmospheric wind, fires on steep slopes can spread rapidly due to upslope winds created by daytime heating, and once the fire becomes active, convective heating of upslope fuels (Pyne 1984, Fryer and Johnson 1988).

(6) Fuel Type – In general, forests with the highest fuel loads have the fastest rates of fire spread, and when those values approach 10 to 20 m per minute crown fires usually result (Canadian Forestry Service 1987). Spruce-fir forests have a much higher rate of fire spread than lodgepole pine, while aspen has the lowest. Grasslands can support high rates of fire spread only if plants are fully cured and dry. This usually occurs only early in the spring prior to regrowth or in the fall after a killing frost. Even under drought conditions, many grasslands will not burn during July or August when most lightning fires occur (see below and Figures 5.5 and 5.6).

Human suppression of active fires by direct attack is dangerous and usually ineffective in mountainous terrain (Weir et al. 1995). Indirect methods of backburning from fuel breaks may work in some situations, but often are not possible. Fortunately, active fire phases are generally of short duration in the Canadian Rockies because cooler nighttime temperatures substantially reduce fire activity. Strong winds that can occur when upper high pressure ridges dissipate usually signal an advancing low pressure system with cooler, moister weather (Nimchuk 1983, Baker 1984), which returns the fire to a smouldering phase where direct suppression is effective along the perimeter.

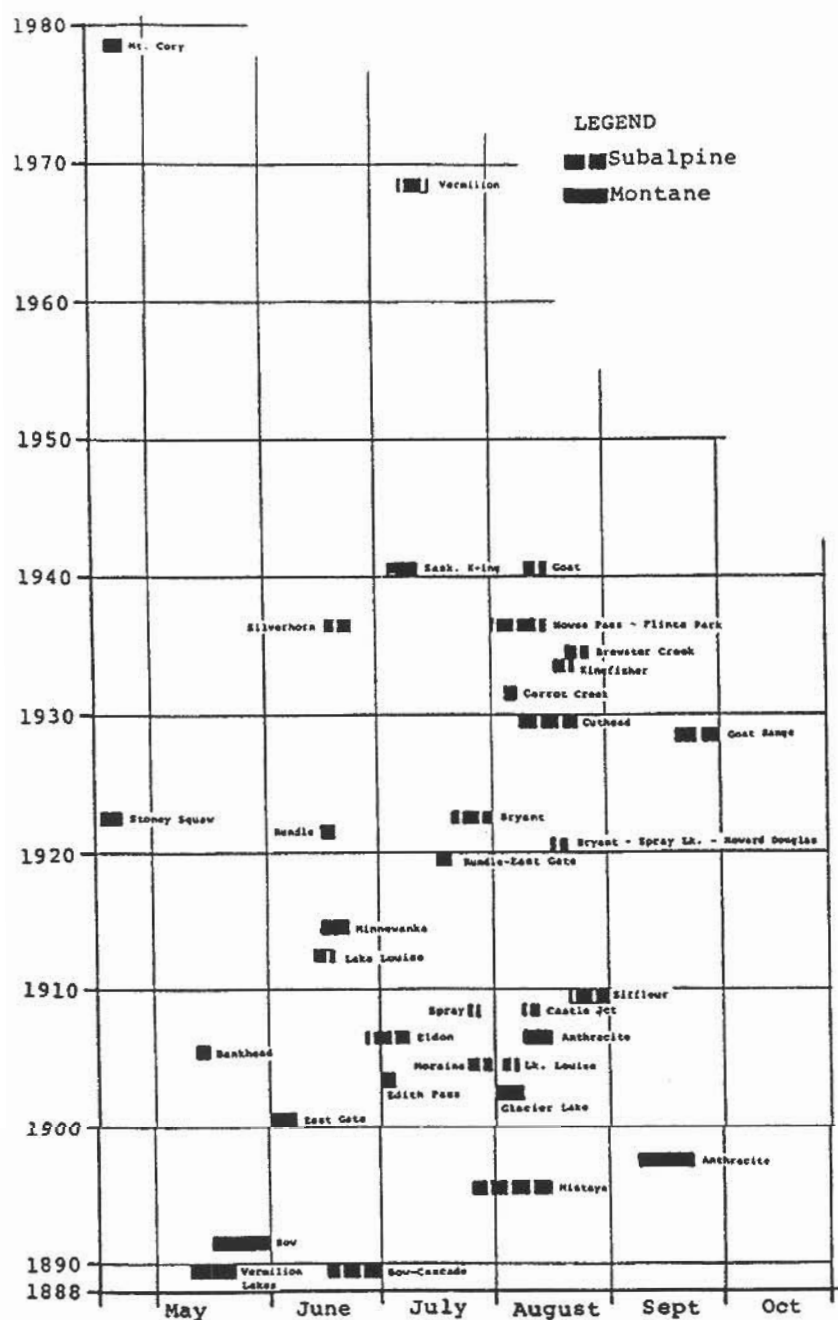


Figure 5.3. Known burn periods for fires greater than 40 ha in Banff National Park from 1888 to 1980. Banff experienced no wildfires more than 40 ha in size from 1980 to 1995.
From White (1985a).

LANDSCAPE LEVEL BURNING PATTERNS

To this point we have focused on in-area factors directly effecting fire occurrence and behavior, but fires entering from adjacent areas may be of equal or greater importance (Figure 5.1). Unfortunately, very little research has been conducted on the juxtaposition of landscapes in interpreting fire regimes. In his study of Kootenay National Park, Masters (1990) suggested that meso-level terrain analysis might best be used to evaluate that area's fire history. Based on models of fire growth at the landscape level, Feunekes et al. (1993) made the following observations for the Rocky Mountains.

(1) Slopes above areas with high ignition potential are more prone to burn because fires tend to spread upslope. For example, higher elevation areas which are too wet during spring could be burned by smouldering valley fires that become active and advance upslope after snow melt.

(2) Areas downwind of regions with high ignition potential are more prone to burn. In the northern Rockies, active fires are predominantly driven by southwest and west winds (White 1985a), so lands to the east and northeast of high ignition areas will also be frequently burned.

(3) The longer the stretch of contiguous fuels in a downwind direction, the greater the probability that those areas will burn, depending on the frequency and duration of the winds, as well as drought conditions. Conversely, areas that are protected from fire spread by rock or water on the upwind side (e.g., to the west and southwest in the Canadian Rockies) have less chance of being burned.

(4) Valley orientation is important with regard to winds and fuel continuity. In the Canadian Rockies, valleys trend southeast to northwest, against the predominant direction of fire spread to the northeast (White 1985a). This limits fire growth. Side drainages that join main valleys from the southeast or northwest are rarely burned. Side drainages that join main valleys from the east, or main valleys that trend to the east or northeast burn more frequently due to fuel continuity in the direction of probable fire spread.

(5) Drier sites tend to burn more frequently than wetter ones. Other factors being equal, drier south-facing slopes are in a flammable condition for more days per year than adjacent north-facing slopes. This also means that lower-elevation areas tend to burn more frequently than higher elevations if ignition is present (Pengelly 1993, Rogeau and Gilbride 1994:72). These sites are snow-free sooner each spring, and drier throughout the summer due to solar heating.

Current management in the Canadian Rockies, however, is changing fire behavior patterns at the landscape level. Not only has ignition potential changed in many areas, but fire control programs eliminate smouldering fires before they can become active (Murphy 1985a). Moreover in developed areas, fuel continuity has been disrupted by timber harvesting, roads, agriculture, urbanization, and hydro-dam developments, while in parks and other protected areas, fuel continuity has actually increased due to years of fire suppression (Pyne 1982, Murphy 1985b, Van Egmond 1990, Risbrudt 1995, Kay 1996).

AREA FIRE REGIMES

The above factors, operating over space and time, create what is termed the fire regime for a given area. This includes fire frequency, intensity, and severity.

Recent Fire Frequency from Fire Reports

The inverse of fire frequency (average annual percent of the area burned) is the fire cycle, or average fire interval (Van Wagner 1978, Johnson and Van Wagner 1985, Johnson and Gutsell 1994). Thus, as the frequency of fire decreases, fire cycles become longer. Moreover, the fire cycle is the time required to burn an area equal to the study area. Some sites may burn more than once during a fire cycle, while others may not burn at all (Van Wagner 1978, Rogeau 1996). Since 1930, government agencies have estimated the area burned for all large fires in the Rocky Mountains. So, recent fire cycles can be determined for various areas by simply dividing the area burned per unit time by the vegetated area. Table 5.2 provides recent fire cycle estimates.

Those calculations show that forests in the Canadian Rockies now experience a low incidence of fire and that current fire cycles far exceed those of the past (see below). This pattern has been observed across southern Canada (Day et al. 1990) and throughout the United States, including the northern Rocky Mountains (McCune 1983; Steele et al. 1986; Arno and Brown 1991; Agee 1993, 1994; Arno et al. 1993; Brown et al. 1994; Risbrudt 1995), inland Pacific northwest rangelands (Shinn 1980), a diverse range of southwest forests (Swetnam and Betancourt 1990, Covington and Moore 1994, Fule and Covington 1995, Minnich et al. 1995, Touchan et al. 1995), California giant sequoia-mixed conifer forests (Kilgore and Taylor 1979, Swetnam 1993, Caprio and Swetnam 1995), and the Boundary Waters Canoe Area (Heinselman 1973). In most cases, current fire cycles are now many times greater than what they were prior to 1880. Masters (1989, 1990), for instance, found that the fire cycle for Kootenay National Park between 1928 and 1988 was in excess of 2,700 years, while between 1788 and 1928 it was but 130 years, and between 1508 and 1779 it was only 60 years – this is a 45-fold decrease in the annual area burned since early historical times (see below). In contrast, there has not been a significant change in fire frequency for Canadian boreal forests (Van Wagner 1988, Day et al. 1990, Johnson 1992).

Historical Fire Frequency from Fire Interval Data

Where multiple burns can be dated using fire-scarred trees, analysis of past fire frequency has focused on the length of fire-return intervals. If the probability of burning is constant with stand age in a homogenous environment over time, the average fire interval will equal the fire cycle (Johnson and Van Wagner 1985). Studies of historical fire frequencies in the northern Rockies show a strong tendency for frequent fires (fire intervals less than 50 years) in lower-elevation and drier forest communities dominated by ponderosa pine or Douglas fir (White 1985b, Steele et al. 1986, Agee 1994, Risbrudt 1995; see Table 5.3). Aspen forests on montane alluvial fans in Banff National Park once had a mean fire interval of around 20 years. The short intervals and low intensities of fires in these areas probably reflects frequent burning by native peoples (White 1985a; see below). With increases in elevation and precipitation, Rocky Mountain forests become dominated by western red cedar (*Thuja plicata*), lodgepole pine, spruce (*Picea* spp.), or subalpine fir (*Abies lasiocarpa*). Fire intervals in those forests were historically longer, on the order of 50 to 150 years. Although Masters (1990), and Johnson and Larsen (1991) concluded that the fire cycle in their Kootenay and Kananaskis study areas generally did not vary by elevation or aspect, that likely is not true for the Rocky Mountain landscape as a whole and it certainly is not true in Banff (Rogeau and Gilbride 1994:72). Wierzchowski (1995), for instance, found that the pattern of fires in Banff National Park was not random but instead was related to topography and isolation in a complex way – even over short distances on the landscape. Similarly, Van Wagner (1995) concluded that Banff's oldest forests were a product of non-random burning. That is to say, Banff's oldest forests grow in places where fires rarely burn due to

topographic or other factors and have not escaped burning due to chance alone, as assumed by time-since-fire models (see below).

Table 5.2. Recent burn area statistics and current fire cycles for the Canadian Rockies.

Location	Vegetated area (ha)	Recent area burned (ha)*	Mean annual burn area (ha)	Current fire cycle (years)	Reference
Waterton NP	24,000	1,100	28	872	McKenzie 1973
Kananaskis, AB	30,000	2,232	43	699	Delisle and Hall 1987
Bow-Crow, AB	999,013	75,332	1,255	795	Pengelly 1993
Banff NP	400,000	12,795	214	1,866	White and Pengelly 1992
Jasper NP	650,000	3,168	67	9,644	Arbor Wildland Management Services 1988
Kootenay NP	100,000	1,892	32	3,174	Masters 1990
Yoho NP	65,000	10,582	137	473	Tymstra 1988

*Waterton (1910-1972), Kananaskis (1931-1983), Bow-Crow (1931-1990), Banff (1930-1990), Jasper (1940-1987), Kootenay (1928-1988), and Yoho (1910-1987).

Table 5.3 Mean historical fire intervals for forests in the northern Rocky Mountains.

Area	Mean fire interval (years) for different vegetation types						Reference
	Aspen	Montane zone		Lower subalpine zone		Upper subalpine zone	
		Ponderosa pine	Douglas fir	Lodgepole pine	Western red cedar	Subalpine fir	
Bitterroot, MT	-	6-12	13-26	22-40	-	63	Arno 1980
Eastern Idaho	-	-	-	-	70-120	-	Arno 1980
Central Idaho 1986	-	11	10-22	-	-	-	Steele et al.
Western Montana Gruell 1983	-	-	35-40	-	-	-	Arno &
Glacier NP, MT al.1991	-	-	36	46	261	202	Barrett et
Bob Marshal, MT	-	-	-	40	-	-	Gabriel 1976
Kananaskis, AB 1980	-	-	-	90	-	153	Hawkes 1979,
Yellowstone NP, WY	25	-	25	-	-	300	Houston 1973 Romme 1982
Jasper NP, AB	-	-	18-27	74	-	-	Tande 1979
Banff NP, AB	21	-	42	94-130	-	181	White 1985b

Historical Fire Frequency from Time-Since-Fire Analysis

Where forests are burned by high-intensity crown fires that remove fire-scar evidence and regenerate even-aged stands, the time-since-fire or stand origin distribution can be used to determine fire frequency (Van Wagner 1978, Johnson and Van Wagner 1985, Johnson and Gutsell 1994, Reed 1994, Rogeau 1996). Stand-age data, for instance, can be used to calculate the annual stand probability of burning (p) and the average fire-return interval or fire cycle ($1/p$) (Van Wagner 1978, Murphy 1985b). If, as example, 2 percent of an area burned each year, then the fire cycle would be 50 years.

Van Wagner (1978) showed that the stand-age distribution of forested landscapes would fit a negative exponential distribution, if certain conditions are met. The assumptions of this model are that the forest is renewed in even-aged patches by fires burning at random without regard to forest age or time. That is to say, the negative exponential model is appropriate only when stand replacing fires are the norm – it is not applicable in areas where ground fires are common or where the fire regime was a combination of crown and ground fires. Thus, this model is not appropriate for grasslands or open-forest types. The negative exponential model also assumes that various-aged forest stands are equally susceptible to being burned; i.e., the probability of a stand burning is constant and does not increase with age. In other words, a 30 year old forest has the same chance of burning as a 300 year old forest. Thus, if burning patterns are controlled by topography, aspect, or forest type, this model is not applicable. The negative exponential model was developed and first utilized in Canada's boreal forests where most of the models' assumptions are apparently met (Van Wagner 1978, Johnson and Van Wagner 1985, Johnson 1992; but see Ratz 1995), and has only recently been applied to the Canadian Rockies where its usefulness is still being debated (Finney 1995, Van Wagner 1995, Weir et al. 1995, Wierzchowski 1995, Rogeau 1996).

One of the simplest ways to use stand-age data is to plot the cumulative percent area on a semi-log scale versus stand age on a nominal scale (Van Wagner 1978, 1995). Those data will fall on a straight line descending to the right if conditions of the negative exponential model are met and the fire regime has remained constant over time. If, on the other hand, the cumulative semilog graphs show breaks in the stand age distribution then either the negative exponential model is inappropriate or the fire regime has changed. In any case, the fire cycle is always the reciprocal of the logarithmic slope of the line (Van Wagner 1978, 1995).

Recently, detailed stand origin maps with fine scale dating (10-20 year age classes) have been produced for much of the Canadian Rockies (Tande 1977, Johnson and Fryer 1986, Masters 1990, Johnson and Larsen 1991, Tymstra 1991, Rogeau and Gilbride 1994, Van Wagner 1995, Weir et al. 1995, Wierzchowski 1995, Rogeau 1996). In general, those cumulative stand-age distributions all show discernable breaks (Figure 5.4) which some have attributed to climatic change (Johnson and Fryer 1986, Masters 1990, Johnson and Larsen 1991, Bessie and Johnson 1995, Weir et al. 1995). The first break for most areas occurred between ca. 1660 and ca. 1750 A.D. when fire cycles increased 2 to 3 fold over the previous period from 50-60 years to 90-150 years. The second and more recent break occurred between 1915 and 1940 when fire cycles increased 5 to 20 fold over the previous interval, 90-150 years to 500-3,000 years (Figure 5.4).

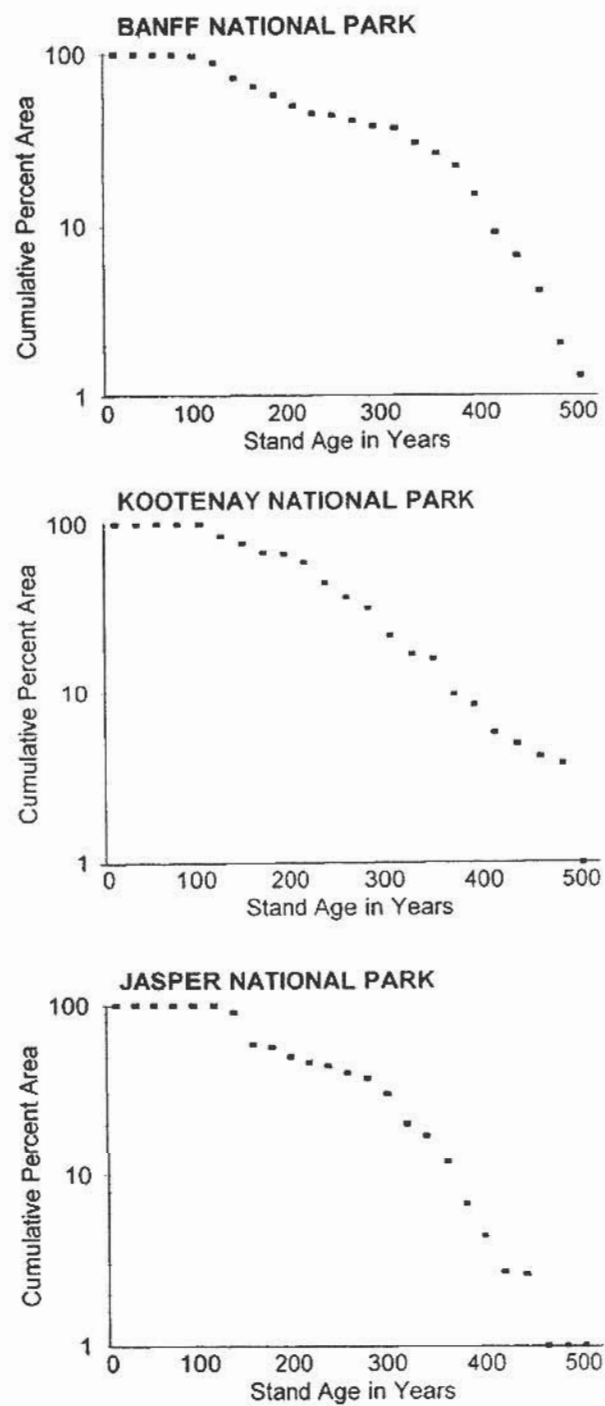


Figure 5.4. Cumulative stand-age distributions for Rocky Mountain forests. Adapted from Van Wagner (1995).

Contrary to previous explanations, we believe that the magnitude and timing of these reductions in fire activity are most directly attributable to changes in human landuse patterns. The first break coincides with early smallpox epidemics that greatly reduced native populations across the Great Plains and throughout the Rocky Mountains (Taylor 1977, Dobyns 1983, Boyd 1985, Trimble 1985, Ramenofsky 1987, Campbell 1990). Also about this time, Peigan bands, who possessed horses and guns, displaced Interior Salish and the Kootenay tribes from much of the southern Rocky Mountains (Palliser 1863, Smith 1984, Kidd 1986; see Chapter 2). This reduction in the native population and these fundamental shifts in human occupation probably reduced the number of aboriginal ignitions, although the remaining natives still undoubtedly set fires (Fidler 1991).

The second, and more significant reduction in fire frequency dates to around 1930, and reflects modern effectiveness in preventing human-caused ignitions and in suppressing incipient wildfires before high intensities occurred (Murphy 1985a, 1985b; White 1985a; Arbor Wildland Management Services 1988; Tymstra 1988; Van Wagner 1995; Rogeau 1996). By the 1930s, trails, telephone lines, and lookout towers spanned the Canadian Rockies, while later, aerial detection became routine (Murphy 1985b). Park and forestry staff also required that permits be obtained before starting a fire, banned fires in high risk areas, and closed much of the Rocky Mountains during periods of extreme fire danger (Murphy 1985a).

In the mountain parks, hundreds of men were employed under the Unemployment Relief Act, the National Forestry Program, and in Alternative Service Work during the 1930s-1940s (Bella 1987). Projects such as the Banff-Jasper Highway were built, and men were diverted to fire duty as required. Also at this time, the portable, gasoline powered water pump came into widespread use (White 1985a). More than any other factor, this revolutionized fire fighting for it provided the high volume of water necessary to suppress smouldering fires before they become active. Although not 100% effective, the sustained fire control effort across the Rocky Mountains has sharply limited fire activity even during drought years and has increased fire cycles to over 450 years in all Rocky Mountain areas (see Table 5.2).

Fire Intensity-Severity

Tree mortality can be used as a measure of fire intensity (flame length) and severity (depth of burn). If most or all of the trees survive, the burn is classified as an understory or ground fire, while if most of the trees are killed, it is termed a crown fire (Kessell 1979, White 1985b). Davis et al. (1980) and Fischer and Clayton (1983) reviewed historical fire intensity and severity for Rocky Mountain habitat types. Prior to European intervention, lower-elevation montane forests of aspen, ponderosa pine, or Douglas fir generally experienced a high frequency of low-intensity fires that did not kill all the standing trees (Steele et al. 1986; Agee 1993, 1994; Risbrudt 1995). Lower subalpine forests, on the other hand, often experienced fires of high intensity-severity that killed entire forests and which propagated even-aged stand regeneration. Upper subalpine forests with continuous fuels usually experienced infrequent fires of high intensity that blackened extensive areas. The more discontinuous the fuels, however, the higher the probability of surface fires which can create a mosaic of burned and unburned areas, even in upper elevation forests (Arno et al. 1993).

Unlike some forest types which may burn randomly regardless of age (see above), fire intensity and severity vary with the length of the non-burn interval. Fires that end long non-burn intervals tend to be more intense and more severe, with greater tree mortality than other fires (Habeck and Mutch 1973). That is to say, as Banff's forests become older the likelihood that the next fire will be a severe crown fire increases. In Banff, fires that end non-burn intervals of less than 50 years generally leave over 50% of the trees alive while fires that end non-burn intervals longer than 200 years tend to kill all the overstory trees.

The data on fire intensity-severity indicates that as modern fire suppression lengthens fire cycles, fires which do burn will likely be of higher intensity and will kill a greater proportion of the forest than happened in the past (Steele et al. 1986, Agee 1994, Fule and Covington 1995, Risbrudt 1995). This is especially true in lower-elevation montane forests where frequent low-intensity fires once kept those stands open and park-like, and where modern fire suppression has allowed trees to both grow-up and thicken-up, setting the stage for high-intensity burns (Steele et al. 1986, Agee 1994, Covington and Moore 1994, Fule and Covington 1995, Minnich et al. 1995, Touchan et al. 1995, Risbrudt 1995). This has also occurred, but to a lesser extent, in subalpine forests where fire suppression has permitted the build-up of fuels (Arno et al. 1993, Risbrudt 1995). That is to say, paradoxical as it may sound, modern fire suppression actually increases the probability that future fires will have higher intensities than past fires, and that because of their high intensity, those fires will resist suppression, thus increasing fire size (Murphy 1985b:129-136, Arno and Brown 1991, Swetnam 1993, Agee 1994, Risbrudt 1995). This is probably what happened in Yellowstone National Park during the summer of 1988 (Omi 1989, Pyne 1989, Bonnicksen 1990, Omi and Kalabokidis 1991, Swetnam 1993).

HUMAN INFLUENCES

We believe that human activity, past and present, is the dominant factor controlling Rocky Mountain fire regimes (Kay and White 1995). We contend that Native Americans were a significant source of ignition, particularly on the eastslopes and in valleys where lightning is less common (Kay 1995a). Those fires started either accidentally from escaped campfires or were deliberately set for various purposes related to subsistence activities. This consistent source of ignition likely diminished, however, during the 1600s and 1700s as smallpox and other epidemics sharply reduced native populations (Dobyns 1983, Ramenofsky 1987, Campbell 1990). Government efforts to control fire have further reduced the area burned, but ironically have set the stage for large-scale stand-replacing firestorms (Steele et al. 1986, Swetnam 1993, Agee 1994, Covington and Moore 1994, Fule and Covington 1995, Risbrudt 1995).

Others, however, maintain that humans have not significantly influenced Rocky Mountain fire regimes, past or present. They claim that (1) recent fire regimes are unaltered from the pre-European period despite modern landuse changes; (2) climate dominates all other factors including human use patterns in regulating the area burned; (3) native people did not use fire in the Rocky Mountains; (4) native people did not utilize some Rocky Mountain areas; (5) human efforts to suppress fire have been ineffective; (6) humans have not started large fires in the recent past; and (7) areas frequented by humans do not have shorter fire cycles.

Past Fire Frequency Remains Unaltered

According to this hypothesis, the frequency of fire in the Canadian Rocky Mountains has not changed in the last 50 to 100 years, or that any reduction in burned area is not statistically significant due to temporal variability (Johnson and Fryer 1986, Johnson and Larsen 1991, Weir et al. 1995). This argument, though, is suspect for at least two reasons. First, if the small area burned in the Rockies since about 1930 (Table 5.2) is only statistically expected normal variation, it would have to be offset by some extremely large fires over the next few years. In Banff National Park, for instance, the current burn area deficit from the historic fire cycle, accumulated since around 1940, is about 150,000 ha (Table 5.4). To return to the historic cycle would require five fires of 30,000 ha each in the near future. Fires of this size, though, are uncommon in the park's narrow valleys (Van Wagner 1995, Rogeau 1996). Since 1880, the largest single fire in Banff

burned less than 10,000 ha and the largest area burned in any decade was less than 40,000 ha (Table 5.4). East of the park, Alberta's 1,000,000 ha Bow-Crow Provincial Forest has accumulated a burn area deficit of nearly 525,000 ha since 1930. To return to its historic fire cycle, 21 fires of 25,000 ha each would have to burn the Bow-Crow in the near future (Pengelly 1993).

Table 5.4. Area burned and number of fires greater than 40 ha during natural and historic periods in Banff National Park. From White and Pengelly (1992).

Period	Area burned (ha)		Number of Prescribed fires (>40 ha)
	Wildfires	fires	
Natural Decade**	32,000	--	--
1880-1889	37,050	--	>6
1890-1899	18,600	--	9
1900-1909	16,050	--	12
1910-1919	3,300	--	6
1920-1929	10,950	--	9
1930-1939	8,050	--	6
1940-1949	4,200	--	2
1950-1959	0	--	0
1960-1969	500	--	1
1970-1979	45	--	1
1980-1989	0	2,517	5*
1990-1993	0	3,910	6*

*These were all prescribed burns conducted by Parks Canada.

**The area burned, on average, per decade in Banff National Park prior to 1880. This was estimated by assuming a fire cycle of 50 years in the park's montane ecoregion (20,000 ha), 100 years in the park's lower subalpine (180,000 ha), and 200 years in the park's upper subalpine (200,000 ha). See White and Pengelly (1992) and Wierzchowski et al. (1995).

Between 1930 and 1990, the largest fire on the Bow-Crow Forest burned only 25,000 ha. As Van Wagner (1995:11) noted, "counting back from the present, there exists for each park [Banff, Kootenay, Jasper] a period of from five to seven decades [50 to 70 years] with almost no burned area No fire-free periods of such extended duration can be found in ... fire history records at any time in the past." Aspen stand-age data also support this interpretation (see Figure 6.11).

Secondly, if the reduction in Canadian Rocky Mountain burn area was due to normal variability, it would be extremely unlikely that it would have also occurred simultaneously throughout the United States and southern Canada. Yet, all fire history studies for those areas show the same sharp reduction in area burned beginning around 1900-1930. Those reports, in conjunction with data from the Canadian Rockies, suggest that this pattern is not attributable to chance alone (Pyne 1982, Murphy 1985b, Van Wagner 1995, Rogeau 1996).

Climatic Change

Although some researchers recognize a reduction in burn area (Figure 5.4) that began in the 1700s (Johnson and Fryer 1986, Johnson and Larsen 1991, Bessie and Johnson 1995, Weir et al. 1995), or in the 1700s and early 1900s (Masters 1990, Johnson et al. 1995), they maintain that this was caused by climatic variation, not changing human use patterns. Johnson and Larsen (1991:199), citing dendrochronological studies, concluded that the climate in the Canadian Rockies was warm and dry in the period from 1500 to 1700, and "from ca. 1700 to the present the climate was generally cooler and wetter."

Recent dendrochronological, palynological, and glacial history studies, though, present a more complex picture of climatic variation over the last few hundred years (Osborne and Luckman 1988; Robertson and Josza 1988; Luckman 1990, 1992, 1993; D'arrigo and Jacoby 1992; Luckman and Seed 1995). Since the commencement of the "Little Ice Age" (post ca. 1200 A.D.), the climate has cyclically fluctuated from cool/moist to warm/dry periods with significant declines in tree-ring width during the periods ca. 1170-80, 1280-90, 1330-1350, 1430-50, 1530-40, 1690-1705, 1810-25 A.D., and generally wide ring widths since the 1850s with a minor dip in the mid-twentieth century (Luckman 1993). These cool/moist periods preceded major periods of glacier advances such as in 1700-1725 and in 1825-1875. The major glacial recession since 1875 throughout the Rocky Mountains corresponds with the generally warmer and dryer climate of the last century (Osborne and Luckman 1988).

According to Luckman and Seed (1995:98-99),

Over the last several hundred years, there appear to have been several warmer and cooler periods, often no more than 30-50 years duration and there is no extended period that, on climatic grounds, could be identified as a cooler/wetter Little Ice Age that continued for several hundred years. Neither do these records show a major shift during the 18th century that could be defined as the inception of the Little Ice Age ... The Little Ice Age is named for, and identified as, a glacier event not a climatic event. Although glaciers clearly respond to change in climate the nature of this response varies from region to region. The paleoenvironmental records ... developed for the Canadian Rockies to date do not show a distinctive, prolonged period of cooler wetter conditions that extended from ca 1700-1850s ...

The significance of this record in terms of fire frequency studies is that, despite citations of our work to support it, it is very difficult to argue that the marked difference in reconstructed fire regimes using Time-Since-Fire analyses [see above] ... can be attributed to a change in climate conditions at the onset of the Little Ice Age. The reconstructed climatic history

using glacier fluctuations and tree-rings does not coincide with the hypothesized "shifts" in fire regime determined from these analyses ...

The idea of periods of homogenous fire regime conditions that extend for several hundred years and [that] can change drastically over short periods of time does not fit available record[s] of climate variability [p. 125].

In other words, it is difficult if not impossible to correlate long-term changes in the fire cycle with climatic variation in the Canadian Rockies.

Moreover, for the last 100 years, the climate has likely been warmer and dryer than anytime in the past 500 years. Ongoing glacial recession has now exposed areas that have been ice-covered since the 13th century (Luckman 1993). This period of a warmer-drier climate should have triggered a rash of forest fires during the last 50 years, not the reduction that has been observed. Feunekes and Van Wagner (1995:5) compared fire-severity weather data over the last 100 years in Banff National Park and found that "there were many years following 1940 with ... [fire-severity indices] to match those that resulted in burned area before 1940 Our conclusion is that the lack of burned area in Banff National Park since 1940 has not been due to a change in fire climate." Similarly, based on a 487 year reconstruction of annual precipitation in southwestern Alberta, Case and MacDonald (1995:267) concluded "that the frequency of droughts in Alberta during the period of instrumental records ... has not been appreciably different from conditions of the preceding four centuries."

Comparison of fire occurrence with long-term dendroclimatological records (Tande 1977, Hawkes 1979) and precipitation records since 1890 does show that large areas burned in most drought years up to about 1910 in Jasper, and up to about 1940 in Banff and Kananaskis. Subsequently, however, the area burned by wildfires has remained relatively low despite a series of dry years in the Canadian Rockies (e.g., 1946, 1947, 1956, 1957, 1961, 1967, 1970, 1971, 1979, 1985, and 1992). Even brief periods of warm-dry weather in April, May, and September (outside the main warm-dry period of July-August) during the last decade favored planned ignition of over 6,000 ha in Banff National Park despite continued low wildfire activity (Table 5.4).

Finally, it is hard to imagine how climatic variation could have produced similar fire- frequency data throughout western North America when "the seasonal climate that promotes fire is distinctly regional, even in areas of similar vegetation" (Knapp 1995:85). As we noted earlier, the observations of reduced fire frequency ca. 1650-1750 and of few fires after ca. 1880-1930 are near universal across the West yet there is no synchrony of climatic variables that could have produced that pattern. Moreover, where adjacent areas have different histories of human use, fire patterns are driven by man not climate. Along the U.S.-Mexico border, for instance, fire history studies show a pattern of reduced burning on the U.S. side, where aggressive fire suppression has been the rule, but do not show a similar reduction on the Mexican side, where there has been little or no effective fire suppression (Fule and Covington 1995, Minnich et al. 1995, Touchan et al. 1995).

Climate may have been an important factor in the Canadian Rockies prior to reduction of widespread human ignition in the 1700s and 1900s, and increased fire control ca. 1930. With continued alteration of human use patterns, though, this relationship has become increasingly uncoupled. A lack of ignition, or of smoldering fires that can be activated by drought, now limit the area burned in the Rocky Mountains (Pyne 1982). In contrast, droughts during recent years have continued to trigger large-scale lightning-caused fires in Canada's northern boreal forests (Van Wagner 1988, Johnson 1992). Due to the vastness of the country, those fires are difficult to detect while they are small and many escape the smoldering phases. So, the area burned in the boreal forest remains highly responsive to climatic variation while that in the Canadian Rockies and the rest of North America does not (Flannigan and Wotten 1991).

Native Peoples Did Not Use Fire

A key argument of researchers who claim past fire frequencies are unaltered is their contention that native peoples did not use fire as a land management tool, so the removal of Native Americans from the ecosystem was inconsequential to the fire cycle. Johnson and Larsen (1991:200), for instance, reported that for their Kananaskis study area, "Indian fires cannot be substantiated. It is hard to find well-documented evidence about why Indians would have caused fires as part of their lifestyles." This statement, though, is not supported by anthropological research on human use of fire in the Rocky Mountains (see above) or elsewhere in the world (Pyne 1993, 1994, 1995a, 1995b). As noted in Chapter 4, Peter Fidler (1991) traveled with Piegan natives from east of Edmonton to the Oldman River and returned during 1792-1793. Not only did Fidler record numerous instances where his native hosts accidentally or purposefully fired the vegetation, but much of that burning occurred during winter when periods of chinook winds melted the snow and provided ideal burning conditions. The burning was so extensive that on their return from the Oldman River to Edmonton in early spring, Fidler and his hosts found very little unburned land on which to pasture their horses. That is to say, nearly the entire area between Edmonton and the Oldman River had been burnt-off in a single year, mostly by native-set fires.

Grass all lately burnt the way we have passed this Day towards the Mountain, but not to the South of us, but at a good distance in that direction the Grass is now burning very great fury, supposed to be set on fire by the cotten na hew Indians. Every fall & spring, & even in the winter when there is no snow, these large plains either in one place or other is constantly on fire, & when the Grass happens to be long & the wind high, the sight is grand & awful ... [Fidler 1991:36]

Grass on fire more Westerly, supposed to be set fire by some Blood Indians who is just now returned from stealing 40 horses from the Snake Indians. [Fidler 1991:41]

... They [natives] did not put out their fire when they left it, which spread amongst the dry grass & ran with great velocity & burnt with very great fury, which enlightened the night like day, and appeared awfully grand. The wind being fresh drove it at a great distance in a little while. [Fidler 1991:58]

Even in wet coastal forests, natives frequently fired the vegetation whenever conditions permitted. In western Washington State, annual or bi-annual aboriginal burning kept prairies and meadows free from trees, and over time, gradually enlarged those grasslands (White 1975, Norton 1979, Boyd 1986). Natives burned these meadows to promote the growth of plants they used for food, and without regular burning, those prairies have long since vanished due to encroachment of Douglas fir and other conifers (White 1975, Norton 1979, Boyd 1986). Similarly, in northern California's wet redwood forests the "majority of the coastal prairie habitat was anthropogenic in nature and quickly reverted to woody vegetation after Euro-American settlement" (Blackburn and Anderson 1993b:22). That is to say, without frequent aboriginal burning, those grasslands have now been replaced by conifers (Bicknell 1992; Bicknell et al. 1992, 1993).

In northwest British Columbia the Gitksan and Wet'suwet'en peoples frequently burned the upper drainages of the Skeena River and the western headwaters of the Fraser River prior to European contact (Gottesfeld 1994). Despite the wet environment, these people used fire to open up the forests and to promote plants that they used for food. The same was true of other areas in British Columbia (Turner 1991). As Pyne (1993) has noted, the question should not be, "Why would aboriginal people have burned?", but "Why would native peoples have not burned?" The evidence is so overwhelming from North America and around the world, that the burden of proof should be on those who claim natives did not burn.

... anthropology's main claim as a science resides with its use of comparisons whereby we show the replicability of relationships and events in different cultures, in different places, and at different times. The replication of behaviours and social patterns [including cross-cultural burning] ... are all examples of human solutions or resolutions to similar problems. ... the ways that hunter-gatherers, in widely separated parts of the world, have developed parallel practices in terms of the seasonality, frequency, and intensity with which they set fires ... and the functionally equivalent practices carried out by hunter-gatherers in closed forest regions ... are important examples of how hunters and gatherers established remarkably parallel practices, in functionally similar environmental settings, while solving technoeological problems in almost identical ways. What these kinds of comparisons do is to verify the potential universality of locally specific practices [such as burning], in much the same way that independent testing does in the fields of experimental science. Comparisons of this type can demonstrate that local practices [of burning] ... represent more than just eccentric responses to unique conditions; they can also represent parallel, human solutions to functionally similar problems in human adaptation. [Lewis 1992:25-26].

As Pyne (1995a:16) asked, "How can anyone dismiss anthropogenic fire as inconsequential or indistinguishable from lightning fire?" Moreover, "the calculated dismissal of precolumbian fire is increasingly absurd on social and political grounds as well Stripping American Indians of the power to shape their environment with fire is tantamount to dismissing their humanity" (Pyne 1995a:17). "Removing anthropogenic fire from many environments may be less an act of humility than of vandalism" (Pyne 1995a:20). Instead, the "use of fire [is] ... an instrument of environmental preservation" (Pyne 1995b:94).

In Australia, where aboriginal burning has been studied more intensively than in North America, vegetation over much of the continent was a fire-climax maintained by native burning prior to European landfall (Hallam 1975; Lewis 1982a, 1989; Flannery 1990, 1994; Pyne 1991; and others). To early Europeans in Australia "a fired countryside was so much the norm that early reporters did not find it note worthy" (Hallam 1975:24). Instead, "so unremarkable [was] a burnt countryside that the absence of burning [became] remarkable" (Hallam 1975:25), and this burning all was the result of aboriginal land management, not lightning-caused fires. As historian Sylvia Hallam (1975:Preamble) noted, "The land the English settled was not as God made it. It was as the Aborigines made it."

Native Peoples Did Not Use Some Areas of the Rocky Mountains

Some researchers have concluded that their study sites were not influenced by human-ignited fires during the pre-European period because those areas were seldom-visited by native peoples (Masters 1990, Tymstra 1991). Although subalpine forests received less use than valley bottoms, there is ample historical data (see Chapter 2) and archeological evidence (see Chapter 3) that Native Americans traveled through or resided in all Rocky Mountains zones during the fire season, and other times of the year as well. Recent surveys in the subalpine and alpine regions of Banff National Park, for instance, have uncovered numbers of archaeological sites, as have similar surveys in other parts of British Columbia and Alberta (Gwyn Langemann, pers. comm. 1993).

Modern Effort to Control Fires is Ineffective

Masters (1990) and Weir et al. (1995) advanced the idea that modern fire control efforts are largely ineffective because it is impossible to suppress active, high-intensity crown fires. This argument, though,

ignores the basic premise of fire control -- "hit them hard, and hit them small." Initial attack is specifically oriented to prioritize fires and to fight those that have high potential before they actually become active (Canadian Parks Service 1990). This strategy has been extremely effective in the Rocky Mountains where most fires remain in a smoldering stage for some time after ignition (see above) and where fire control organizations have had good access and communication systems for much of the last century (White 1985a).

If fire control efforts are reduced, and a dry year occurs, then large fires should result (Murphy 1985b, Fule and Covington 1995). This is precisely what happened in many prescribed natural fire zones in Yellowstone National Park and surrounding wilderness areas during the summer of 1988 (Pyne 1989, Bonnicksen 1990). Although that drought was of record magnitude and was widespread throughout the western United States, the area that burned was not -- except for Yellowstone Park and adjacent "let burn" wilderness areas (Brown et al. 1994). Outside Yellowstone, all fires were suppressed as soon as they were detected, while in the park, at least some lightning fires were allowed to smoulder. Those smoldering fires were later fanned by high winds into raging firestorms that blackened over 400,000 ha (Rome and Despain 1989a, 1989b).

Humans Have Not Caused Fires in the Recent Past

A further argument of those proposing that humans have not influenced Rocky Mountain fire regimes is that Europeans did not burn large areas during the exploration and settlement period. Johnson and Wowchuk (1993:1215), citing their unpublished data for a large area of the Rockies, claimed that, "Over the last 100 years, fires greater than 400 ha have almost always been caused by lightning." This statement, though, is not supported by agency fire reports which show that many large fires are human caused (Table 5.1) or that lightning fires are uncommon east of the divide (Figure 5.2). In fact, most Canadian land management legislation and agency organizational structure related to forest fires are the legacy of the many large blazes started by humans during the early 1900s (Byrne 1968, Murphy 1985a, White 1985a). As Van Wagner (1985:98) observed, there are "no laws of physics that support the argument that a particular fire's behavior depends on its mode of ignition once it has left its immediate vicinity of its point of origin." This was demonstrated in the Yellowstone Ecosystem during the summer of 1988. Of the 400,000 ha which burned during that fire season, approximately half was burned by fires of human origin (Schullery 1989a, 1989b).

Areas Frequented by Humans Do Not Have Shorter Fire Cycles

A final argument against the hypothesis of strong human influences on Rocky Mountain fire regimes is that some researchers contend there are no differences in fire cycles between lower-elevation zones used by humans and less-frequented areas at higher elevations. Two studies in the Canadian Rockies (Masters 1990, Johnson and Larsen 1991), for instance, reported no spatial variation in fire cycles. Both those studies were based upon time-since-fire analysis. In contrast, studies using fire-interval data (Table 5.3) show a consistent pattern of shorter fire cycles in lower-elevation forests.

We and others (Arno et al. 1993, Finney 1995, Luckman and Seed 1995, Rogeau 1996) believe that the time-since-fire approach has limitations in evaluating variability of fire cycles over space and time. First, the last burn may have been large, and totally masked frequent smaller fires in the past (Rogeau 1996). In Jasper National Park, for example, Tande (1977, 1979) reported that a rich mosaic of numerous small historic fires was completely burned over by a large fire in 1889. A time-since-fire map, though, would show only one date for most of the area, 1889, and mask the region's true fire history (Arno et al. 1993, Rogeau 1996). Second, the methods used for time-since-fire analysis may be too insensitive to detect variation in fire

cycles between areas (Rogean 1996). Montane areas with short fire cycles, and sheltered upper subalpine basins with long fire cycles, are in spatially limited and unique terrain configurations, but these were not adequately sampled in past analyses. Third, it is also extremely difficult to accurately map time-since-fire in montane forests burned by low intensity fires, or in very old subalpine forests where "burn lines" are no longer visible and the last fire may pre-date the oldest trees, thus biasing results (Arno et al. 1993, Rogean 1996).

Furthermore, there is the problem of the "missing tail" that is associated with time-since-fire stand-age analyses (Finney 1995, Van Wagner 1995). Because the area-by-age distribution is assumed to be negative exponential, it should extend theoretically to infinity, but real data do not because individual trees do not live forever. If the missing tail is not taken into account the right end of the cumulative graph, where the data are smallest, will tend to curve downward biasing the analysis (Finney 1995, Van Wagner 1995).

Similarly, Luckman and Seed (1995:123) noted that "once trees exceed 3-400 years it is very difficult to find a sound tree [to age] because of heart rot [or other diseases]." This problem has also been noted by other researchers (Lorimer 1985, Fox 1989, Johnson and Fryer 1989, Duncan and Stewart 1991, Huckaby and Moir 1995, Rogean 1996). Luckman and Seed (1995) went on to suggest that this was akin to the missing tail problem but would tend to bias the oldest 10-15% of the area sampled and would cause the right end of the cumulative graph to bend sharply downward. That is to say, Luckman and Seed (1995) postulated that the increase in fire frequency seen before ca. 1730 may be a statistical artifact instead of denoting a change in fire regimes (see above). Similarly, based on computer simulation modeling, Rogean (1996) found that apparent changes in the fire cycle may be nothing more than normal statistical variation. If this is true, then the entire use of the time-since-fire method needs to be reevaluated (Rogean 1996).

Other evidence also suggests that the time-since-fire negative exponential approach may not be applicable in the Canadian Rockies because the models assumptions are routinely violated (Rogean 1996). First as explained earlier, most of the vegetation patterns seen at historical contact in the Canadian Rockies (Chapter 4) were the result of low-intensity, not stand-replacing fires, especially in montane zones (Tymstra 1991, Wierzchowski 1995). Rogean and Gilbride (1994), for instance, reported scores of different-aged fire scars on trees in Banff's Bow Valley – an indication that low-intensity fires were once common. Similarly, Wierzchowski (1995) found that low-intensity fires were once the norm in Banff's montane areas. Second, as discussed above, fires in the Canadian Rockies do not burn at random as required by the negative exponential model (Wierzchowski 1995, Rogean 1996). Instead, burning patterns in Banff and other areas are related to topography, aspect, elevation, and isolation in a complex pattern (Tymstra 1991, Van Wagner 1995, Wierzchowski 1995) that is more reflective of spring aboriginal burning than late-summer lightning-caused fires (Kay 1995a, Kay and White 1995, Wierzchowski 1995:148).

BANFF'S ECOSYSTEM MODEL

Recognition that humans are perhaps the most important long-term regulator of fire activity in the Rocky Mountains enables us to understand the critical human-fire-aspen linkage of our ecosystem model (Figure 1.1). It also allows us to quantify historical patterns relating to the time of burning, fire intensity, and fire frequency for the Banff Ecosystem.

Time of Burning

When most lightning fires occur in the Canadian Rockies (see Figures 5.5 and 5.6), it is physically impossible to burn aspen, and even large fires that sweep through nearby conifer forests leave aspen stands untouched (DeByle et al. 1987, Johnson 1992; see Chapter 6). Terms such as asbestos type and firebreak

are often applied to the nonflammability of aspen communities during the summer growing season (Murphy 1985b:68, DeByle et al. 1987:75). This phenomena has led fire behavior specialists to recommend planting aspen around facilities to reduce the fire danger (Fechner and Barrows 1976).

Aspen forests will readily burn only before spring "green up", or during autumn after leaf-fall and when understory plants have cured (Murphy 1985b:68, Bailey 1986, Brown and Simmerman 1986). Rates of spread over 10 m/min are possible with flame lengths in excess of 10m (Quintilio et al. 1989). Historically, montane areas occupied by aspen burned primarily during April and May (Figure 5.3). This, however, is outside the normal lightning season (Tymstra 1989:36-38, Johnson and Larson 1991, Nash and Johnson 1993), and implies that those fires were set by native peoples (White 1985a; see Chapter 6). It is no surprise that people prehistorically and historically made heavy use of aspen-dominated areas. Throughout the Alberta Foothills and Canadian Rockies, archeological sites are often found in or near aspen communities or in areas that historically supported aspen.

Similarly, grasslands in the Canadian Rockies are generally too green to burn during July and August when most lightning fires occur (Wierzchowski 1995:134). In fact, lightning fires rarely start in grasslands (Keeley 1982:434, Pyne 1984). Since grasslands once had fire-frequencies even higher than forested-types, this further supports the native burning hypothesis as do other data. In the Selway-Bitterroot Wilderness Area of western Montana-eastern Idaho, most lightning-caused fires have been allowed to burn since 1979 under a "prescribed natural fire" program. Brown et al. (1994) recently compared the area burned by forest-type since 1979 with the area burned by fires before 1935; i.e. prior to European settlement and fire suppression. They found that lightning fires alone only burned about one-half the area blackened in presettlement times and that the lowest-elevation montane areas, which once had the highest fire frequency, now seldom burn at all. This is not surprising since lightning fires generally start on mid- or upper-elevation slopes and burn uphill (Caprio and Swetnam 1995). It also suggests that much of the original fire frequency was due to other than lightning; i.e. native burning.

This is even more pronounced in Yellowstone National Park (Kay 1995a, in press b). Prior to park establishment, Yellowstone's northern range had a fire-return interval of once every 25 years (Houston 1973, 1982) – the northern range is the lowest area in the park and is mostly grasslands with scattered stands of aspen, Douglas fir, and lodgepole pine. Yellowstone has had a "let burn" policy for nearly 25 years, yet during that period, lightning-caused fires have burned practically none of the northern range. In 1988, fire did burn approximately one-third of the area, but according to agency definitions, that was "unnatural" because the fire was started by man, not lightning. Besides, the 1988 fires are thought to be a 100-300 year event (Schullery 1989a, 1989b), so similar fires could not have caused the original 25 year fire frequency.

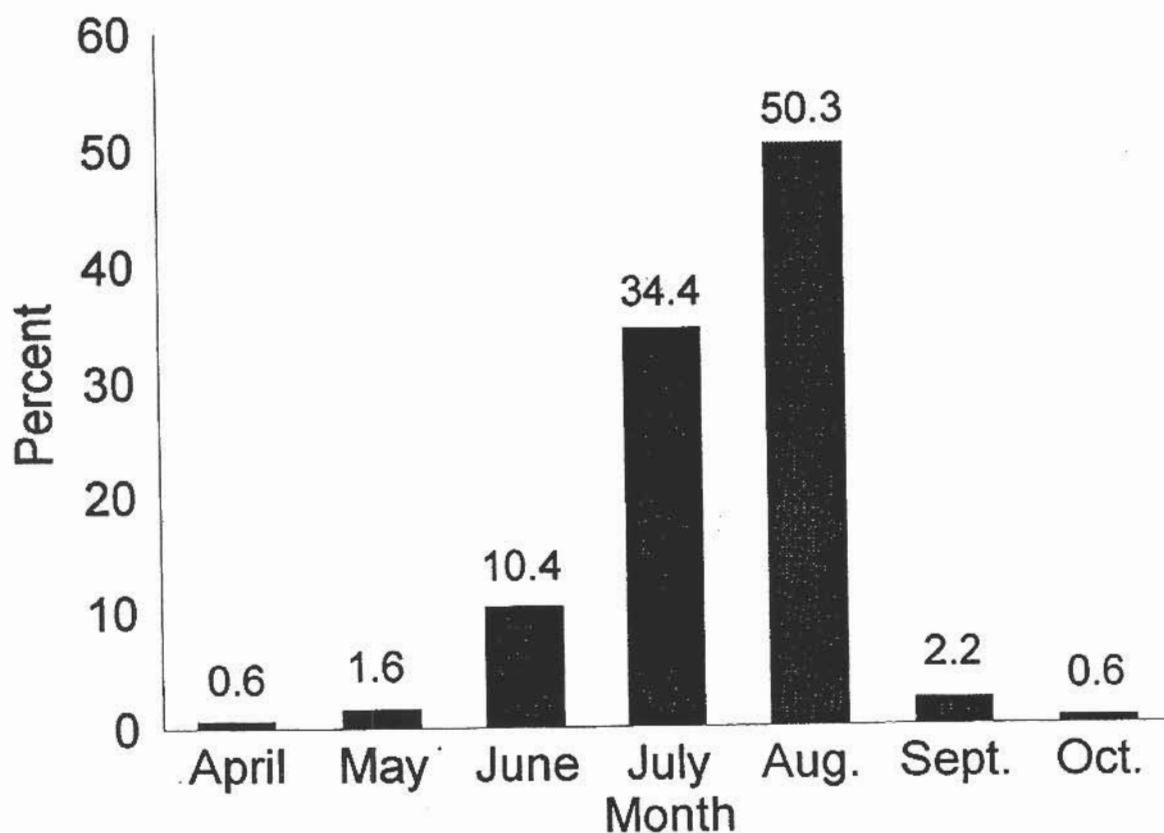


Figure 5.5. The distribution of lightning-caused fires in Banff, Kootenay, and Yoho National Parks. When aspen is normally dry enough to burn in early spring or late in the fall, there are few lightning-caused fires and those that do start only burn small areas (see Figure 5.6). Although there are few lightning fires capable of burning aspen, historical photographs indicate that aspen in the Canadian Rockies burned frequently during the early 1800s. This suggests that those fires had to have been set by Native Americans, as the Canadian Rockies were not settled by Europeans until ca. 1880. As discussed in Chapter 6, this pattern is common throughout western North America. Yoho National Park 1920-1988 data from Tymstra (1989:36-38); Kootenay National Park 1920-1994 data from Al Dibb (pers. comm. 1996); and Banff National Park 1920-1995 data from Ian Pengelly (pers. comm. 1996); $n=183$.

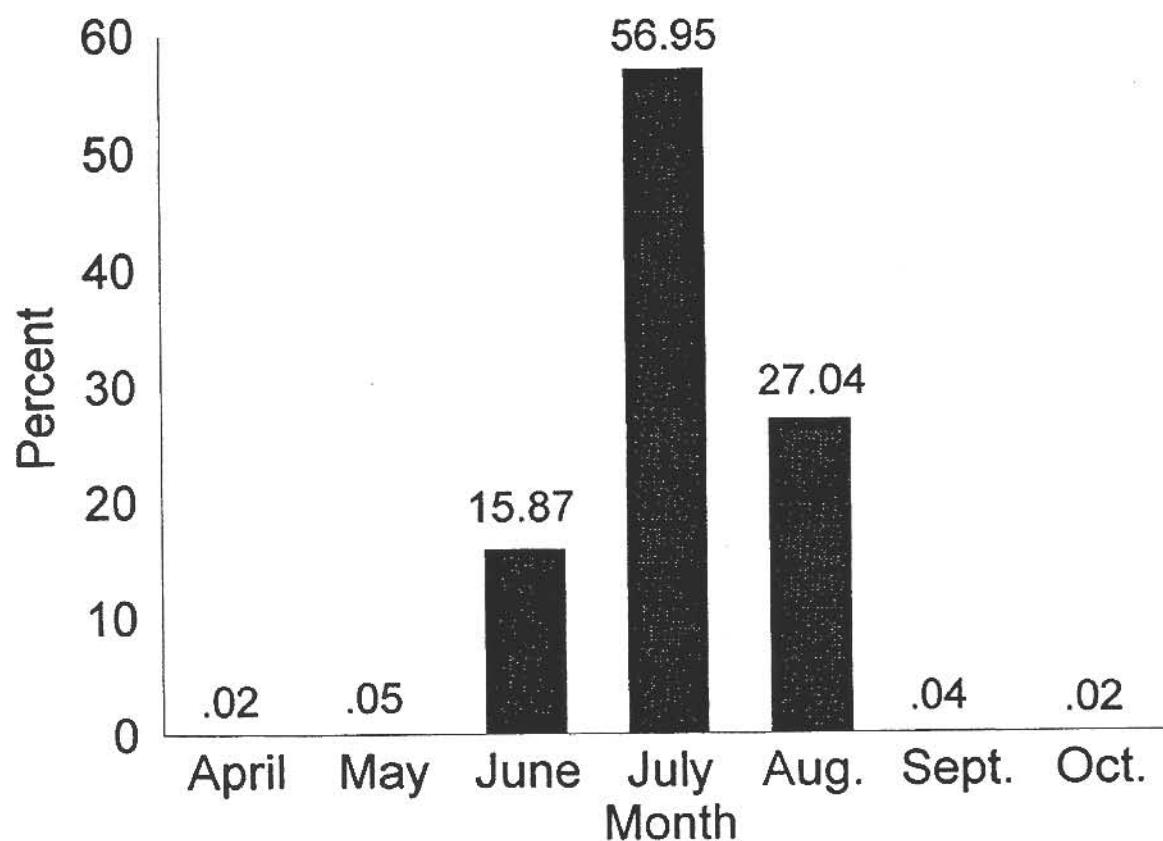


Figure 5.6. The area burned by lightning fires in Banff, Kootenay, and Yoho National Parks. When aspen is normally dry enough to burn in early spring or late in the fall, there are few lightning-caused fires (see Figure 5.5) and those that do start only burn small areas. Although there are few lightning fires capable of burning aspen, historical photographs indicate that aspen in the Canadian Rockies burned frequently during the early 1800s. This suggests that those fires had to have been set by Native Americans, as the Canadian Rockies were not settled by Europeans until ca. 1880. As discussed in Chapter 6, this pattern is common throughout western North America. Yoho National Park 1920-1988 data from Tymstra (1989:36-38); Kootenay National Park 1920-1994 data from Al Dibb (pers. comm. 1996); and Banff National Park 1920-1995 data from Ian Pengelly (pers. comm. 1996); n=22,686 ha.

Despite a series of droughts, why has Yellowstone's northern range remained virtually unburned? Park biologists contend that this is because "lightning has chosen not to strike very often on the northern range" (Despain et al. 1986:109). That assertion, though, is not supported by data from the Bureau of Land Management's Automatic Lightning Strike Detection System which shows that on average, lightning strikes the northern range 4 times per km²/yr (Kay 1990:136-137). So lightning strikes, but why doesn't the range burn? The answer is that when most lightning strikes occur, the herbaceous vegetation is too green to carry a fire which, in turn, suggests that the original 25 year fire frequency was due primarily to native burning (Kay 1995a).

Intensity of Burning

Due to the heavy ungulate grazing that occurs in Banff's aspen communities today, ground fuels are barely adequate to sustain a fire during spring, and at many locations, not even during fall (C. White, personal observation; Brown and Simmerman 1986). Yet in those same forests, fires historically scarred lodgepole pine and Douglas fir, and often regenerated aspen stands (White 1985b, Rogeau and Gilbride 1994). This suggests that aboriginal hunting and/or wolf predation reduced elk and other ungulate densities in those areas either by direct mortality or by displacement. With reduced herbivore pressure came an increase in fine fuels that could support moderate intensity surface fires (Brown and Simmerman 1986, Savage and Swetnam 1990, Touchan et al. 1995). For example, Figures 6.4-6.6 illustrate the difference in stand structure and forest fuels at the 10.5-mile aspen exclosure in Banff National Park. Outside the exclosure where ungulate herbivory is high, fuels are barely adequate to carry a fire, especially in spring. While inside the exclosure, accumulated shrub biomass and ungrazed understory plants would fuel a more intense fire. In fact, there is a negative correlation between ungulate numbers and the area burned. When ungulate populations are high, they consume most of the fine fuels which decreases the area burned — in some cases to near zero (Norton-Griffiths 1979, Savage and Swetnam 1990, Touchan et al. 1995). Thus, the widespread burning of grasslands and prairies that occurred in historical and pre-Columbian times provides another line of evidence that large numbers of elk and other ungulates did not inhabit the Rocky Mountains until recently (Kay in press b).

Fire Frequency

Montane aspen in the Canadian Rockies historically had fire cycles of around 20 years (Table 5.3), shorter than most other forest communities. The high fire frequency undoubtedly limited conifer competition and stimulated aspen regenerating (see Chapters 4 and 6). This short fire cycle, largely under human control, was an important factor in the development and maintenance of Banff's aspen communities. Since burning today has failed to regenerate Banff's aspen stands due to repeated ungulate browsing of the newly emerged suckers (see Chapter 6), carnivore and/or aboriginal limitation of prehistoric ungulate numbers may also have been of critical importance.

CHAPTER 6

ASPEN ECOLOGY

INTRODUCTION

The autecology of aspen varies across Canada (Bird 1930, 1961; Moss 1932; Lynch 1955; Buell and Buell 1959; Maini 1960; Bailey and Wroe 1974; Bailey et al. 1990; Jelinski and Cheliak 1992; Peterson and Peterson 1992, 1995; McCartney 1993; Stelfox 1995). In what are termed the aspen parklands, which form a broad band between the prairies and the coniferous forests of Alberta, Saskatchewan, and Manitoba, aspen is climax. Prior to European settlement, fire swept the parklands so frequently that it actually restricted the growth and development of aspen communities in many areas. With modern fire suppression and the elimination of native burning, though, aspen in the parklands has increased markedly, often invading grasslands (Canada National Defense 1994, Olson 1994).

In Rocky Mountain and boreal forests, however, the situation is reversed. There, aspen is primarily "seral," and most stands will be replaced by conifers unless burned at infrequent 20 to 130 year intervals (Noble and Slatyer 1980). So with modern fire suppression, aspen has decreased in those areas; the exact opposite of what has happened in the aspen parklands. Not all aspen in the Canadian Rockies, though, is "seral." Long-term stable or climax aspen exists throughout the Intermountain West (Youngblood and Mueggler 1981; Mueggler and Campbell 1982, 1986; Mueggler 1988, 1989; Kay 1990:59-60), but becomes less frequent in the northern Rockies (Peterson and Peterson 1992, 1995; Stelfox 1995).

Unfortunately, detailed aspen ecology studies have not been conducted in the Canadian Rockies but, in general, climax or stable aspen communities can be distinguished from "seral" stands because they (1) contain variable-age trees (ramets), (2) have characteristic understory plants, and (3) lack substantial conifer invasion. "Seral" aspen, on the other hand, is characterized by (1) single-age-class trees, (2) heavy conifer encroachment, and (3) different understory species (Harper 1985, Mueggler 1988, Kay 1990; Peterson and Peterson 1992, 1995; Stelfox 1995). The presence of a limited number of conifers, however, is insufficient evidence on which to classify aspen stands as "seral" (Hoffman and Alexander 1980:25). Conifers must be prominent, not merely present, because occasional conifers can be found in basically stable aspen communities (Mueggler 1976). "An uneven-aged conifer understory generally is reliable evidence of a seral aspen site" (Mueggler 1985:46). Aspen stands must have 5% to 10% conifer canopy cover before they are considered fast-"seral," a term foresters assign to aspen that will be replaced by conifers within 100 years (Mueggler 1988).

As discussed earlier (see Chapters 1 and 4), aspen in Banff National Park has declined since the early 1900s, and previous researchers have identified repeated browsing by elk as the primary cause (Cowan 1944, 1947a, 1950; Webb 1957; Flook 1959, 1964; Trottier and Fehr 1982, Bernard et al. 1995). To determine if this conclusion is correct, or if perhaps Banff's aspen has declined due to climatic change or fire suppression, we surveyed aspen inside and outside Banff National Park. Since these areas have similar histories of fire suppression and climatic change, any difference between inside and outside aspen communities has to be due primarily to different levels of elk use. Outside the park where they are hunted, elk numbers have been lower. So if aspen has successfully regenerated outside the park, but not within, that would support the browsing hypothesis, while if aspen has declined both inside and outside, the climate change or fire suppression hypotheses might apply (Kay 1990). As explained in Chapter 1, we also measured aspen stands inside and out both Kootenay and Yoho National Parks (Kay 1996).

Exclosures are widely used to study the successional status and trend of plant communities, as well as to measure the impact of grazing (Laycock 1975). Exclosures can also be used to evaluate climatic effects since the general climate is the same within the exclosures and on adjacent outside plots. So as outlined in Chapter 1, we surveyed aspen communities inside and outside long-term grazing exclosures in Banff's Bow Valley. Unfortunately, there are no aspen exclosures in either Kootenay or Yoho.

Since aspen could also have declined because of past fire suppression policies (see Chapters 1, 4, and 5), we measured aspen regeneration in stands killed by Banff's prescribed burning program to determine if fire can be used to successfully regenerate the park's aspen communities despite ungulate browsing as has been claimed in Yellowstone (Houston 1982, Despain et al. 1986). If fire-killed aspen stands successfully regenerate in Banff today, that would implicate the park's previous fire suppression program, but if new sucker growth is suppressed by repeated browsing, that would suggest Banff's elk population is primarily responsible.

BANFF NATIONAL PARK

Inside-Outside Park Comparisons

Banff's Bow Valley

Our survey of aspen communities inside and outside the park revealed an interesting pattern. In Banff's Bow Valley, aspen stands generally lack regeneration. Aspen suckers are often abundant, but are kept from growing more than 0.5 m tall due to repeated ungulate browsing. Except for the Bison Paddock (see below), and a few other scattered locations, most aspen in the Bow Valley are being invaded by conifers (see Figure 6.1).

Aspen in the Bow Valley also bear evidence of repeated elk bark scarring. When numbers are high (Jezierski and Kuczawski 1987:758), elk eat the soft bark of aspen by digging their lower front teeth into the bark and moving their heads upwards while applying pressure to the trees (Krebill 1972, DeByle 1985:118-119, Kay 1990). This enables elk to gnaw-off or strip-off large pieces of bark, often down to the sapwood. In response to this, or any other injury, aspen develop black scar tissue. So when bark damage is extensive, as in Banff's Bow Valley, the lower 2 m of aspen trunks are black instead of their normal white coloration (see Figure 6.1). Elk induced bark damage also subjects trees to pathogen attack which increases stem mortality (Hinds 1985, Hart 1986).

Eastgate - Canmore

As one leaves the park and travels east down the Bow Valley to Canmore, however, many aspen stands have successfully regenerated without fire or other disturbance. Even "seral" communities often produce multi-aged aspen. There is also little evidence of ungulate browsing or highlining, and elk bark scarring is generally absent. Some aspen stands are being invaded by conifers, but many are not.



Figure 6.1. A typical aspen stand in Banff National Park's Bow Valley. Aspen suckers are present but are kept from growing more than 0.5 m tall due to repeated ungulate browsing. Aspen normally have white-colored bark, but trees in Banff's Bow Valley have been scarred by elk bark stripping as high as the animals can reach. When populations are high, elk eat the soft bark of aspen by digging their lower front teeth into the bark and then moving their heads upwards while applying pressure to the trees. This enables elk to gnaw-off or strip-off large pieces of bark, often down to the sapwood. In response to this, or any other injury, aspen develop black scar tissue. When bark damage is extensive, as is characteristic in Banff's Bow Valley and other national parks, the lower 2 m or so of aspen trunks are black instead of their normal white coloration. Elk bark damage also subjects aspen to attack by pathogenic fungi which increases stem mortality. The black marks on the upper white trunks are branch scars which form when lower branches die as the trees grow. This stand is located along Highway 1A and shows invasion by conifers which is common in the park. Under present conditions and in the absence of fire, Banff's aspen clones will gradually die out and be replaced by conifers. Survey pole (2 m) for scale. August 1993 photo by Charles Kay (No. 3716-36A).

The apparent increase in stable or climax aspen communities outside the park may be due to environmental factors, but it could also be related to the high level of elk use Banff has historically experienced. In the Yellowstone Ecosystem, aspen stands subject to lower levels of elk browsing have fewer invading conifers (Kay 1990). Young (1977:50) and Cooper (1975:80-81) suggested that ungrazed herbaceous understories may prevent conifer establishment since they afford few sites for conifer seedling establishment and they also provide heavy competition for light and moisture. By repeated grazing and browsing, elk not only prevent aspen regeneration but render those communities more susceptible to conifer encroachment (Kay 1990).

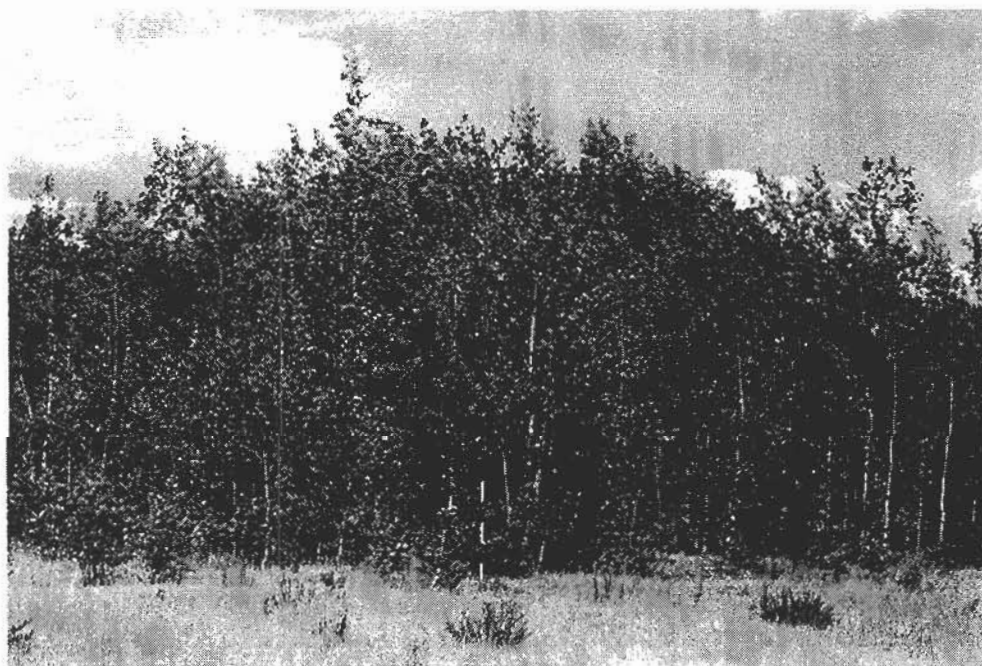
North Saskatchewan

Unlike the Bow drainage where aspen sucker growth has been suppressed, aspen in Banff's North Saskatchewan Valley have successfully regenerated (see Figure 6.2a). Disturbance has been a factor in the growth of aspen with the highway right-of-way, but undisturbed stands have also produced new aspen stems greater than 2 m tall. Since this area has not burned, that factor cannot be responsible for the condition of aspen along the North Saskatchewan. This area, however, has lower elk densities than the park's Bow Valley (Skjonsberg 1993, Bernard et al. 1995, Komex International 1995). Relatively little winter range exists in Banff's portion of the North Saskatchewan forcing most ungulates to winter outside the park where they are subjected to sport hunting and native harvest. Furthermore, this was the first region of the park to be repopulated by wolves during the 1960s, and wolf predation may also be limiting elk numbers (see Chapters 1 and 7). In Jasper National Park, Dekker (1985a, 1985b) reported that wolf predation caused a significant decline in local elk populations which, in turn, resulted in the growth of dense stands of aspen saplings for the first time since park establishment.

Figure 6.2. Typical aspen stands along the North Saskatchewan and on Kootenay Plains. (a) During construction in the North Saskatchewan, the road right-of-way was cleared and aspen have since regenerated via root suckering. Undisturbed stands, though, have also produced new stems greater than 2 m tall. Elk numbers are low in this part of the park, and aspen show no signs of browsing, high-lining, or bark stripping. Most aspen outside the right-of-way are heavily invaded by conifers and will eventually disappear unless burned. Fire in this portion of Banff would probably be successful in regenerating aspen and suppressing conifers. Survey pole (2 m) for scale. August 1993 photo by Charles Kay (No. 3712-18). (b) Despite an absence of fire or other disturbance, aspen on Kootenay Plains have been able to successfully regenerate. The stands are multi-aged and, for the most part, are not being invaded by conifers – two indications that these aspen communities may be stable or climax. Few elk or other ungulates use Kootenay Plains despite low snowfall and an abundance of forage because Highway 11 allows easy access for sport hunting and year-long native subsistence hunters. According to present regulations, natives can hunt on the part of Kootenay Plains that the Stoney lease, but not on the rest of the Ecological Reserve or in the wildlife sanctuary that runs along the David Thompson Highway – a 400 m strip on either side of the road is closed to hunting. Sport hunting is also not permitted on the Ecological Reserve or in the David Thompson Wildlife Sanctuary (Derry Armstrong, Alberta Parks Service, pers. comm. 1994). These no hunting zones, however, are very narrow and do not afford elk and other ungulates much protection, certainly not enough to allow the animals to concentrate on Kootenay Plains. Survey pole (2 m) for scale. August 1993 photo by Charles Kay (No. 3712-28).



a.



b.

Kootenay Plains

As noted in Chapter 4, Kootenay Plains are located approximately 20 km east of Banff National Park along the North Saskatchewan River and are managed by the Province of Alberta as an Ecological Reserve. Despite an absence of fire or other disturbance, aspen on Kootenay Plains have been able to successfully regenerate (see Figure 6.2b). Most stands have a multi-age structure and many are not being invaded by conifers, both indications of stable or climax aspen communities, a rarity this far north in the Canadian Rockies (Peterson and Peterson 1992).

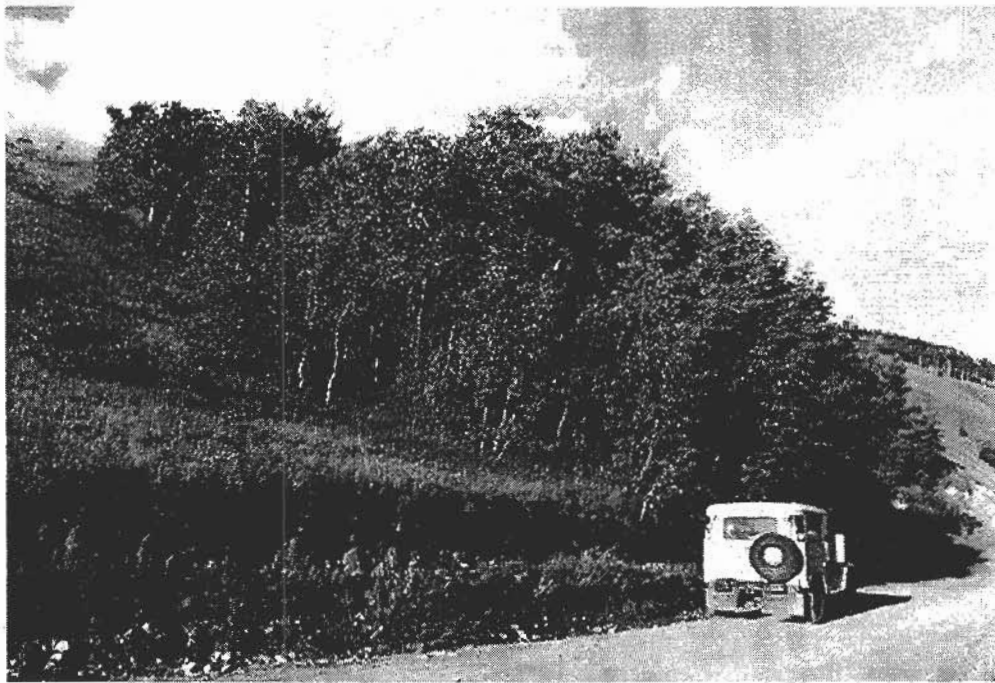
Despite low snowfall and abundant forage on these low-elevation montane grasslands, few elk or other ungulates use Kootenay Plains. The David Thompson Highway bisects the area and allows convenient year-round access for sport and native subsistence hunters. In fact, part of Kootenay Plains is leased to the Stoney who have a reserve below Bighorn Dam.

Ya Ha Tinda

The Ya Ha Tinda is located in the Red Deer Valley approximately 10 km east of Banff National Park (Morgantini 1995). The Ya Ha Tinda Ranch is owned by Parks Canada but is not part of Banff National Park. Instead, the Ya Ha Tinda is administered by Parks Canada's Regional Office and is subject to provincial wildlife regulations. That is to say, both sport and native hunting are permitted. The Ya Ha Tinda's montane grasslands are surrounded by forested mountains (see Figure 4.9), and the valley contains numerous aspen communities. In addition, over 2,000 elk now winter on the Ya Ha Tinda (Morgantini 1995).

Aspen on the Ya Ha Tinda exhibit interesting regeneration patterns. Near access roads, aspen have regenerated profusely and show little sign of ungulate browsing (see Figure 6.3a). But with increasing distance from the roads, aspen exhibit signs of intense browsing and generally lack regeneration (see Figure 6.3b). Since most hunters spend their time near the Ya Ha Tinda's roads, elk are displaced to more remote areas where the animals concentrate and repeatedly browse those aspen communities. This pattern cannot be attributed to site or climatic differences because the stands farthest from the roads are generally at increasing elevations, and if anything receive more precipitation. A similar situation exists in Wyoming's Jackson Hole where human use has displaced elk from along roads and allowed nearby aspen to regenerate (Kay 1985, 1990). Hunted elk are sensitive to disturbance, even if it occurs after the hunting season, and they often move long distances to avoid humans (Lyon 1979a, 1979b, 1980, 1983; Edge and Marcum 1985; Edge et al. 1985a, 1985b; Lyon et al. 1985).

Figure 6.3. Typical aspen stands on the Ya Ha Tinda east of Banff National Park. (a) Aspen along the main access road, such as the stand shown here, have regenerated successfully without disturbance and exhibit a multi-age structure characteristic of stable or climax communities. Many aspen stands on the Ya Ha Tinda also lack conifers, another indication that they are not "seral." These stands regenerated because hunting displaced elk that would otherwise have grazed these areas. Away from traveled roads, however, where the Ya Ha Tinda's 2,000+ wintering elk concentrate, repeated browsing is suppressing aspen regeneration. (b) Shown is an aspen stand on the ridge above the Ya Ha Tinda's main access road — viewed west up the Red Deer River to Banff National Park. Since few hunters climb this far, elk here are relatively undisturbed and repeatedly browse these aspen communities preventing regeneration. Elk-induced bark wounding is also common, though, not as extensive as in Banff's Bow Valley. It is thought that elk are also having a negative impact on the Ya Ha Tinda's grasslands (Morgantini 1995). August 1993 photos by Charles Kay (No. 3716-3 and 3716-10).



a.



b.

Apparently this has also occurred in Banff's Bow Valley. During the 1940s, 1950s, and early 1960s when Parks Canada thought elk were overgrazing Banff's winter range, they shot animals to reduce the herd (Flook 1964, 1970). Because of the difficulty in retrieving dead elk, most of the culling took place near park roads. For a number of years, this displaced elk from those areas and apparently allowed some roadside aspen to regenerate.

In the recent past, when the elk herd on the Ya Ha Tinda was smaller than it is today, many aspen stands at intermediate distances from access roads were also able to regenerate. With increasing elk numbers, however, the animals are now having a significant impact of those aspen communities. Elk have browsed off all the lower branches as high as the animals can reach, termed highlining, and bark wounding has become common (Kay et al. 1994:6-18).

In the absence of browsing or with reduced browsing, many aspen stands on the Ya Ha Tinda apparently would be stable or climax since conifer invasion is low. In fact, many stands lack conifers, especially those on the main ridge above the east entrance. The Ya Ha Tinda contains some of the best montane aspen communities that are left in the Central Canadian Rockies. Under present conditions, however, aspen on the Ya Ha Tinda, will come to resemble those in Banff's Bow Valley. Morgantini (1995) also suggested that elk are having a negative impact on the Ya Ha Tinda's grasslands and recently several hundred elk were trapped and moved to other areas.

Aspen Exclosures

10.5 Mile Exclosure

Banff National Park has only one long-term grazing exclosure which contains aspen. That exclosure, referred to locally as the 10.5 mile exclosure, was constructed in 1944 and has been measured at periodic intervals (Webb 1957, Flook 1959, Trottier 1976, Trottier and Fehr 1982:28-33). As explained in Chapter 1, the fenced plot measures 18x30 m and is located 17.7 km west of Banff townsite along Highway 1A.

The exclosure was last measured in 1981 by Trottier and Fehr (1982:28-33) who noted that "Browsing by elk in this area has a tremendous influence on shrub and tree regeneration in the aspen forest. ... Under protection there were plants [aspen] in all height classes indicating that growth to tree stage was proceeding. On the browsed plot all plants were less than 100 cm." Yet densities of aspen stems less than 1 m tall were greater outside, as was total stem density. Nevertheless, Trottier and Fehr concluded that elk were limiting aspen regeneration because none of the outside stems were able to escape browsing.

Moreover, the protected plot also had greater shrub density and a more diverse height class distribution than the browsed plot. "About 97% of the shrubs in the browsed plot were less than 100 cm high and there were no plants taller than 150 cm" (p. 30). Rose (*Rosa acicularis*) was much more abundant on the protected plot, and shrub birch (*Betula glandulosa*), which was found in all height classes under protection, was absent on the browsed plot outside the exclosure. Willow (*Salix glauca*), the key browse species at this site, was also more abundant inside the exclosure. Outside the exclosure, no willows were taller than 1 m due to repeated browsing while inside, willows grew to heights of 4 m.

These differences are illustrated in Figure 6.4. Outside the exclosure, aspen suckers are abundant but all are kept at heights under 0.5 m by repeated browsing, and aspen trees show extensive elk-induced bark damage. Shrubs are rare, and all except the generally unpalatable buffaloberry (*Shepherdia canadensis*),

are less than 1 m tall. Grasses dominate the understory. In contrast, aspen inside the exclosure have successfully regenerated and have an understory dominated by palatable shrubs. Bark damage, aside from normal branch scars, is also lacking.

The changes that have occurred at the 10.5 mile exclosure can also be seen in repeat photographs. When the exclosure was erected in 1944, one photopoint was established outside the exclosure and a second was established inside. Aspen suckers outside the exclosure have been suppressed by repeated ungulate browsing while those inside have developed into mature trees. Grasses still predominate outside the exclosure, but the understory grasses inside the exclosure in 1944 have been replaced by palatable shrubs. Clearly, elk have had a major impact on this aspen community (Figures 6.5 and 6.6).

Highway Right-of-Way

When the Trans-Canada Highway that bisects Banff's Bow Valley was twinned during the early 1980s, a 2.4 m woven-wire fence was installed along both sides of the freeway to reduce ungulate-vehicle collisions (Woods 1988). This fencing, in effect, created a de facto exclosure through the Bow Valley and at numerous points within the fenced right-of-way where aspen is now protected, it has successfully regenerated while outside it has not (Figure 6.7). Not only are elk having a dramatic effect on these aspen communities, but they are also having a measurable impact on small mammals and coyotes. Microtine rodent populations within the fenced right-of-way are two and one-half times higher than outside the fence where elk graze. This attracts coyotes which spend much of their time hunting within the fenced right-of-way where they are often struck and killed by vehicles (Gibeau 1993). "Of the 24 known [coyote] mortalities between July 1991 and March 1993, all but 3 were highway kills" (Gibeau 1993:21). Apparently, elk grazing reduces plant cover and litter that small mammals need. So as discussed earlier, elk browsing impacts more than aspen.

Figure 6.4. Aspen communities inside and outside Banff's 10.5 mile aspen exclosure. (a) Aspen immediately north of the exclosure show the effects of repeated elk browsing. Aspen regeneration has been suppressed, shrubs are rare, and the aspen show extensive elk-induced bark damage. Survey pole (2 m) for scale. August 1993 photo by Charles Kay (No. 3726-1). (b) While less than 20 m away, protected aspen have successfully regenerated and have an understory dominated by shrubs and other palatable plants. Bark damage, aside from normal branch scars, is also lacking. Survey pole (2 m) for scale. August 1993 photo by Charles Kay (No. 3726-6).



a.



b.

Figure 6.5. Repeat photoset of Banff's 10.5 mile aspen exclosure's outside plot. (a) The exclosure was built in 1944, the year this photograph was taken. The photopoint is on the south side of the exclosure viewed north to Highway 1A. Note that the old aspen show elk bark scarring. Photo taken in November by an unknown photographer. Original on file in the Banff Warden Office. (b) That same scene 49 years later. The exclosure fence has been replaced at least once since the earlier photograph which explains why the location of the fence posts is different in the two photos. Nevertheless, the change is striking. Aspen suckers outside the exclosure have been suppressed by repeated ungulate browsing while those inside have developed into mature trees. There are also major differences in understory species composition. Shrubs dominate inside but have been suppressed outside where they are repeatedly browsed by elk. The regenerated aspen lack bark damage except for normal branch scars. August 1993 photo by Charles Kay (No. 3726-36).



a.

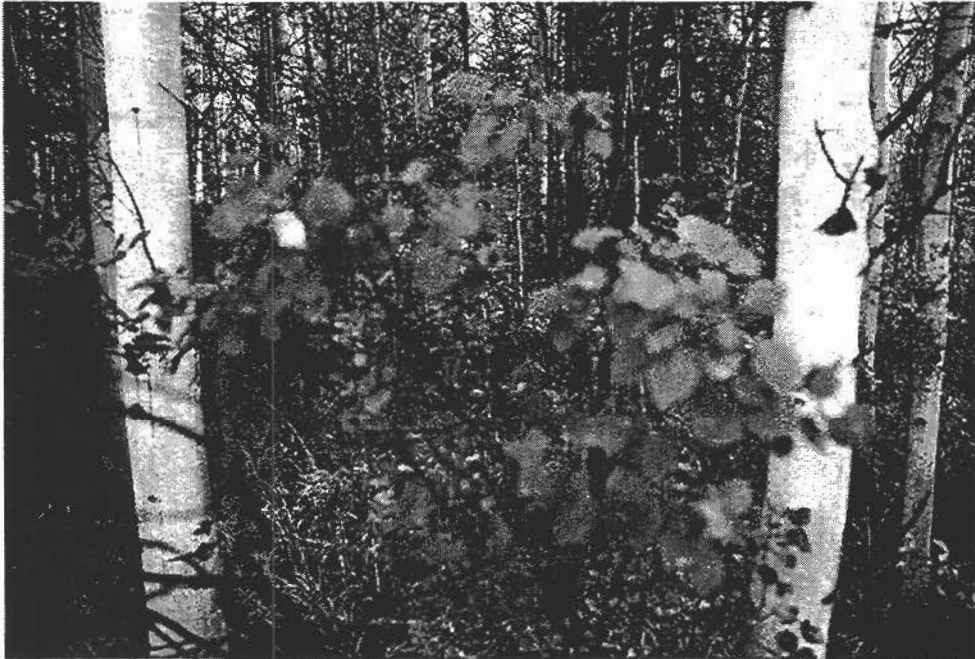


b.

Figure 6.6. Repeat photoset of Banff's 10.5 mile aspen exclosure's inside plot. (a) This photograph was taken in 1944, the year the exclosure was constructed. The photopoint is on the south fenceline viewed north into the exclosure — Highway 1A is visible in the background. Note that the old aspen show elk bark scarring. Photo taken in November by an unknown photographer. Original on file in the Banff Warden Office. (b) That same scene 49 years later. Aspen suckers inside the exclosure have developed into mature trees. With protection, the original grass understory has been replaced by shrubs and other plants elk prefer. The regenerated aspen show branch scars but lack other bark damage. August 1993 photo by Charles Kay (No. 3726-26).



a.



b.

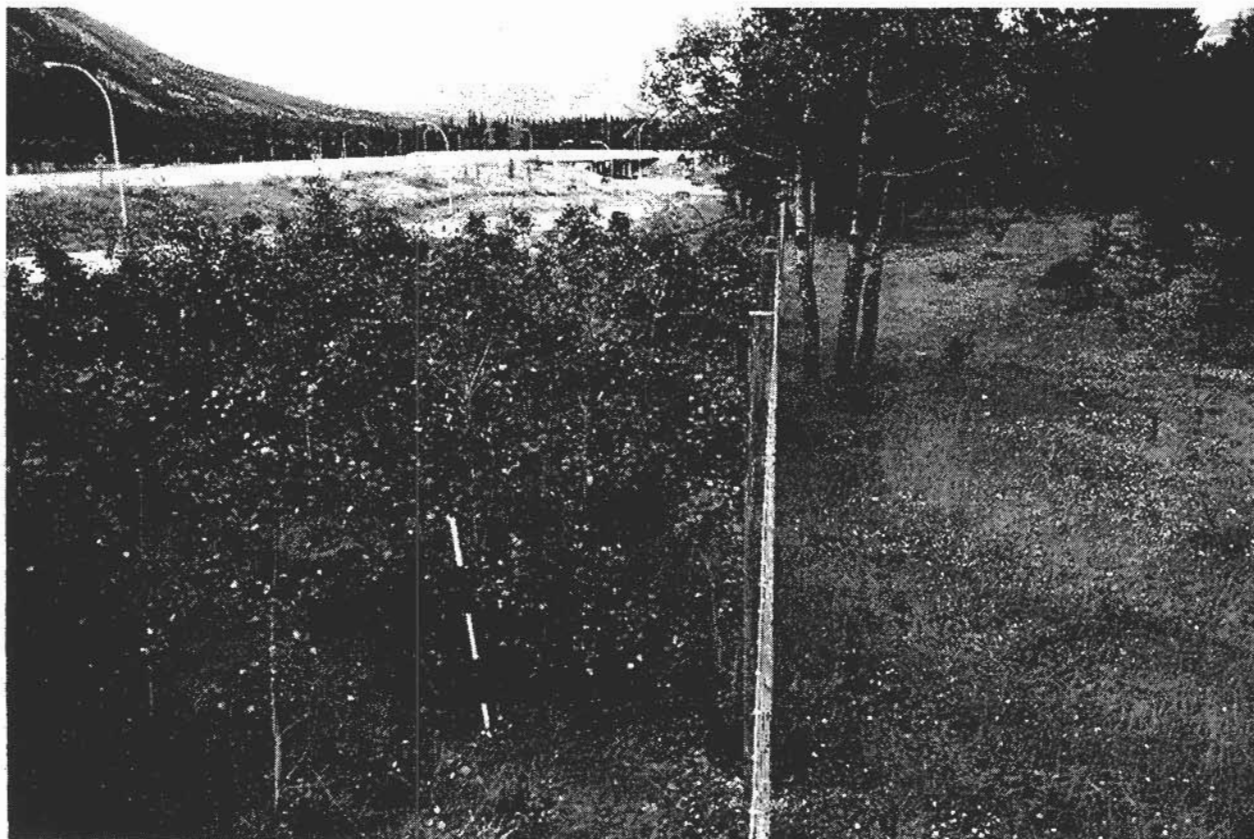


Figure 6.7. Aspen inside and outside the fenced Trans-Canada right-of-way in Banff's Bow Valley. Shown is the Minnewanka interchange viewed east. Since this area was fenced in the mid-1980s, aspen within the highway right-of-way (photo-left) have been able to successfully regenerate while those exposed to elk (photo-right) have not. Survey pole (2 m) for scale. August 1993 photo by Charles Kay (No. 3716-31).

Bison Paddock

As noted in Chapter 1, the Bison Paddock north of Banff townsite has been fenced since the early 1900s. The fence keeps bison in and generally prevents other ungulates, such as elk, from entering (Kopjar 1987). Because bison do not normally browse aspen (Telfer and Cairns 1979, Cairns and Telfer 1980, Hudson and Frank 1987), stands within the paddock were able to regenerate (Cowan 1947a). Much of the aspen within the paddock is multi-aged and conifer invasion is generally absent, two indications of stable or climax aspen communities. In fact, this is one of the few locations in Banff's Bow Valley that supports climax aspen.

With twinning of the Trans-Canada Highway during the mid 1980s, however, concerns grew that wildlife movements were being disrupted by the Bison Paddock and the newly fenced highway. So in 1985, a portion of the paddock fence nearest the Trans-Canada Highway was removed. Bison no longer have access, but elk and other ungulates now freely use the area. The impact on the formally protected aspen has been dramatic. Within a short time, elk browsed-off all the aspen's lower branches creating a visible browse-line or highline (Kay et al 1994:6-32 to 6-33). The elk also eliminated new aspen regeneration and began to bark scar the older trees. In short, elk initiated the process of aspen decline seen throughout the Bow Valley.

Other Aspen Exclosure Studies

Mueggler and Bartos (1977) reported that shrubs increased inside two, three-part aspen exclosures in southern Utah where mule deer and cattle were the primary herbivores. They concluded that

... the most striking difference in understory attributable to animal use was the great reduction in total shrubs ... After 41 years, the ungrazed area at Grindstone Flat produced almost 10 times more shrubs than the area grazed by both cattle and deer and over three times more than that grazed just by deer. The graminoids increased under grazing at Grindstone Flat ... [p. 13].

Aspen protected from all grazing developed multi-size-class stands while those outside did not.

Coles (1965:38-41) measured the age structure of aspen communities inside and outside a three-part exclosure in central Utah. Where all ungulates were excluded, aspen were multi-aged. Where cattle were excluded but mule deer were not, few new stems had grown taller than 2 m. However, "Damage to aspen reproduction was even greater on the open plot grazed by both deer and cattle" (Coles 1965:40). Not only did cattle consume some of the aspen, but "an indirect effect of cattle grazing appeared to be the destruction of desirable game forage which forced game to utilize aspen [more heavily]" (Coles 1965:56).

Milner (1977) measured aspen communities inside and outside four exclosures in Alberta's Elk Island National Park where elk and moose are the major ungulates. Inside each exclosure, aspen "attained a greater basal area, height and DBH class" than on outside plots (p. 52). Moreover, "Regeneration of the tree structure was restricted in unprotected areas ... [and] shrub height and diameter class were greater in the exclosures" (pp. 52-53). Highly palatable shrubs increased significantly inside the exclosures. That is to say, ungulate browsing prevented aspen regeneration and favored grasses over shrubs.

Gysel (1960), Olmsted (1977), Hart (1986), Stevens (1980), and Hess (1993) reported on aspen exclosures in Colorado's Rocky Mountain National Park where elk and mule deer are the primary ungulates. In three out of four exclosures, aspen developed multi-aged stands while those outside did not. In the fourth,

aspen was completely replaced by conifers (Hart 1986), but conifers did not establish in the other exclosures (Olmsted 1977:27). Inside the three exclosures, aspen spread into and replaced grasslands while outside, grazing changed aspen communities into grasslands (Gysel 1960, Stevens 1980, Hart 1986). Shrubs were more common inside the exclosures than out (Stevens 1980). A temporary reduction of elk numbers in Rocky Mountain National Park allowed some aspen stems to escape browsing and to grow into larger size classes (Olmsted 1977, 1979).

Kay (1990:84-122) measured 14 aspen containing exclosures in the Yellowstone Ecosystem where elk comprise 80% of the ungulate community. He found that all aspen stands protected from ungulates successfully regenerated and developed multi-age structures. He also found that repeated ungulate use had completely changed understory plant communities. Inside exclosures, shrubs and palatable forbs dominated, while grasses were a minor component. Conversely outside exclosures, aspen understories were dominated by non-native grasses resistant to grazing, while shrubs and palatable forbs were rare. In the absence of grazing, Yellowstone's aspen exhibited multi-age structures and understory species compositions of climax communities, while outside the exclosures, aspen displayed all the characteristics of grazing disclimaxes and retrogressive plant succession. Moreover, few exclosures had been invaded by conifers.

So, aspen exclosure studies throughout the western United States and Canada show that, in general, protected aspen will successfully regenerate without disturbance while outside, ungulate browsing eliminates sucker height growth and prevents aspen regeneration. Ungulates also have a major impact on understory species composition. Repeated browsing and grazing tends to eliminate shrubs, especially the more palatable species, while favoring the growth of unpalatable forbs and less palatable grasses. Browsing may also promote conifer invasion. Exclosures also demonstrate that climatic variation has had little effect on aspen communities compared to ungulates. Since the climate is the same on both inside and outside plots, its influence is constant. The more profuse vegetation inside the exclosures itself alters the microclimate, but that is an incorporated variable caused by the plants' response to elimination of ungulate browsing, not the cause of the vegetation's response. Such microclimatic conditions would prevail in any aspen stand not subject to heavy ungulate use, whether in an exclosure or not.

Aspen Burns

As noted above, much of the aspen in Banff National Park is "seral" and will be replaced by conifers unless the stands burn. After fire kills the overstory trees, aspen stands usually produce an abundance of new suckers from their soil-protected roots (Peterson and Peterson 1992, 1995; Shepperd 1993; Shepperd and Smith 1993). Post-fire sucker densities commonly range from 10,000 to over 200,000 stems per ha (Schier et al. 1985). Moreover, it has been suggested that burned aspen stands will be able to successfully regenerate despite ungulate browsing. For instance, U.S. Park Service biologist Houston (1982:127) claimed that "Data from [Yellowstone Park's] northern range and adjacent areas showed that aspen often reproduced successfully when burned in the presence of ungulate populations." While Despain et al. (1986:107) added that "Data from some locations on [Yellowstone's] northern range have proven that aspen, when burned, has actually regenerated despite heavy elk use." Gruell and Loope (1974:19-20) and Gruell (1980a:2) contended that aspen stands burned in Wyoming's Jackson Hole were also able to regenerate successfully despite heavy browsing. Others, however, have reported that although fire increased the number of aspen suckers, elk browsing eliminated incremental height growth after the first summer (Basile 1979; Bartos and Mueggler 1979, 1981; Bartos et al. 1991, 1994; Walker 1993).

Under Parks Canada's prescribed fire program, the agency burned six areas in Banff National Park that contained aspen to see, in part, if those stands could successfully regenerate under present conditions.

Burns were conducted in 1983, 1988, 1990, 1992, and 1993 (Kay et al. 1994:6-38). Unfortunately, data were not collected on sucker densities or growth immediately after any burn. As outlined in Chapter 1, however, we measured aspen regeneration on these burns during August 1993.

Two Jack

A small area (17 ha) near Two Jack Lake in the Bow Valley east of Banff townsite was burned in September 1983. This was the first prescribed fire in the park and it burned an aspen stand that had been heavily invaded by conifers. Ten years after this area burned, aspen suckers averaged 1,300 stems per ha and had a mean height of only 23 cm (Kay et al. 1994:6-40). All stems more than one year old had been repeatedly browsed and elk use on this site has suppressed aspen regeneration (see Figure 6.8). Spruce seedlings averaged over 19,000 per ha, and this area will revert to a spruce forest under present conditions.

Upper Minnewanka

Near the head of Lake Minnewanka, 1,200 ha was burned in April 1988, including several aspen stands. In 1993, aspen suckers on the burn had a mean density of over 45,000 stems per ha and averaged 116 cm tall (Kay et al. 1994:6-42). Only 0.4% of the stems had been browsed, as few elk use this area, but 97% of the regenerating aspen were heavily infected with shepherds crook (Kay et al. 1994:6-43). The disease had killed back many of the stems and was responsible for the low mean height of the aspen suckers. The cool, wet summer (1993) apparently was very favorable to the spread of shepherds crook as aspen suckers are usually not this heavily infected (Hinds 1985).

Stems without shepherds crook averaged 206 cm tall while infected plants only averaged 114 cm (Kay et al. 1994:6-43). Some undiseased stems were over 3 m tall. Conifer seedlings were not observed on any of the aspen plots. Under present conditions, these aspen will eventually grow into mature trees.

Palliser

In 1990, 550 ha of the Palliser Range in Banff's Cascade Valley was burned by Parks Canada. The area is heavily grazed by elk and other ungulates primarily during winter, but some summer use also occurs. Three years after the fire, 100% of aspen suckers more than one year old had been browsed, and they had an average height of only 31 cm (Kay et al. 1994:6-45). Aspen suckers had a mean density of 6,868 stems per ha while spruce and lodgepole seedlings each numbered less than 1,000 per ha. Elk browsing is suppressing aspen regeneration and this burn will, in time, revert to a coniferous forest.



Figure 6.8. Aspen protected from elk at the Two Jack burn in Banff's Bow Valley. This area was burned in 1983 and elk browsing has surpassed aspen regeneration. Shown are five aspen suckers partially protected from browsing within a 1.25 m diameter wire cage. The suckers are only as tall as the wire cage (1 m), because elk consume any foliage or stems that grow above the wire. Survey pole (2 m) for scale. August 1993 photo by Charles Kay (No. 3705-10).

Lower Minnewanka

A 400 ha area on the north side of Lake Minnewanka was also burned during 1990. Although the area is only moderately used by elk and mule deer in summer and winter, few aspen suckers (mean=487/ha) were observed in 1993 (Kay et al. 1994:6-46). Our plots also contained few conifer seedlings, and of the aspen suckers more than one year old, 100% had been browsed. Apparently, there is enough ungulate use on this site to suppress aspen regeneration.

Mount Norquay

The Escargot burn (160 ha) on Mount Norquay northwest of Banff townsite occurred in May 1992. Later that summer, a 20x20 m exclosure was built in an aspen clone killed by the fire. Aspen suckers were not measured in 1992, but permanent belt transects were established inside and outside the exclosure in 1993 (see Chapter 1). This area is heavily used by elk during winter and some elk also summer near the exclosure. Suckers on protected plots had a mean density of 21,282 stems/ha in 1993 and 14,947 in 1994, a 30% decrease which may have been caused by a heavy (93%) infestation of shepherds crook in 1993. Mean height on protected plots was 53 cm in 1993 and 73 cm in 1994, an increase of 38%. Suckers on unprotected plots had a mean density of 41,185/ha in 1993 and 17,133/ha in 1994, a 58% decline due to shepherds crook and ungulate browsing as 100% of the stems were browsed each year. Mean height on unprotected plots was 30 cm in 1993 and 42 cm in 1994 (Kay et al 1994:6-48 to 6-49; and Parks Canada unpub. data). To date, shepherds crook has confounded interpretations, but elk are clearly having an impact on the unprotected suckers.

Sawback

The Sawback burn (2,000 ha) along Highway 1A west of Banff townsite occurred in May 1993 and eight permanent aspen regeneration plots were established in August of that year. After they were measured, four plots were protected inside a newly constructed ungulate-proof exclosure (see Chapter 1). Aspen suckers on newly fenced plots has a mean density of 75,015 stems/ha in 1993 and a density of 79,083 in 1994, a 5% increase. While on unfenced plots, sucker densities averaged 67,680/ha in 1993 and 43,417/ha in 1994, a 36% decline. After one year, protected suckers were also significantly taller (Parks Canada unpub data). In the past, this section of the Bow Valley supported large numbers of wintering elk but over the last 15 years that population has declined by approximately 90% due, primarily, to wolf predation (Paquet 1993). Nonetheless, the remaining elk are still limiting aspen regrowth on the Sawback burn as measured inside and outside this exclosure.

So although fire stimulated aspen suckering, burned aspen stands in Banff National Park still failed to produce new stems greater than 2 m tall due to repeated ungulate browsing. Only on the upper Minnewanka burn were aspen able to successfully regenerate because few elk use that area (Table 6.1). Evidence also suggests that a combination of fire and continued heavy elk use may actually hasten the demise of the park's aspen communities. Thus, it is unlikely that Banff's fire suppression policy alone is responsible for the decline of aspen in the Bow Valley, especially since aspen continues to flourish in the absence of fire inside exclosures and outside the park where fires have also been suppressed.

Contrary to claims made by the U.S. Park Service, there is also no evidence that fire can successfully regenerate aspen in the Yellowstone Ecosystem (Bartos et al. 1994). Kay (1990:123-140) measured 467 burned aspen communities in the Yellowstone Ecosystem and reported that most stands failed to regenerate due to repeated ungulate browsing. Only where elk populations were low did burned aspen successfully regenerate. After Yellowstone's 1988 fires, which burned approximately 30% of the aspen in the park, Kay (unpub. data) established 765 permanent plots in 131 burned aspen stands. Except where protected from elk, none of those stands have been able to successfully regenerate because elk browsing has prevented height growth. On some plots, fire plus subsequent elk browsing have completely eliminated entire aspen clones (Kay unpub. data).

Table 6.1 Prescribed fires in Banff National Park that burned aspen. Adapted from White and Pengelly (1992) and White (pers. comm. 1993).

Burn unit	Date	Area (ha)
Two Jack	Sept. 26, 1983	17
Upper Minnewanka	April 17, 1988	1,200
Palliser	Sept. 24, 1990	550
Lower Minnewanka	Sept. 25, 1990	400
Mount Norquay	May 6, 1992	160
Sawback*	May 15, 1993	2,000

*Sawback I was burned on May 20, 1986 and killed aspen that we planned to measure for this study. Sawback II and III, however, were prescribed burned in May 1993 and, unfortunately, much of Sawback I was reburned at that time. This prevented us from including Sawback I aspen in our research.

Flammability of Aspen Revisited

Although aspen is often thought of as a "seral" community that needs to burn at frequent intervals if it is to maintain its dominance or presence at a site, experience and research have shown aspen is extremely difficult to burn (Fechner and Barrows 1976, Brown and DeByle 1982, Jones and DeByle 1985, Brown and Simmerman 1986, DeByle et al. 1987, Peterson and Peterson 1992). Terms such as "asbestos type" and "firebreak" are often used to describe aspen (DeByle et al. 1987:75). Crown fires in conifers drop to the ground when they reach aspen communities and, prior to autumn leaf-fall, spread only short distances into aspen stands (Fechner and Barrows 1976:15). DeByle et al. (1987) noted that "Wild fires that had burned thousands of acres of shrubland or conifer types during extreme burning conditions usually penetrated less than 100 ft into pure aspen stands." Lightning-fire ignition rates for aspen communities are also the lowest of any forest type and overall ignition rates are less than half that for all other cover types (Fechner and Barrows 1976). DeByle et al. (1987:73) reported that at current rates of burning "it would require about 12,000 years to burn the entire aspen type in the West." While in northern British Columbia, it would now take approximately 100,000 years to burn the entire aspen type (Smith 1981:524).

Since litter rarely accumulates in aspen stands, due to relatively rapid decomposition, fires usually are carried through those communities by the current year's growth of understory species and any accumulated shrub biomass (Bailey 1986, Brown and Simmerman 1986). Moreover, understory plants must have a low moisture content if fire is to carry the stand. This happens only after aspen leaf-fall and after the understory plants have dried following a killing frost (Brown and DeByle 1982, Bailey 1986, Brown and Simmerman 1986, Peterson and Peterson 1992). These conditions usually occur in the Central Canadian Rockies only after the latter half of September or later, but precipitation during this period can curtail burning (Murphy 1985b, Bailey 1986). At best there is only a 6-week window from mid-September to early November when aspen communities can normally be burned. Due to precipitation events and especially early snowfall, in some years it may be impossible to burn aspen during fall.

In many years, though, aspen stands can be burned in early spring after snowmelt but before understory regrowth (Jones and DeByle 1985, Murphy 1985b, Peterson and Peterson 1992). Paradoxically, during the infrequent years when aspen is dry enough to burn in early spring and late fall, there are few lightning strikes and virtually no lightning-started fires in the Central Canadian Rockies (see Figures 5.5 and 5.6). So if aspen stands burned at frequent intervals in the past, as suggested by historical photographs (see Chapter 4), it is likely that many of those fires were set by Native Americans (see Chapter 5).

KOOTENAY NATIONAL PARK

Kay (1996) measured 168 aspen stands in or near Kootenay National Park and found that ungulates were also having a significant impact on those communities, especially where elk and/or moose numbers were high. South of the park in the Kootenay Valley, Kay (1996:42-47) measured logged and unlogged aspen to see if that disturbance had stimulated sucker growth and aspen regeneration (Crouch 1983, 1986; Shepperd 1993). Although logging and associated soil disturbance increased sucker densities by 60 fold (mean=291 stems/ha unlogged vs. 17,337 stems/ha logged), the logged stands were not able to successfully regenerate because virtually all the suckers had been repeatedly browsed by elk and other ungulates. A few stems, though, escaped ungulate browsing, and in only eight years, those plants attained 3 to 4 m in height, which suggests that both the site and the climate can support excellent aspen growth (Bartos et al. 1994). It

also indicates that ungulate browsing, not other factors, was primarily responsible for the inability of these stands to regenerate.

Kay (1996:97) also found a correlation between ungulate use and aspen regeneration in undisturbed stands. Where ungulate use was high, no stands were able to successfully produce new stems greater than 2 m tall, but where ungulate use was low, as measured by the mean percent aspen suckers browsed and the mean percent aspen bark damage, aspen stands successfully regenerated without disturbance (see Figure 6.9). A linear regression of the ungulate use index and aspen sapling density produced a correlation coefficient of $r^2=0.96$, which suggests a strong negative relationship between ungulate use and aspen regeneration.

Kay (1996) also found that most aspen stands in Kootenay National Park were heavily invaded by conifers, and in the continued absence of fire, will eventually be replaced by conifers. Aspen, however, is not "seral," as that term is commonly used. Campbell et al. (1994), for instance, claimed that aspen "is an early successional tree species [which] ... often occupies recently disturbed sites." This, though, is not true because aspen does not grow from seed either in the Canadian Rockies or the western United States (see Chapter 1). That is to say, if a coniferous forest is burned, aspen will not establish from seed. The only way aspen will "appear" after a burn is if it is already there; i.e. the clones are already established. By eliminating conifers and at the same time stimulating aspen growth, aspen does become more visible after fire, but only when the species is already present.

In addition, plant succession with large numbers of elk is different from succession with only a few or no elk. It is clear that many "seral" aspen stands in Kootenay National Park can produce new stems greater than 2 m tall without disturbance if ungulate browsing is low (Figure 6.9). Thus, even "seral" aspen can maintain its presence on a site while it "waits" for the next fire to remove the encroaching conifers. It is equally clear, though, that ungulate browsing has had a major impact on many of Kootenay's aspen communities similar to that reported in other national parks (Olmsted 1977, 1979; Kay 1985, 1990; Hart 1986; Hess 1993). So by limiting aspen regeneration, elk in Kootenay National Park have not only contributed to that plant's decline, but repeated browsing may also have eliminated some clones that could not "wait" for the next fire.

North of the park in the Kootenay Valley, Kay (1996:81-90) compared regeneration on 10 unlogged and 18 logged aspen stands. All unlogged aspen successfully regenerated without disturbance, as had all logged stands, but stem densities were higher in the logged areas. Mean aspen stem densities were (1) unlogged -- less than 2 m tall = 1,167/ha; greater than 2 m tall but less than 5 cm diameter at breast height (DBH) = 950/ha; 6-10 cm DBH = 433/ha; 11-20 cm DBH = 17/ha; greater than 21 cm DBH = 183/ha and (2) logged -- < 2 m = 3,288/ha; 2 m << 5 cm DBH = 6,131/ha; 6-10 cm DBH = 2,593/ha; 11-20 cm DBH = 269/ha; > 21 cm DBH = 0. Ungulate use levels were low in all stands which probably explains why these aspen regenerated. So disturbance can regenerate aspen in Kootenay, but only if ungulate use is not excessive. Aspen has not burned in Kootenay over the last 60 years, but the available evidence suggests that fire would probably not regenerate the park's aspen due to the level of elk and moose browsing that occurs, especially in the Kootenay Valley.

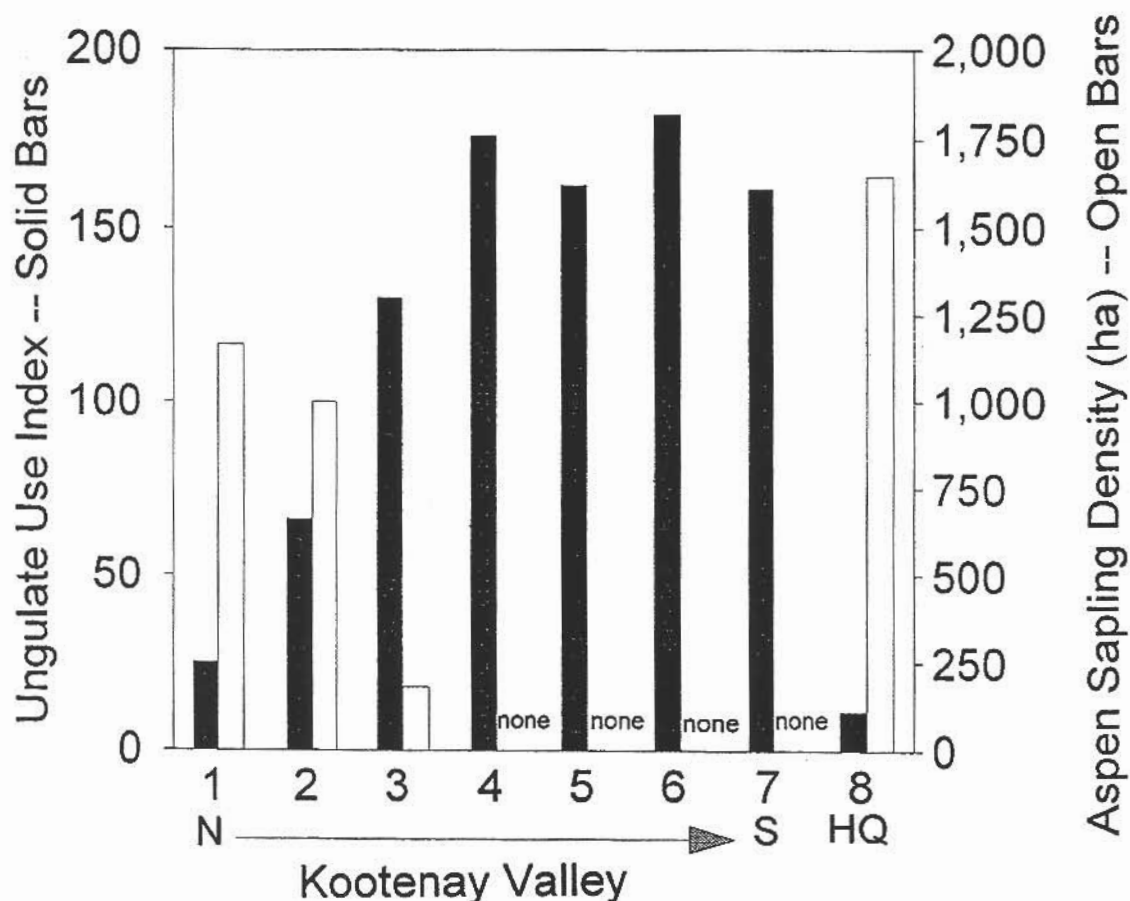


Figure 6.9. The relationship between ungulate use and aspen regeneration in Kootenay National Park. The ungulate use index (solid bars) is a combination of the mean percent aspen suckers browsed plus the mean percent aspen bark damage and is plotted with the density (ha) of aspen stems greater than 2 m tall but less than 5 cm DBH. Areas 1-7 are all in the Kootenay Valley from north to south, with one north of the park and seven south of the park while HQ is the area around park headquarters in the Columbia Valley. Where elk use is low, undisturbed aspen stands have successfully regenerated at more than 1,000 stems/ha but as ungulate use increases, stem density declines. At ungulate levels above 140 no stands have successfully produced new stems greater than 2 m tall. Linear regression – Aspen Sapling Density (ha) = $-9.36 (\text{Ungulate Use Index}) + 1567.73$ $r^2 = 0.96$. (1) Unlogged area north of the park including aspen stands KNP-131 to 133, 139, 146, 147, 153, and 156 to 158; (2) west Kootenay fire road north KNP-60 to 66; (3) west Kootenay fire road south KNP-86 to 99; (4) Highway 93 KNP-80 to 86 and 100-102; (5) east Kootenay fire road KNP-27 to 42; (6) Cross River eastside fire road KNP-11 to 18; (7) south of park KNP-7 to 10 and 51 to 54; and (HQ) park headquarters KNP-43 to 50. From Kay (1996:97).

YOHO NATIONAL PARK

Kay (1996) also measured 101 aspen stands in or near Yoho National Park. Most aspen in Yoho have been heavily invaded by conifers, and except for a handful of stands, no aspen communities have successfully regenerated in the main valley due primarily to repeated browsing. While no aspen have burned in Yoho for the past 60 years, stands outside the park have been logged over the last 10-15 years.

Approximately 5 km west of Yoho's Kicking Horse entrance, the British Columbia government cut and burned two large areas to increase forage for wintering ungulates, primarily elk (Kay 1996:121-129). The cut-blocks are on steep south-facing slopes above the Trans-Canada Highway. Prior to treatment, both areas were predominately aspen with low to moderate conifer invasion, mostly Douglas fir. The trees were felled and then burned in place. That is to say, the area was not technically logged, as none of the trunks were removed and no roads were built. Thus, unlike logging areas, there is no vehicle access to these cut-blocks. In addition, a 100 m \pm strip of vegetation was left along the highway so the cut-blocks are not visible from the pavement which prevents hunters shooting into the treated areas from the road.

At one cut-block, Kay (1996) measured four uncut aspen stands, four felled aspen stands at the edge of the cut-block, and four felled aspen stands in the center of the cut-block. The aspen regeneration pattern that emerged was most informative (Figure 6.10). Uncut aspen stands had low sucker densities and had not successfully regenerated. While 14 years after they were treated, aspen within the edge of the cut-block had slightly elevated sucker densities, but successful regeneration was absent. That is to say, repeated ungulate browsing limited aspen height growth and prevented any of those stems from growing more than 1 m tall. In the center of the cut-block, however, where browsing was less, aspen sucker densities were significantly higher and some stems had recently grown beyond the reach of ungulates.

Elk use the edges of cut-blocks more frequently than they do the centers because the animals are reluctant to venture far from cover where they can be shot (Lyon 1979; Edge and Marcum 1985; Edge et al. 1985a, 1985b; Lyon et al. 1985). While sportsmen cannot drive into these cut-blocks, the areas are still hunted because they are so close to the Trans-Canada Highway. Although there are no data on aspen sucker densities immediately following treatment, it is likely that the low sucker densities now seen around the inside edge of these cut-blocks are also a result of ungulate browsing. Initial sucker densities were probably on the order of 20,000 to 40,000 more per ha but browsing over 14 years has killed most of those stems. Other studies have shown that repeated elk use after aspen stands are burned not only leads to reduced sucker densities but may eventually lead to the loss of entire clones (Kay 1990, Bartos et al. 1994, Shepperd and Fairweather 1994).

Kay (1996:133-142) also measured logged and unlogged aspen along the Ice River south of Yoho National Park. In the unlogged stands there were no aspen suckers nor any aspen regeneration due to dense conifer overstories and thick conifer regeneration, primarily white spruce. When adjacent aspen stand were logged and burned, however, aspen resprouted profusely. Mean stem densities 12 to 14 year after logging were: <2 m = 4,313/ha; 2 m $<$ 5 cm DBH = 6,647/ha; and 6-10 cm DBH = 834/ha. Moreover, many of the regenerated stems had already reached more than 6 m in height and showed no evidence of ungulate browsing or bark damage. A network of logging roads facilitates both sport and native subsistence hunting which apparently keeps elk and other ungulates from using these cut-blocks. Clearly, aspen can regenerate in Yoho if ungulate use is low.

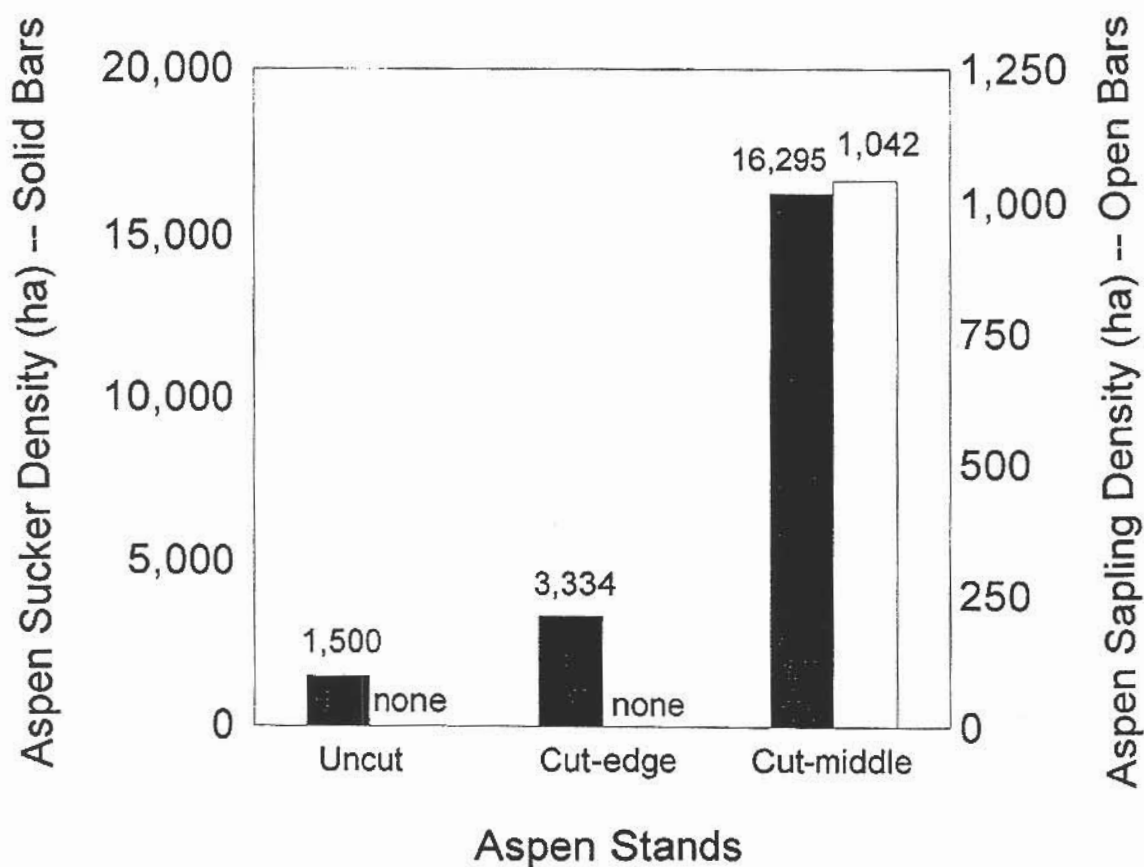


Figure 6.10. The impact of cutting and ungulate browsing on aspen regeneration west of Yoho National Park. Uncut stands had low sucker densities and no successful aspen regeneration. Fourteen years after they were treated, aspen within the edge of the cut-block had slightly elevated sucker densities but *successful regeneration was absent*. In the center of the cut-block, however, where browsing was less, aspen sucker densities were significantly higher and some stems had recently grown beyond the reach of ungulates. Adapted from Kay (1996:123).

SUMMARY AND CONCLUSIONS

So based on the data and analyses presented above, we offer the following conclusions on the condition and trend of aspen communities in Banff, Kootenay, and Yoho National Parks.

1. Aspen in the three parks is declining due to advancing forest succession and an absence of fire.
2. Aspen, though, should not be considered "seral" because it does not grow from seed. Instead, the presence of aspen indicates that historically, disturbance, primarily fire, was frequent enough to maintain the species.
3. The fire-return intervals in Banff, Kootenay, and Yoho are now longer than that necessary to maintain aspen. As fire intervals lengthen, aspen is eliminated. Noble and Slatyer (1980:16) found that a 20 to 130 year fire frequency was necessary to maintain aspen in Rocky Mountain forests. Fire cycles in the three parks are now well beyond that range (see Chapter 5).
4. Aspen is also declining due to ungulate browsing, primarily by elk. Forest succession with high ungulate densities is different than if animal numbers were lower.
5. Whether or not aspen can successfully regenerate after fire will depend on the level of post-burn ungulate herbivory.
6. Aspen is a critical indicator of ecological integrity and its decline has ramifications beyond the loss of a single species.
7. Under current conditions, aspen's position in the ecosystem will continue to diminish from historical levels, and species that depend on aspen will also decline.
8. If present trends continue, Banff, Kootenay, and Yoho will lose the aspen communities that they once contained.
9. The decline of aspen is not unique to these parks, but is also occurring in Jasper and throughout the southern Canadian Rockies and the western United States (Cartwright and Burns 1994). We believe that this decline has a common cause, namely the elimination of aboriginal land management practices (Kay 1994, 1995a; Kay and White 1995).
10. As discussed in Chapter 5, Weir et al. (1995: 276) claimed that elimination of native burning and modern fire suppression had "produced no change in fire frequency for ... Yoho National Park ... [and that] the apparent change in fire frequency ... distribution for Kootenay National Park after 1930 is not statistically significant." The aspen stand-age distribution (or more correctly, the age of the oldest aspen trees in the stands) for Kootenay and Yoho, however, does not support that interpretation (Figure 6.11). Instead, there have been virtually no stand replacing fires during the last 60 years, while in earlier times aspen stands were frequently regenerated by fire. Thus, present conditions are outside the range of historical variability; i.e. the system lacks ecological integrity.

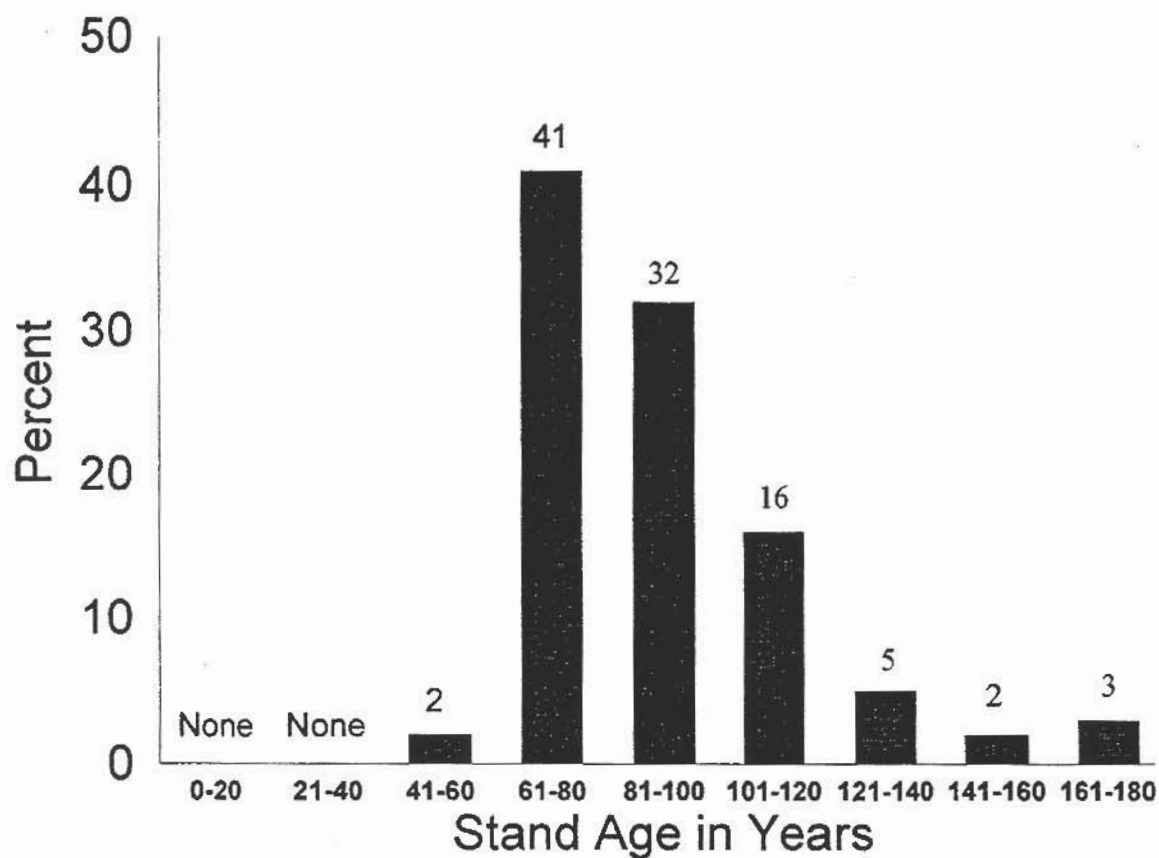


Figure 6.11. Fire initiated age classes of aspen stands in Kootenay and Yoho National Parks. Contrary to claims by Weir et al. (1995:276), fire suppression has had a dramatic impact on Kootenay and Yoho's montane forests. There have been virtually no stand replacing fires during the last 60 years while before aspen stands were frequently regenerated by fire. There are few stands with trees older than 150 years because that is near the maximum longevity of individual aspen stems. From Kay (1996:156), $n=198$. Logged aspen stands were not included.

CHAPTER 7

SUMMARY AND DISCUSSION

ASPEN

Since Banff National Park was established, aspen has declined markedly due to fire exclusion and elk browsing. Under present conditions, however, even when burned, aspen has failed to successfully regenerate due to repeated elk browsing (Chapter 6). If this trend continues, aspen in Banff's Bow Valley is unmistakably headed towards extinction except where it is protected. Since aspen in the Canadian Rockies seldom establishes from seed under present climatic conditions, it is thought that Banff's aspen clones are at least several hundred, and perhaps as much as several thousand years old. In fact, Peterson et al. (1995) classified aspen as old-growth ancient forest. Through all those centuries of climatic variation, aspen has maintained its presence via vegetative regeneration, but under park management it has declined precipitously. The same is true in Kootenay and Yoho National Parks. Clearly, something is different today than at any other time in the last 10,000 years. The very persistence of aspen in the Central Canadian Rockies over the millennia, indicates that ungulate usage, and especially elk browsing, was not as intense in the past as it is now; i.e., the ecology of aspen suggests that elk and other ungulate numbers were probably much lower in pre-Columbian times than they are at present.

The ecology of aspen also indicates that aboriginal burning may have been more important than lightning fires in structuring pre-Columbian vegetation communities throughout western North America. Historical photographs (Chapter 4) and fire frequency studies indicate that aspen communities burned at frequent intervals in Banff's Bow Valley prior to park establishment. As discussed in Chapters 5 and 6, however, aspen will carry fire only when it is leafless and when understory fuels are dry, conditions which occur only in early spring or late fall. During both those periods, however, there are few lightning strikes and virtually no lightning fires in the Canadian Rockies, something that is true throughout the range of aspen in western North America. Thus, if aspen burned frequently in the past as data suggest it did, then the vast majority of those fires were likely set by native peoples (see below).

Finally, it must be remembered that aspen communities have exceedingly high biodiversity. So, the diminution of aspen is indicative that other plants and animals have also declined, as no doubt have other ecosystem processes. The grazing-induced reduction of aspen, for instance, has probably altered soil chemistry and fertility (Cryer and Murray 1992) similar to what moose overbrowsing has done at Isle Royale National Park (see below). In a very real sense then, aspen is an indicator of ecosystem structure and function and its decline has ramifications far beyond the loss of a single species (Kay 1991a, Woodley and Theberge 1992, Woodley 1993, Woodley et al. 1993, Bernard et al. 1995, Komex International 1995).

FIRE

Repeat photographs (Chapter 4), historical observations (Chapter 2), and fire ecology data (Chapter 5) all indicate that frequent, low-intensity, fires were the norm in Banff's Bow Valley and in other montane areas of the Canadian Rockies prior to park establishment. Grasslands, open forests, aspen, and shrubfields were once common, but have now largely been replaced by conifers under 100 years of fire exclusion and fire suppression. Forests have both grown-up and thickened-up since Banff National Park was established setting the stage for high-intensity crown fires, something that rarely occurred in the past. Fire

exclusion policies, which have permitted abnormal accumulation of forest fuels, and hence increased the difficulty of fire suppression, may also have predisposed the park, and other areas in the Canadian Rockies, to larger fires than those that burned in the past.

Although this effect has been most dramatic in montane ecoregions, similar trends have occurred in the park's valley-bottom subalpine forests. Where light surface fires or small crown fires were once the rule, fires today would be much more intense and probably larger as well, especially under extreme burning conditions. Most importantly, frequent, but low-intensity fires that burned in the past created entirely different vegetative mosaics and plant communities than those that exist in the park today or that would become established if lightning fires are allowed to run their course under present conditions. In other words, the Banff of the 1880s was much different vegetatively than the Banff of today because the fire regimes are vastly different.

In addition, the available evidence suggests that aboriginal burning was once a very important part of the natural fire regime in Banff National Park and the Central Canadian Rockies. The ecology of aspen (see above) supports this conclusion, as does the pattern of burning seen in early photos, and fire history data. Since lightning strikes most often on upper slopes, the only way valleys could have burned more frequently than mountainsides in the past, as data indicate they did, was if there was additional ignition by native peoples. As indicated in the archeological and historical observations chapters, many archaeological sites and travel routes were located in montane valleys, suggesting that those areas would have been subject to a high incidence of aboriginal burning.

Patterns of aboriginal burning throughout North America and around the world plus repeat photographs and other fire frequency data all indicate that most montane prairies, meadows, and open-forests seen in the Canadian Rockies ca. 1800 were primarily the product of aboriginal, not lightning, fires. The available evidence suggests that native peoples would also have started fires in other parts of the park and that fires set in the valleys would have spread upslope and burned higher-elevation forests more frequently than lightning fires alone. That is to say, the Canadian Rockies as first seen by Europeans ca. 1800 were not as they had been created by God, but as they had been created by native peoples (see below). As indicated in Chapter 5, the cross-cultural evidence that natives used fire to enhance their hunting-gathering activities is so universal that the question should not be, "Why would native peoples have burned?" but "Why would aboriginal inhabitants not have burned?"

ELK

Repeat photographs (Chapter 4), aspen ecology (Chapter 6), historical observations (Chapter 2), and archaeological data (Chapter 3) all indicate that elk are more abundant in Banff's Bow Valley today than at any point in the past. There is no evidence that current elk densities are reflective of conditions at park establishment or in pre-Columbian times. Moreover, early photographs and fire history studies (Chapter 5) indicate that the amount of winter range available for elk in Banff's Bow Valley and other montane areas in the Canadian Rockies was much greater in the past than at present (Van Egmond 1990). Based on repeat photographs, it appears that prime elk feeding areas such as grasslands, aspen, and shrubfields have declined approximately 90% since Banff was set aside as Canada's first National Park in 1885. So if food was the only factor limiting elk numbers, as proposed by the U.S. National Park Service under its "natural regulation" program in Yellowstone (Houston 1982, Despain et al. 1986, Kay 1990), elk should have been more abundant in the past than they are today (Peck 1980, 1988; Peck and Peek 1991) – the exact opposite of the documented trend. This suggests that some factor besides food limited ungulate numbers prior to 1885.

In addition, if competition for resources (food) was the only factor that structured ungulate communities, again as proposed under "natural regulation" in Yellowstone Park (Houston 1982, Despain et al. 1986), archaeological and historical data should indicate that elk were as common in the past as they are now. Since elk are superior competitors to deer and bighorn sheep on intermountain winter ranges (Cliff 1939; Cowan 1947a, 1950; Flook 1964; Stelfox 1971, 1974, 1976), they should have outcompeted those smaller ungulates and dominated past ungulate communities as they do today. Again, that this was not the case in historic or pre-Columbian times, suggests that some factor besides food structured ungulate communities in the Canadian Rockies before the arrival of Europeans.

WOLVES

Carnivore predators are one factor that could have limited ungulate numbers in pre-Columbian times. In the early years of wildlife management, it was thought that wolves and other carnivores decimated game populations which, in part, was used as justification to eradicate predators, even in national parks (see Chapter 1). This attitude changed in the 1960s with the belief that wolves and other predators only killed the sick, the diseased, the old, and the young, but otherwise had little impact on ungulate numbers. This view is still held by many people, but long-term predator-prey studies support a different interpretation.

Recent research in Alaska, British Columbia, Yukon, Alberta, and other Canadian provinces indicates that wolves and other carnivores, more often than not, limit ungulates (Seip 1989a, 1989b, 1991, 1992a, 1992b; Messier 1989a, 1989b, 1991, 1994; Bergerud 1990, 1992; Ballard 1991, 1992; Gasaway et al. 1992; Carbyn et al. 1993; and others). These studies can be summarized as follows. (1) In many situations, wolves and other predators limit ungulate populations below the level set by food resources; that is, ungulates are not resource limited or "naturally regulated" and any compensatory response of the ungulate population to predators is not enough to offset predation losses. (2) Human predation and carnivore predation on ungulate populations are additive, not compensatory. (3) If grizzly or black bears are present, they often prey heavily on newborn and, to a lesser degree, adult ungulates. Wolf and bear predation are additive, not compensatory, and together can have a major impact on ungulate numbers. In some areas, grizzlies kill more ungulates than wolves (Gasaway et al. 1992). (4) If ungulate populations have been reduced by severe weather, human exploitation, or other causes, wolves and other predators can drive ungulate numbers even lower and maintain them at that level. This condition is commonly called a predator pit, and there is no field evidence that ungulates can escape from a predator pit even if hunting is banned, unless wolves and other predators are reduced by direct management actions; i.e., predator control. As Alaska biologists have noted, "prey [ungulate] populations can reach extremely low densities under natural conditions, contrary to the 'balance of nature' concept" (Gasaway et al. 1983:6). Throughout much of Canada and Alaska, ungulate populations are now being kept at low levels by the combined actions of carnivorous predators even in areas where they are not hunted; i.e., national parks.

Wolves and other carnivores limit ungulate numbers by reducing recruitment and increasing adult mortality, not by killing off all the game, instances of surplus killing notwithstanding. In any given year, a number of adults die from natural causes, disease, or predation. When expressed as a percentage, this is termed the adult mortality rate. In that same year, a number of calves or fawns are born, but those young also face disease, accidents, and predation, and only a few survive their first year of life to join the adult population. This is called the recruitment rate. For a stable population, recruitment, and especially female recruitment, must balance adult mortality. If recruitment is less, the population declines, and if it is greater, numbers increase (Bergerud 1990, 1992).

Wolves and other carnivores prey most heavily on young-of-the-year, which lowers the recruitment rate of the prey populations. Predators also kill a few prime-age adults. By increasing adult female mortality and at the same time lowering recruitment, carnivores can cause ungulate populations to decline. Stabilizing recruitment for caribou is about 15 female yearlings per 100 cows. Caribou herds with few predators have

recruitment rates of 20 to 40 female yearlings per 100 cows, which allow those populations to increase, while caribou herds subject to heavy predation have recruitment rates of 10 or less (Bergerud 1990, 1992). Moreover, predation has been shown to have an impact on all ungulate species from moose and bison to deer and even mountain goats (Smith et al. 1992). So predation causes ungulate populations to gradually decline over time -- wolves do not normally wipe out game herds in a single year or two.

This is what happened in Canada and Alaska (Seip 1989a). During the 1950s and 1960s, when wolf control was widespread and effective, game herds grew and the north country became known as a wildlife paradise. Government wolf control ended by 1970, and predator populations began to expand, but it took 10 years or longer before significant declines were seen in game herds. In Wood Buffalo National Park, for instance, there were approximately 12,000 bison when wolf control was terminated, but today there are fewer than 3,500 and the population is still falling. Wolf predation of calves has been identified as the primary factor responsible for that decline, as the bison are not hunted (Carbyn et al. 1993).

Similarly, Dekker (1985a, 1985b, 1989; pers. comm. 1993, 1994) has suggested that wolves are primarily responsible for the decline in elk numbers recently seen in Jasper National Park. Since wolves returned to Jasper, occupied elk winter range has decreased by 50% and elk appear to be concentrating near Jasper townsite and heavily traveled park highways as a strategy to avoid wolf predation. In the Bow Valley west of Banff townsite, wolves appear to be having a significant impact on elk numbers by limiting calf survival (Paquet 1993). While elk in this section of the Bow Valley are declining, those which occupy Banff townsite and surrounding developed areas are increasing. Elk in town have high calf survival because wolves and other predators avoid developed areas (see Chapter 1). Recently, wolves began to travel and den east of Banff townsite and studies are in progress to determine what impact wolf predation will have on elk in that area (Paquet 1993).

Across Canada and Alaska, moose and caribou populations not subject to heavy predation have densities ten times greater than populations where carnivore numbers are high (Bergerud 1990, 1992; and others; see Table 7.1). The presence of large numbers of carnivores also reduces the numbers of ungulates available for human hunters by up to 90% or more. As in the case of Wood Buffalo National Park, wolves alone can completely eliminate any "surplus" ungulates that would otherwise be available for human consumption. Moreover, if carnivore predators can limit ungulate numbers, and if they are less efficient predators than Native Americans, as argued below, then it is easy to see how aboriginal peoples could have had a major impact on pre-Columbian ungulate populations.

Predator-prey models have also been developed in which carnivore and human predation act in concert on ungulate populations (Haber 1977, Walters et al. 1981).

Table 7.1. The impact of carnivore predation on caribou populations in Canada and Alaska. In eastern Canadian forests where caribou have no effective anti-predator strategy, wolves can take caribou populations to very low levels especially in areas where wolves have alternative prey such as white-tailed deer. By dispersing to high elevation areas to calf, mountain caribou avoid some of the effects of wolf predation, but wolves still have a significant impact on those herds. By migrating long distances, though, caribou can avoid most impacts of carnivore predation but those populations still have lower densities than herds without predators. Long distance migrations probably evolved, primarily, as a strategy to avoid predation, not as a strategy to secure additional resources (food) (Bergerud 1990, 1992; Seip 1991; Crete and Huot 1993:2295). Mean caribou densities from Seip (1991:47).

Caribou population	Predation intensity	Mean caribou density no./km ²
A. Predators absent	None	7.45
B. Migratory herds	Low	1.08
C. Mountain herds	High	0.15
D. Eastern forest herds	Extreme	0.03

Computer simulations with these models have shown that small amounts of human predation added to wolf-bear-ungulate systems can cause the virtual collapse of both ungulates and wolves, even if humans are limited to killing only males (see Figure 7.1). That is to say, the combined action of hunting and carnivore predation on a common ungulate prey is additive and synergistic, not compensatory. So if Native American hunters even slightly lowered ungulate numbers, carnivores alone could continue to drive prey numbers lower, and keep those herds from recovering. Carnivore predation not only greatly complicates any harvest system, maximum sustained yield or otherwise, but it also probably precluded Native Americans from developing specific practices to conserve ungulates (Kay 1994, 1995a).

Now, some people cite Michigan's Isle Royale National Park as an example of where large numbers of moose and wolves live in apparent harmony (Mech 1970, Peterson 1977, Peterson et al. 1984, Peterson and Page 1988). They also cite Isle Royale as proof that wolves have no effect on ungulate numbers. This, however, is incorrect because Isle Royale is not representative of predator prey systems throughout North America. Moose densities on Isle Royale are ten times higher than anywhere else in Canada where moose are subject to carnivore predation (Messier 1994).

First, of all North American ungulates, moose is the most difficult species for wolves to kill. If they have a choice, they will usually kill any ungulate other than moose. So, the impact of wolves on Isle Royale's moose is less than if other ungulates inhabited the island. On islands off the Alaskan coast, for instance, introduced wolves killed-off all the deer (Merriam 1964, Klein 1970). Second, there are no bears on Isle Royale. Again this is not comparable to mainland situations because, as noted above, it is generally the combined effect of wolf and bear predation that limits ungulate populations. In other words, where black and/or grizzly bears are common, as in the Canadian Rockies and across much of Canada, the Isle Royale situation simply does not apply.

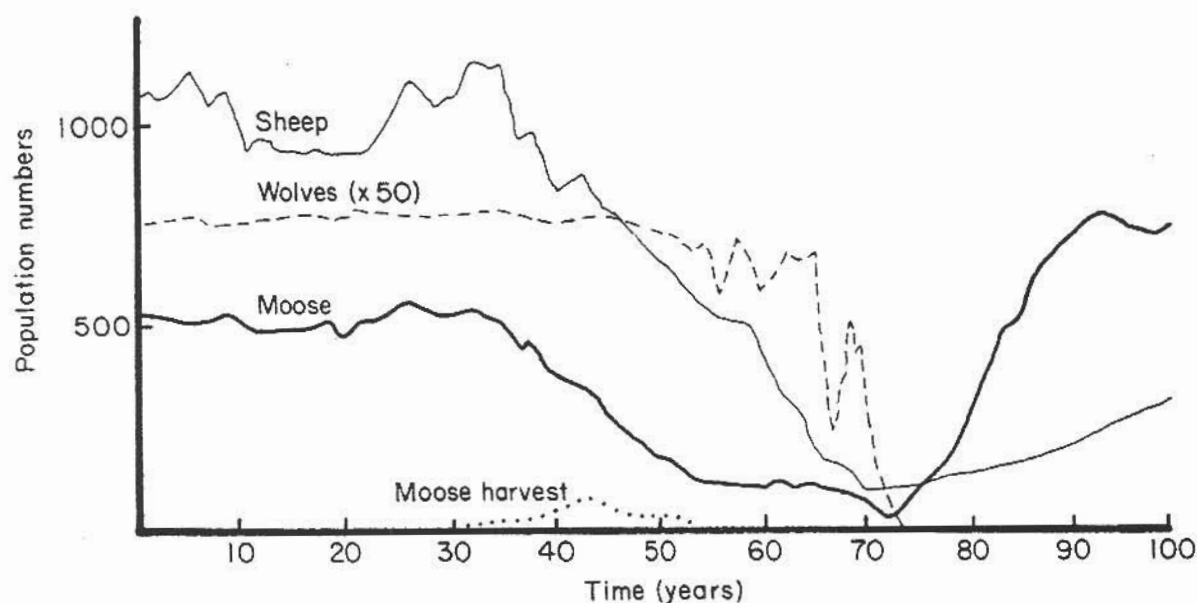


Figure 7.1 Model of Alaskan wolf-ungulate interactions simulated under circumstances in which human harvest of moose triggered a decline in both predator and prey. Without hunting, wolves, moose and Dall sheep (*Ovis dalli*) numbers are low, but relatively stable. The addition of a small amount of human moose harvest, however, destabilizes the entire system. Even after hunting is halted, wolves continue to drive the moose population downward. Wolves then switch to Dall sheep and drive those numbers down as well. In this simulation, wolves go extinct before they can kill the few remaining ungulates, allowing prey populations to recover. This would not be the case, though, if non-ungulate foods allowed humans to continue to prey on the ungulates (see Chapter 3 and below) or in an open system where wolves could recolonize the area. Grizzly bear predation on newborn moose calves, and to a lesser extent adults, is also important in this system, but that factor was not modeled separately. Instead, grizzly predation was included in calculation of moose survival rates internal to the model. Adapted from Haber (1977) and Walters et al. (1981).

Third, as an island in Lake Superior, there is no immigration of wolves to Isle Royale. Moose first colonized the island in the 1920s and a single pair of wolves arrived during the 1950s, but since that time no other wolves have reached the island (Wayne et al. 1991). Lake Superior seldom freezes and Isle Royale is 30 km from the mainland. Without immigration, when wolf numbers fall as the most vulnerable moose are killed-off, the moose population rebounds faster than the wolves can recover. This allows the moose to "get ahead" of the wolves, something that does not happen in other areas. On the mainland, lone wolves and dispersing animals quickly reoccupy any area vacated by other wolves. This keeps wolf numbers high and allows those predators to exert a significant influence on their prey. This island effect also probably explains why wolves apparently have little impact on ungulate numbers in Canada's Riding Mountain National Park (Carbyn 1974b, 1980). Riding Mountain is now surrounded by a sea of agricultural development, as well as, people who kill wolves that leave the park. In essence and in fact, Riding Mountain is now an island.

Finally, wolves and moose on Isle Royale do not represent some idyllic "balance-of-nature", instead that national park exhibits signs of ecological degradation. Overgrazing has eliminated most understory shrubs and aquatic plants that moose prefer (Murie 1934, Hansen et al. 1973, Krefting 1974, Aho and Jordan 1979). Despite wolves, moose overbrowsing is so severe that even common tree species are declining (Brander 1986, Risenhoover and Mass 1987, Brander et al. 1990). By eliminating deciduous trees, like aspen, and at the same time promoting the dominance of unpalatable species such as spruce (*Picea glauca* and *P. mariana*), moose have changed not only plant species composition but soil chemistry and soil fertility as well (Pastor et al. 1987, 1988, 1993; McInnes 1992; Pastor and Naimann 1992). Clearly, moose overbrowsing/overgrazing has altered the ecosystem over the entire island. Archaeologically and historically there is no evidence that moose inhabited Isle Royale before the 1900s. Any moose that reached the island in pre-Columbian times would soon have fallen prey to Native Americans who, at least seasonally, inhabited Isle Royale.

HUMANS

Archaeological data indicate that Native Americans made extensive use of Banff National Park and surrounding areas for at least the last 10,000 years. The Canadian Rockies were not a cultural backwater uninhabited by native peoples, as some people have suggested. Instead, the mountains, foothills, and the Columbia Trench have always been home to Native Americans — a home that they modified to suit human needs. We have already discussed the impact aboriginal burning had on Banff and the Canadian Rockies. By repeatedly firing the vegetation, Native Americans not only structured plant communities but they created many of the landscapes viewed as "natural" today.

Writers have long recognized, though, that Native Americans lacked immunological resistance to epidemic and endemic European diseases and that many epidemics reduced aboriginal numbers by 50% to 90% at each passing (Cook 1939, Stearn and Stearn 1945, Boyd 1985, Cook and Lowvell 1992, and others). Only recently, however, has it been shown that many epidemics swept in advance of even the earliest explorers. Dobyns (1983) postulated that Native American populations were severely reduced 100 to 200 years before the first European chroniclers. Ramenofsky (1987), who tested Dobyns' hypothesis against the archaeological record, found that the tribes along the middle Missouri River were decimated by European disease ca. 1600 A.D., two hundred years before the arrival of Lewis and Clark (1893). Campbell (1990) tested Dobyns' hypothesis against the archaeological record of the Columbia Plateau and concluded that European disease decimated those populations ca. 1550 A.D. So, it is likely that these earliest epidemics also struck native populations across western Canada. Taking this factor into consideration, several authors have recently revised pre-1492 aboriginal population estimates for North America upwards by as much as ten-fold, to 100 million or more.

Clearly, North America was not a "wilderness" waiting to be "discovered" but instead was home to tens of millions of aboriginal peoples before European-introduced diseases decimated their numbers. Prior to European arrival, the continent was owned, used, and modified by native peoples (Denevan 1992, Gomez-Pompa and Kaus 1992, Simms 1992, and others). The idea that North America was a "wilderness" untouched by the hand of man prior to 1492 is a myth, a myth created, in part, to justify appropriation of aboriginal lands and the genocide that befell native peoples (Bowden 1992, Stannard 1992).

The anonymous Indian, on being asked what it was like to live in a wilderness and, replying, said that it was not a wilderness until Europeans came, was both figuratively and literally correct in that the regions most intensively exploited by Indians were no less cultural artifacts than were the managed forests of the Old World. [Lewis 1990a:223].

There is also an associated, extremely romanticized belief that "primitive people" live, or at least once lived, in some undefined condition of "harmony with nature," engaged in environmentally benign ways of exploiting resources which either could not or would not have allowed people to alter "what nature provides." However, among a growing number of ecologists, foresters, parks officials, and others there is the recognition that the "wilderness" found by Europeans – what Longfellow erroneously referred to as the "forest primeval" – was, in most parts of the continent and in varying degrees, a human artifact. [Lewis 1993:395].

The most damaging misconception that Europeans brought with them to [the Americas] was the belief that they were entering a "natural wilderness." [Shipek 1993:388].

Another common misconception is that Native Americans were original conservationists who were too wise and knowledgeable to overexploit their environment. This belief has a long history in the popular press and can be traced to Rousseau's concept of the "noble savage." Diamond (1988, 1992), Butzer (1992), Denevan (1992), Heinen and Low (1992) and others, however, have concluded that for humans conservation is seldom an evolutionary stable strategy. That is to say, conservation will not be favored by natural selection or evolution. More specifically, Kay (1994, 1995a) postulated that Native Americans had no effective practices to conserve ungulates. Instead, all native hunters are essentially opportunistic and tend to take high-ranking ungulates regardless of the size of the prey populations or the likelihood of their becoming extinct. Native Americans had no concept of maximum sustained yield and did not manage ungulate populations to produce the greatest offtake (Kay 1994, 1995a). As shown in Figure 7.1, human predation and predation by carnivores are additive and work in concert to reduce ungulate numbers. Moreover, competition from carnivores tended to negate any possible conservation practices.

Kay (1994, 1995a) also concluded that Native Americans were much more effective predators than wolves or other carnivores. Because they could prey switch to small mammals, vegetal foods, and fish, Native Americans, unlike purely carnivorous predators, could take their preferred ungulate prey to low levels or extinction without having an adverse effect on the human population. Contrary to the notion that Native American diets were primarily meat, anthropologists have long noted that native peoples should more appropriately be called gatherer-hunters for, except in the Arctic and perhaps on the plains, vegetal foods and fish comprised 80% to 90% of aboriginal diets.

Kay (1994, 1995a, in press a) proposed that native hunting was once so intense that it limited the numbers of elk and other ungulates throughout much of western North America. While the demonstrated lack of elk in U.S. and Canadian archaeological sites (Chapter 3) may at first appear to negate the Aboriginal Overkill hypothesis, in fact, the opposite is true. Optimal-foraging theory predicts that high-ranked items, like elk, are more susceptible to overexploitation than low-ranked items. According to optimal-foraging models, high-ranked items will seldom appear in the diet if they are being overexploited (Smith 1983, Stephens and Krebs 1986, Smith and Winterhalder 1992). So, ungulate species unearthed from archaeological sites with the lowest frequency, such as elk were probably subjected to extreme overexploitation. The highly fragmented nature of bone recovered from Canadian and U.S. intermountain archaeological sites (see

Figure 3.1), also suggests that all species of ungulates were rare in pre-Columbian times, at least in the mountains.

While this view of native hunters may be new, it is not unique. Large concentrations of grizzly bears on Alaskan salmon streams, for instance, are thought by many to be "natural" and to represent the epitome of "unspoiled wilderness." Yet Birkedal (1993:229) pointed out that this "'bear heaven' is not a creation of Mother Nature, rather, it is a cultural artifact of [Park Service] management" that has excluded native people from the ecosystem. Bears were rare or absent from these streams prior to the 1900s because aboriginal hunters simply killed them off—even natives armed with no more than spears and hunting dogs. On many of the most productive salmon streams there are dense concentrations of archaeological sites dating back at least 6000 years. To aboriginal hunters, bears were simply large packages of fat meat that they killed at will. This also explains why grizzlies usually defer to humans and why grizzlies den in such inaccessible areas in the Canadian Rockies and other ecosystems. These are simply evolutionary responses to 10,000 plus years of intense native hunting. Bears that did not avoid humans or that dened in accessible areas were simply killed-off, leaving only the most cautious and wary individuals to perpetuate the species.

Humans and animals in Alaska shared a predator-prey relationship for at least 14,000 years, and this fact could have profound ... implications for [park] management today. The "natural" park ecosystems of Alaska may indeed be "unnatural" artifacts of the recent past when long-standing predator-prey adaptations between humans and other animals were irrevocably broken. [Birkedal 1993:228].

This ... examination of human-bear relationships suggests that the U.S. National Park Service could profitably adopt a more historical perspective in wildlife and ecosystem management, one recognizing that ... Native Americans were part of, not extraneous to, the premodern ecosystems If we are not careful and fail to place these ecosystems in a long-term, comparative historical perspective we may end up blindly perpetuating what are truly "unnatural" situations in nature. [Birkedal 1993:223].

Similarly in Australia, Flannery (1990, 1994) reported that aboriginal people had a profound influence on that continent's ecosystems prior to European contact. Except for areas that were too wet to burn and deserts that were too dry to produce enough vegetation to support fire, virtually all Australia was a pyroclimax maintained by high-frequency but low-intensity native-set fires. When aboriginal burning stopped, high-intensity lightning fires became more common and burned larger areas than at any time in the past. This not only completely changed plant communities, but also led to increased soil erosion, at least in some areas. In addition, aboriginal hunting was so intense that the first Europeans to cross Australia found very little wildlife—large numbers of kangaroos and other species became common only after native populations were decimated by European diseases and other factors.

In Chapter 2, we presented data from journals written by the first Europeans to explore the Canadian Rockies. In our discussion of those observations, we noted that when David Thompson first entered the North Saskatchewan and Athabasca Valleys he met no Native Americans and reported little sign of aboriginal peoples. We attributed this to either European-introduced epidemics which decimated native populations and/or a buffer zone effect as advancing Piegan pushed earlier inhabitants west of the mountains. We suggested that this temporary absence of native people probably explained why David Thompson saw more game in those areas than later explorers.

It must be remembered, however, that even the earliest chroniclers did not see the country as it was prior to European influence. If aboriginal hunting once limited ungulate numbers and distribution, and if native populations were decimated by European diseases 100 to 200 years before actual face to face contact, then game populations would have increased. In other words, the first explorers may actually have seen more game than what existed in pre-Columbian times because European disease decimated native

populations in advance of actual contact. Rostlund (1957, 1960), for instance, noted that bison moved into the southeastern United States only after European diseases decimated aboriginal populations. Until then, native hunting was so intense that it kept bison out, although the region always contained habitat suitable for bison.

Similarly, Kay (1994, 1995a) concluded that native populations supported by abundant alternative foods like salmon, precluded the formation of large herds of ungulates in the Columbian Basin, and kept moose populations exceedingly low throughout western North America including much of Alaska. This may also explain why bison that apparently reached the Kootenay Valley (see Chapter 3) failed to prosper, and why there were so few moose in British Columbia at historical contact. Despite European diseases, native populations were still apparently of sufficient size to keep moose from increasing. It was only after Europeans physically occupied British Columbia and displaced native groups that moose populations irrupted.

Kay (1994, 1995a), however, noted that there were exceptions to aboriginal overkill. According to predator-prey theory, prey populations will increase if they have a refugium where they are safe from predation (Taylor 1984, and others). So, ungulates that could escape aboriginal hunters in time or in space should have been more abundant. Moreover, refugia do not have to be complete to be effective. Partial refugia will also enable prey populations to survive.

Unlike other areas of the West, archaeological sites on the Washington, Oregon, and British Columbia coasts usually contain elk remains. Of the ungulate bones unearthed at those sites, elk comprise about 50% (Kay 1990). Heavily timbered coastal forests provided some refuge for elk because those communities were usually too wet to burn. Although, native peoples did employ fire, they could not open-up the country and make hunting easier to the same extent that they did in other ecosystems. Because coastal regions receive little snowfall, aboriginal hunters could also not kill animals by chasing them into deep snow as natives commonly did elsewhere.

Early explorers reported that elk were also common in California's Central Valley along the Sacramento and San Joaquin Rivers (McCullough 1971). When disturbed, though, those elk would flee into swamps where they could not be hunted. This behavior was observed by John Work (1945) who led a Hudson's Bay Company fur brigade through California in 1831-1832.

The people are rather short of food and no more can be got, the hunters are not able to kill the elk. There are a good many along the marshy borders of the lake but they seldom venture out on the hard ground and when any of them happen to be found out, they fly immediately in among the water and bulrushes where they cannot be pursued. [p. 62].

Work noted, however, that when flood waters forced elk from the swamps, they were easily killed by natives, who simply ran the animals down and killed them with knives or spears. Without refuge provided by the tule swamps, large numbers of elk would not have survived in California's Central Valley.

Physical refugia also explain why bighorn sheep were relatively more abundant than other ungulates in the Canadian Rockies prehistorically (Chapter 3) and historically (Chapter 2). By fleeing into cliffs, bighorn sheep not only avoided most carnivorous predators, like wolves, but they also had at least a partial refugium from native hunters armed with spears, spear-throwers, or bows and arrows. This anti-predator strategy worked well for thousands of years until Europeans arrived with firearms that killed at a greater distance.

Herds of bison on the Great Plains and caribou in the Arctic had no physical refugia, instead, they had refugia in time. By undertaking extensive migrations, bison and caribou were able to outdistance most of their human and carnivorous predators. Wolves with young, for instance, simply could not keep pace or even follow the migrating herds (Bergerud 1990, 1992; Crete and Huot 1993). The same was true of humans who

had to transport children, as well as their possessions. Caribou which migrate long-distances today have densities ten times greater than nonmigratory populations (Bergerud 1992, Crete and Huot 1993).

Similarly, research in Africa's Serengeti has shown that resident ungulates are limited by predators while migratory animals are not (Fryxell et al. 1988) and that Serengeti ungulates migrate primarily to avoid predation, not to secure food (Crete and Huot 1993:2295). This probably was also true in North America. That is to say, bison and caribou would have been much less abundant if they had not migrated long distances. Migration not only took bison and caribou beyond the reach of most humans, but the Great Plains and the Arctic tundra provided few alternative foods that could sustain aboriginal populations when ungulates migrated. Tribal boundary or buffer zones also provided refugia for some ungulate populations. Without refugia, few ungulates would have been able to withstand the onslaught of human predators (Kay 1994, 1995a, in press b).

By repeatedly firing the vegetation and by limiting ungulate numbers below the level set by available food or carnivore predation, Native Americans were the ultimate keystone species that structured entire ecosystems, including the Canadian Rockies, in pre-Columbian times and even into the early historical period. Systems with native peoples are entirely different from those without aboriginal populations (Western and Gichohi 1993, and others). Setting aside an area as wilderness today will not preserve some remnant of the past but instead create conditions that have not existed for the last 10,000 years. A "hands-off" or "natural regulation" let-nature-take-its-course approach by modern land managers will not duplicate the ecological conditions under which those communities developed. If aboriginal burning and native predation created those ecosystems, then the only way to maintain "natural areas" today is to understand the significance of aboriginal processes and to maintain those influences where required (Wagner and Kay 1993, Budiansky 1995, Kay 1995a, Wagner et al. 1995).

MOUNTAIN BISON

While elk are the dominant ungulate in Banff's Bow Valley and other areas of the Canadian Rockies today, archaeological evidence (Chapter 3) and early historical observations (Chapter 2) suggest that bison were once relatively more common than elk. Archaeologically, bison have been recovered from the Bow, Red Deer, and North Saskatchewan Valleys, and David Thompson observed bison on Kootenay Plains and in Jasper National Park's Athabasca Valley. It has been suggested that these were mountain or wood bison (*Bison bison athabascae*) which maintained populations separate from bison (*B. b. bison*) found on the plains (Meagher 1973, Kopjar 1987, and others). The available data, however, does not support this interpretation.

First, there is no morphometric evidence that mountain or wood bison is a valid subspecies (McDonald 1981). Geist (1991) reported that wood bison was an ecotype not a subspecies, a conclusion supported by recent genetic analyses (Bork et al. 1991, Strobeck 1993). This suggests that whatever bison were in the mountains in pre-Columbian times or historically, they were not isolated from bison on the Canadian prairies. In all likelihood, bison on the plains moved into the mountains, and bison in the Rockies moved onto the prairies.

Second, unless constantly replenished with animals from the plains, it is unlikely that bison could have maintained viable populations in the mountains. As indicated above, long-term studies in Wood Buffalo National Park indicate that wolf predation alone can have a dramatic impact on bison numbers, keeping the population well below the level the range could support (Carbyn et al. 1993). The addition of native hunting to a bison-wolf-bear system would have reduced bison numbers even more, perhaps to local extinction.

In Yellowstone National Park, for example, there are now 3,000 to 4,000 bison under "natural regulation" management. According to the U.S. Park Service, this number of bison is thought to be natural

and to represent the pristine condition of the park (Meagher 1973, Houston 1982, Despain et al. 1986). Between 1835 and 1876, however, 20 different parties spent a total of 765 days traveling through the Yellowstone Ecosystem on foot or horseback, yet they reported seeing bison only three times, none of which were in what is now Yellowstone Park. Bison were seen twice to the south in Wyoming's Jackson Hole and once to the west near Idaho's Henry's Lake (Kay 1990, in press b). Bison sign was reported in Yellowstone Park, so a few animals may have resided there, but certainly not in the numbers seen today when bison are limited only by the available supply of food (forage), not Native Americans and wolves.

As noted in Chapter 3, historically bison in Waterton Lakes National Park, Crowsnest Pass, and Banff's Bow Valley would have had little trouble in moving back and forth between the mountains and the plains, as grassland-lined valleys provided easy access. Today, however, it is hard to imagine how bison could have reached the Red Deer, North Saskatchewan, or Athabasca Valleys in the Canadian Rockies, as 50 km to 100 km or more of dense forests now block the way.

First, bison will move through forested areas, especially if the timber is somewhat open (Meagher 1973, Carbyn et al. 1993). Second, prior to fire suppression and elimination of aboriginal burning, the forested areas between Alberta's prairies and mountains were more open than they are today. Historical photographs, present stand-age analyses, and early accounts all suggest that these areas once supported more grasslands and open timber than is now the case. So, native burning not only maintained montane grasslands favored by bison in the mountains, but aboriginal burning also created corridors that bison could use to move from the plains to the mountains and back. Our interpretation complements the view that bison once summered on the Canadian prairies but then moved into the foothills and aspen parklands, and we would add montane valleys, to avoid harsh winters on the open plains (Moodie and Ray 1976, Morgan 1980, Hanson 1984, Chisholm et al. 1986, Bamforth 1987, Epp 1988). Some bison may have summered in the mountains, but non-migratory animals would have been under intense predation by Native Americans, wolves, and bears.

MANAGEMENT CONSIDERATIONS

We have shown that the Banff of today is not the Banff of the 1880s, and that neither are representative of pre-Columbian times. The ecosystem states and processes as defined by aspen, fire, ungulates, humans, and carnivore predation are different today than at any point in the last 10,000 years. If we measure present ecological integrity by the state of the ecosystem that existed before European arrival, as has been proposed by Canadian scientists (Kay 1991a, 1991b; Woodley and Theberge 1992; Woodley 1993; Woodley et al. 1993), then Banff's Bow Valley and much of the Central Canadian Rockies today lack ecological integrity. But what Banff should Parks Canada manage for?

As noted in Chapter 1, the Canadian National Parks Act as amended in 1988 mandates that Canada's national parks be managed "so as to leave them unimpaired for the enjoyment of future generations" and "ecological integrity ... shall be the first priority" in park management, but does this mean the Banff of 1996, 1880, or the Banff of pre-Columbian times? Whatever baseline is chosen will determine whether the present ecosystem does or does not lack ecological integrity. Science, in and of itself, cannot define ecological integrity, instead that definition hinges on social values (Kay 1991a, Woodley et al. 1993, Shrader-Frechette and McCoy 1995). We suggest, however, that defining ecological integrity based on pre-Columbian ecosystem states and processes will keep personal biases and politics to a minimum.

It must be remembered, though, that doing nothing, so called "natural regulation" or "hands-off" management, is really a value judgement and a decision that has wide-ranging consequences (Budiansky 1995; Pyne 1995a, 1995b; Wagner et al. 1995). In Banff, for instance, following the status quo means, among other things, that (1) aspen will eventually be eliminated from most of the Bow Valley along with other species, (2) elk will continue to dominate the ungulate community especially in Banff townsite and developed

areas avoided by wolves and other predators, (3) biodiversity will continue to decline as the forests age and replace grasslands in the absence of frequent low-intensity fires (Bunnell 1995), and (4) forest fuels will continue to accumulate setting the stage for high-intensity crown fires that could not only threaten park developments and human life, but which would also create burn patterns unlike any seen in Banff before. In addition, other ecosystem variables not discussed here, such as soil chemistry and nutrient cycling, no doubt will be effected as well.

Throughout North America, most national parks, wilderness areas, and nature reserves are supposedly managed to represent the conditions that existed in pre-Columbian times; i.e., so-called natural or pristine conditions. But what is natural? If Native Americans repeatedly fired the vegetation and limited ungulate numbers which, in turn, determined the structure of entire plant and animal communities, that is a completely different situation than letting nature take its course today (Wagner and Kay 1993, Budiansky 1995, Wagner et al. 1995). Moreover, Canada, like many other countries, has chosen to use her national parks as baseline reference areas from which to judge the health of other, more developed ecosystems (Woodley et al. 1993:131-153, Hodgins 1994, McNamee 1994, Young 1994). But again, what is natural? If ecological conditions in Canada's national parks are changing due, in part, to the elimination of aboriginal land management practices, as we have argued, then are those parks the proper standard with which to measure ecosystem health and ecological integrity in other areas? Then too, there is another question we were not asked to address; how much development is allowable before national parks lose what ecological integrity they have left (Bernard et al. 1995, Krakauer 1995, Pacas et al. 1995)? It is also important to remember that a species can be ecologically extinct¹ before it is demographically extinct.

We believe that the only hope in answering these and similar difficult questions rests with studies which focus on historical ecology and how ecosystem states and processes have changed over time (Winterhalder 1994). Moreover, those studies should be independent of internal and external park politics (Wagner et al. 1995). To again quote Aldo Leopold, "if we are serious about restoring ecosystem health and ecological integrity, then we must know what the land was like to begin with" (Covington and Moore 1994:45). We hope that this report is a step in that direction.

¹Ecological extinction is defined as "the reduction of a species to such low abundance that although it is still present in the community it no longer interacts significantly with other species as it once did" (Estes et al. 1989:253). That is to say, "populations may have been reduced to such an extent that they no longer perform their ecological function. What is needed is movement beyond the genetically based concern with demographic size to a new emphasis on minimum ecologically operational population size that incorporates interactions between plant and animal species" (Redford 1992:420-421).

CHAPTER 8

FURTHER RESEARCH NEEDS

As we have noted at various points in this report, Parks Canada has a legislative mandate to manage the lands entrusted to its care in such a manner as to leave them unimpaired for future generations, and the agency is required to accord ecological integrity the highest priority. To this end, we recommend that Parks Canada, in cooperation with provincial land management agencies, undertake the following research.

First, the repeat photo work begun by Cliff White in Banff National Park should be extended to the entire Canadian Rockies including Jasper National Park. Archives across Canada should be searched to locate all available earliest photographs. The scenes in those pictures should then be rephotographed and evaluated. A representative selection of those photosets should be published and made available, not only to land managers, but also to the general public, so that everyone will understand the bases for management decisions which may be necessary to restore ecological integrity.

Second, an aspen ecology study should be initiated for the entire Central Canadian Rockies, again including Jasper National Park similar to the recent work in Kootenay and Yoho (Kay 1996). The condition and trend of aspen communities inside and outside Banff and Jasper should be measured. Aspen inside and outside existing ungulate-proof exclosures should also be measured, and additional exclosures constructed at representative locations. Long-term studies of burned and unburned aspen communities should be initiated to determine whether or not aspen can successfully regenerate under the level of ungulate use present today. This should include aspen on the Ya Ha Tinda and Kootenay Plains. Aspen should be used as a key indicator of ecological integrity.

Third, available fire history data for the entire Central Canadian Rockies should be compiled in one comprehensive report. Emphasis should be placed on the role of aboriginal burning in pre-Columbian times, because whether or not natives burned, and the extent of that burning, are critical to our understanding of ecological integrity and ecosystem development. This is also germane to programs of prescribed burning which may or may not be implemented by Parks Canada and other land management agencies.

Fourth, a comprehensive archaeological research program should be formulated and implemented. Emphasis should be placed on how aboriginal peoples interacted and used their environment, not on traditional archaeological interests such as cultural sequences, lithics, and the like. We need to know whether or not Native Americans were the keystone that structured western ecosystems. Models from modern evolutionary ecology should be employed and archaeological sites excavated, as needed, to test those predictions. We envision a team of researchers from Parks Canada, Canadian universities, and their counterparts from institutions in the United States following a research program modeled after Utah's recent Silver Lake Expedition (Madsen in press). We suggest that this research be concentrated in the Red Deer-Ya Ha Tinda-James Pass region, as that area contains a large number of relatively undisturbed archaeological sites, plus it currently supports a large population of wintering elk, as well as extensive aspen communities.

Fifth, Parks Canada should initiate a major research effort to define ecological integrity, and especially what is meant by unimpaired for future generations. Not only must the agency formulate broad conceptual models (see Kay 1991a, 1991b; Woodley 1992, 1993; Woodley and Theberge 1992; Woodley et al. 1993; and others), but it must also develop quantifiable ecological definitions and objectives that are species and site specific, and which can be implemented and monitored by managers (Gauthier 1995, Henry

et al. 1995). We suggest that such a pilot program be developed for the Central Canadian Rockies Ecosystem. Not only is Banff Canada's oldest national park and the flagship of the national park systems, but a wealth of ecological information is available that can be used to guide additional research (Bernard et al. 1995, Pacas et al. 1995, Peterson et al. 1995). To solicit as wide a range of opinions as possible, we also suggest that Parks Canada sponsor a symposium on defining ecological integrity in the Canadian Rockies.

This brings us to our final recommendation. To improve our understanding of these systems, all management and research activities should follow principles of adaptive management (Walters 1986). If Parks Canada is committed to ecosystem management, the agency's programs must not only be founded on sound ecological principles, but should also be open to review (Grumbine 1994, McNamee 1994). For an adaptive management approach to be successful, we recommend that each park establish an independent "ecosystem management board" or "scientific advisory panel" which would routinely evaluate performance in achieving policy and legislative mandates. A system of adaptive management would insure that all opinions are fully discussed, and that monitoring programs are designed to collect the types of data that are necessary to separate between competing hypotheses.

LITERATURE CITED

- ABRAMS, H.L. Jr. 1987. The preference for animal protein and fat: A cross-cultural survey. Pages 207-222 in M. Harris, and E.B. Ross, eds. Food and evolution: Toward a theory of human food habits. Temple University Press, Philadelphia, PA. 633 pp.
- ACHUFF, P.L. W.D. HOLLAND, G.M. COEN, and K. VAN TICHEM. 1984. Ecological land classification of Kootenay National Park, British Columbia. Vol. 1: Integrated resource description. University of Alberta, Alberta Institute of Pedology Pub. M-84-10. 373 + 73 plates.
- ACHUFF, P.L., W.S. TAYLOR, and L.J. KNAPIK. 1993. Ecological land classification of Yoho National Park, British Columbia. Unpub. rep. on file Yoho Warden Office, Yoho National Park, Field, BC. March draft. 283 pp.
- AGEE, J.K. 1989. Wildfire in the Pacific West: A brief history and implications for the future. Pages 11-16 in N.H. Berg, ed. Proceedings of the symposium on fire and watershed management. U.S. For. Ser. Gen. Tech. Rep. PSW-109.
- AGEE, J.K. 1993. Fire ecology of Pacific Northwest forests. Island Press, Washington, DC. 493 pp.
- AGEE, J.K. 1994. Fire and weather disturbances in terrestrial ecosystems of the eastern Cascades. U.S. For. Ser. Gen. Tech. Rep. PNW-320. 52 pp.
- AHO, R.W., and P.A. JORDAN. 1979. Production of aquatic macrophytes and its utilization by moose on Isle Royale National Park. Pages 341-348 in Linn, R.M., ed. Proceedings of the First Conference on Scientific Research in National Parks. USDI National Park Service Transactions and Proceedings Series No. 5.
- AKENSON, H.A. 1992. Spatial relationships and behavior of bighorn sheep sharing a winter range with mule deer and elk in central Idaho. M.S. Thesis, University of Idaho, Moscow, ID. 75 pp.
- ALBERTA FOREST SERVICE. 1987. Fire weather notes for mountain and foothill forests of Alberta. Weather Section, Forest Protection Branch, Edmonton, AB. 46 pp.
- ALEXANDER, S. 1992. Aspen ecosite analysis Banff National Park, Alberta - March-October 1992. Unpub. Contract Rep. No. KBP 2098 on file, Banff Warden Office, Banff National Park, AB. 22 pp.
- ALVARD, M.S. 1993a. Testing the ecologically noble savage hypothesis: Conservation and subsistence hunting by the Piro of Amazonian Peru. Ph.D. Dissertation, University of New Mexico, Albuquerque, NM. 398 pp.
- ALVARD, M.S. 1993b. Testing the "ecologically noble savage" hypothesis: Interspecific prey choice by Piro hunters of Amazonian Peru. Human Ecol. 21:355-387.
- ALVARD, M.S. 1994. Conservation by native peoples: Prey choice in a depleted habitat. Human Nature 5:127-154.
- ALVARD, M.S. 1995. Intraspecific prey choice by Amazonian hunters. Curr. Anthropol. 36:789-818.
- ANDERSON, H.E. 1968. Sundance fire: An analysis of fire phenomena. U.S. For. Ser. Gen. Tech. Rep. INT-56.

- ANDERSON, L., C.E. CARLSON, and R.H. WAKIMOTO. 1987. Forest fire frequency and western spruce budworm outbreaks in western Montana. *For. Ecol. and Manage.* 22:251-260.
- ANDERSON, M.K. 1991. Wild plant management: Cross-cultural examples of the small farmers of Jaumave, Mexico, and the Southern Miwok of the Yosemite region. *Arid Lands Newsletter* 31:18-23.
- ANELL, B. 1969. Running down and driving of game in North America. *Studia Ethnographic Upsaliensia* No. 30:1-129.
- ARBOR WILDLAND MANAGEMENT SERVICES. 1988. Volume III – Data analysis- fire reports: Jasper National Park. Consultant report to Jasper National Park, Jasper, AB. 52 pp.
- ARCHAEOLOGICAL RESEARCH SERVICES UNIT. 1989a. Archaeological resource description and analysis: Banff National Park. Western Regional Office, Canadian Parks Service, Environment Canada, Calgary, AB. Unpub. Rep. 237 pp.
- ARCHAEOLOGICAL RESEARCH SERVICES UNIT. 1989b. Jasper National Park: Archaeological resource description and analysis. Western Regional Office, Canadian Parks Service, Environment Canada, Calgary, AB. Unpub. Rep. 210 pp.
- ARCHAEOLOGICAL RESEARCH SERVICES UNIT. 1989c. Archaeological resource description and analysis: Kootenay National Park. Western Regional Office, Canadian Parks Service, Environment Canada, Calgary, AB. Unpub. Rep. 174 pp.
- ARCHAEOLOGICAL RESEARCH SERVICES UNIT. 1993. Yoho National Park: Archaeological resource description and analysis. Western Regional Office, Canadian Parks Service, Environment Canada, Calgary, AB. Unpub. Rep.
- ARNO, S.F. 1976. The historical role of fire on the Bitterroot National Forest. *U.S. For. Ser. Res. Paper* INT-187. 29 pp.
- ARNO, S.F. 1980. Forest fire history in the northern Rockies. *J. For.* 78:460-465.
- ARNO, S.F. 1985. Ecological effects and management implications of Indian fires. Pages 81-86 in J.E. Lotan, B.M. Kilgore, W.C. Fisher, and R.W. Mutch, eds. *Proceedings – symposium and workshop on wilderness fire*. *U.S. For. Ser. Gen. Tech. Rep.* INT-182. 434 pp.
- ARNO, S.F., E.D. REINHARDT, and J.H. SCOTT. 1993. Forest structure and landscape patterns in the subalpine lodgepole pine type: A procedure for quantifying past and present conditions. *U.S. For. Ser. Gen. Tech. Rep.* INT-294. 17 pp.
- ARNO, S.F., and G.E. GRUELL. 1983. Fire history at the forest-grassland ecotone. *J. Range Manage.* 36:332-336.
- ARNO, S.F., and J.K. BROWN. 1991. Overcoming the paradox in managing wildland fire. *Western Wildlands* 17(1):40-46.
- ARTHUR, G.W. 1975. An introduction to the ecology of early historic communal bison hunting among the Northern Plains Indians. *Archaeological Survey of Canada Paper* No. 37. Ottawa, ON.
- BAILEY, A.W. 1986. Prescribed burning for range and wildlife management. *University of Alberta Agric. For. Bull.* 9(3):10-14.

- BAILEY, A.W., B.D. IRVING, and R.D. FITZGERALD. 1990. Regeneration of woody species following burning and grazing in aspen parkland. *J. Range Manage.* 43:212-215.
- BAILEY, A.W., and R.A. WROE. 1974. Aspen invasion in a portion of the Alberta parklands. *J. Range Manage.* 27:263-266.
- BAKER, D.L., and D.R. HANSEN. 1985. Comparative digestion of grass in mule deer and elk. *J. Wildl. Manage.* 49:77-79.
- BAKER, K.A. 1984. Weather patterns and wildland fire in Banff National Park. Unpub. Rep. on file, Banff Warden Office, Banff National Park, AB. 171 pp.
- BAKER, W.L. 1987. Recent changes in the riparian vegetation of the montane and subalpine zones of western Colorado, U.S.A. Ph.D. Dissertation, University of Wisconsin, Madison, WI. 942 pp.
- BAKSH, M. 1985. Faunal food as a "limiting factor" on Amazonian cultural behavior: A Machiguenga example. *Res. Econ. Anthropol.* 7:145-175.
- BALDA, R.P. 1975. Vegetation structure and breeding bird diversity. Pages 59-80 in Smith, D.R., ed. Symposium on management of forest and range habitats for nongame birds. U.S. For. Ser. Gen. Tech. Rep. WO-1.
- BALEE, W. 1989. The culture of Amazonian forests. *Advances in Economic Botany* 7:1-21.
- BALL, B.F. 1986. Site classification and prehistoric settlement systems in the upper Athabasca River valley. *Archaeol. Survey of Alberta Occ. Pap.* 30:133-159.
- BALLARD, W.B. 1991. Management of predators and their prey: The Alaskan experience. *Trans. N.A. Wildl. and Nat. Res. Conf.* 56:527-538.
- BALLARD, W.B. 1992. Bear predation on moose: A review of recent North American studies and their implications. *Alces (Supplement 1)*:162-176.
- BAMFORTH, D.B. 1987. Historical documents and bison ecology on the Great Plains. *Plains Anthropol.* 32(115):1-16.
- BARRETT, S.W. 1980a. Indians and fire. *Western Wildlands* 6(3):17-21.
- BARRETT, S.W. 1980b. Indian fires in the pre-settlement forests of western Montana. Pages 35-41 in *Proceedings of fire history workshop*. U.S. For. Ser. Gen. Tech. Rep. RM-81. 147 pp.
- BARRETT, S.W. 1981. Relationship of Indian-caused fires to the ecology of western Montana forests. M.S. Thesis, University of Montana, Missoula, MT. 198 pp.
- BARRETT, S.W., and S.F. ARNO. 1982. Indian fires as an ecological influence in the northern Rockies. *J. For.* 80:647-651.
- BARRETT, S.W., S.F. ARNO, and C.H. KEY. 1991. Fire regimes of western larch - lodgepole pine forests in Glacier National Park, Montana. *Can. J. For. Res.* 21:1711-1720.
- BARROWS, J.S. 1951. Fire behavior in northern Rocky Mountain forests. U.S. For. Ser. Northern Rocky Mountain Forest and Range Exp. Sta. Paper 29. 251 pp.

- BARTOS, D.L., J.K. BROWN, and G.D. BOOTH. 1994. Twelve years biomass response in aspen communities following fire. *J. Range Manage.* 47:79-83.
- BARTOS, D.L., and W.F. MUEGGLER. 1979. Influence of fire on vegetation production in the aspen ecosystem in western Wyoming. Pages 75-78 in Boyce, M.S. and L.D. Hayden-Wing, eds. *North American elk: Ecology, behavior and management*. University of Wyoming, Laramie, WY. 294 pp.
- BARTOS, D.L., and W.F. MUEGGLER. 1981. Early succession in aspen communities following fires in western Wyoming. *J. Range Manage.* 34:315-318.
- BARTOS, D.L., W.F. MUEGGLER, and R.B. CAMPBELL JR. 1991. Regeneration of aspen by suckering on burned sites in western Wyoming. U.S. For. Ser. Res. Paper INT-448. 10 pp.
- BASILE, J.V. 1979. Elk-aspen relationships on a prescribed burn. U.S. For. Ser. Res. Note INT-271. 7 pp.
- BAYHAM, F.E. 1979. Factors influencing the archaic pattern of animal exploitation. *Kiva* 44:219-235.
- BEALL, R.C. 1976. Elk habitat selection in relation to thermal radiation. Pages 97-100 in S.R. Hieb, ed. *Proceeding elk-logging-roads symposium*. University of Idaho, Moscow, ID. 142 pp.
- BELLA, L. 1987. *Parks for profit*. Harvest House, Montreal, PQ. 216 pp.
- BELYEA, B., ed. 1994. *Columbia journals: David Thompson*. McGill-Queens University Press, Montreal, PQ. 336 pp.
- BERGERUD, A.T. 1990. Rareness as an anti-predator strategy to reduce predation risk. *Transactions of 19th I.U.G.B. Congress. Proceedings held September 1989. Trondheim, Norway. Vol. 1. Population dynamics: 15-25.*
- BERGERUD, A.T. 1992. Rareness as an antipredator strategy to reduce predation risk for moose and caribou. Pages 1008-1021 in McCullough, D.M., and R. Barrett, eds. *Wildlife 2001: Populations*. Elsevier Applied Science, NY. 1163 pp.
- BERNARD, D, C. PACAS, and N. MARSHALL. 1995. *State of the Bow Valley report*. Compiled by Banff Bow Valley Study Secretariat, Banff, AB; ESSA Technologies Ltd., Vancouver, BC; and Praxis, Inc., Calgary, AB for Banff-Bow Valley Task Force, Banff, AB. August 26.
- BESSIE, W.C., and E.A. JOHNSON. 1995. The relative importance of fuels and weather on fire behavior in subalpine forests. *Ecology* 76:747-762.
- BETTINGER, R.L. 1987. Archaeological approaches to hunter-gatherers. *Ann. Rev. Anthropol.* 16:121-142.
- BICKNELL, S.H. 1992. Vegetation of coastal California sites prior to European settlement. Paper presented at Eighth California Indian Conference, University of California at Berkeley, Berkeley, CA. Oct. 16-18th.
- BICKNELL, S.H., A.T. AUSTIN, D.J. BIGG, AND R.P. GODAR. 1992. Late prehistoric vegetation patterns at six sites in coastal California. *Bull. Ecol. Soc. of Amer.* 73:112.
- BICKNELL, S.H., R.P. GODAR, D.J. BIGG, AND A.T. AUSTIN. 1993. *Mount Tamalpais State Park prehistoric vegetation: Final report*. Unpub. rep. by Forestry Department, Humboldt State University

- to California Department of Parks and Recreation. Interagency Agreement 88-11-1013. June. 44 pp. + appendices.
- BINFORD, L.R. 1978. *Nunamiut ethnoarchaeology*. Academic Press, New York, NY. 509 pp.
- BINFORD, L.R. 1981. *Bones: Ancient men and modern myths*. Academic Press, New York, NY. 320 pp.
- BIRD, R.D. 1930. Biotic communities of the aspen parkland of central Canada. *Ecology* 11:356-442.
- BIRD, R.D. 1961. *Ecology of the aspen parkland*. Canada Department of Agriculture Research Branch Pub. 1066. 155 pp.
- BIRKEDAL, T. 1993. Ancient hunters in the Alaskan wilderness: Human predators and their role and effort on wildlife populations and the implications for resource management. Pages 228-234 in Brown, W.E., and S.D. Veirs, Jr., eds. *Partners in stewardship: Proceedings of the 7th Conference on Research and Resource Management in Parks and on Public Lands*. The George Wright Society, Hancock, MI. 479 pp.
- BLACKBURN, T.C., and K. ANDERSON, eds. 1993a. *Before the wilderness: Environmental management by native Californians*. Ballena Press, Menlo Park, CA. 476 pp.
- BLACKBURN, T.C., and K. ANDERSON. 1993b. Introduction: Managing the domesticated environment. Pages 15-26 in Blackburn, T.C., and K. Anderson, eds. *Before the wilderness: Environmental management by native Californians*. Ballena Press, Menlo Park, CA. 476 pp.
- BLACK-ROGERS, M. 1986. Varieties of "starving": Semantics and survival in the subarctic fur trade, 1750-1850. *Ethnohistory* 33:353-383.
- BLAKE, M. 1975. Report of Wildhorse River archaeological salvage project, site DjPv-14, in the East Kootenay region of British Columbia. Unpub. Rep. on file, Heritage Conservation Branch, Victoria, BC. Permit 1975-15. 134 pp + appendices.
- BLAKE, T.M. 1981. Archaeological investigations at the Wild Horse River (DjPv-14). Occ. Pap. British Columbia Heritage Conservation Branch 6:1-119.
- BLITZ, J.H. 1988. Adoption of the bow in prehistoric North America. *N. Amer. Archaeol.* 9:123-145.
- BONNICKSEN, T.M. 1990. Restoring biodiversity in park and wilderness areas: An assessment of the Yellowstone wildfires. Pages 25-31 in A. Rasmussen, ed. *Wilderness areas: Their impacts -- Proceedings of a symposium*. Utah State University, Logan, UT. 79 pp.
- BORK, A.M., C. STROBECK, F.C. YEH, R.J. HUDSON, AND R.K. SALMON. 1991. Genetic relationship of wood and plains bison based on restriction fragment length polymorphisms. *Can. J. Zool.* 69:43-48.
- BOWDEN, M.J. 1992. The invention of American tradition. *J. of Historical Geography* 18:3-26.
- BOYCE, M.S. 1989. *The Jackson elk herd: Intensive wildlife management in North America*. Cambridge University Press, Cambridge, MA. 306 pp.
- BOYD, R.T. 1985. *The introduction of infectious disease among the Indians of the Pacific Northwest, 1774-1874*. Ph.D. Dissertation, University of Washington, Seattle, WA. 599 pp.
- BOYD, T. 1986. Strategies of Indian burning in the Willamette Valley. *Can. J. Anthropol.* 5:65-86.

- BRANDNER, T.A. 1986. Density dependent effects of moose herbivory on balsam fir in Isle Royale National Park, Michigan. M.S. Thesis, Michigan Technological University, Houghton, MI. 29 pp.
- BRANDNER, T.A., R.O. PETERSON, AND K.L. RISENHOOVER. 1990. Balsam fir on Isle Royale: Effects of moose herbivory and population density. *Ecology* 71:155-164.
- BRIGHTMAN, R.A. 1987. Conservation and resource depletion: The case of the boreal forest Algonquians. Pages 121-141 in McCay, B.J., and J.M. Acheson, eds. *The question of the commons*. University of Arizona Press, Tucson, AZ. 439 pp.
- BRINK, J.W. 1974. Research progress report, 1974 (Grande Cache-Eastern Slopes) (ASA Permit 74-6). Staff report on file, Archaeological Survey of Alberta, Edmonton, AB. 9 pp.
- BRINK, J.W. 1975. Report on the excavations at the Smoky Site, Grand Cache Alberta, 1975 (ASA Permit 75-9). Staff report on file, Archaeological Survey of Alberta, Edmonton, AB. 5 pp.
- BRINK, J.W., and R.J. DAWE. 1986. An introduction to the archaeology of the Grande Cache region in the north Alberta Rocky Mountains. *Archaeol. Survey of Alberta Occ. Pap.* 30:161-246.
- BROUGHTON, J.M. 1994a. Declines in mammalian foraging efficiency during the Late Holocene. San Francisco Bay, California. *J. Anthropol. Archaeol.* 13:371-401.
- BROUGHTON, J.M. 1994b. Late Holocene resource intensification in the Sacramento Valley, California: The vertebrate evidence. *J. Archaeol. Sci.* 21:501-514.
- BROUGHTON, J.M. 1995. Resource depression and intensification during the Late Holocene, San Francisco Bay: Evidence from the Emeryville shellmound vertebrate. Ph.D. Dissertation, University of Washington, Seattle, WA. 331 pp.
- BROWN, J.K., and N.V. DEBYLE. 1982. Developing prescribed burning prescriptions for aspen in the intermountain west. Pages 29-49 in Symposium: Fire - its effects. Intermountain Fire Council and Rocky Mtn. Fire Council Proc. Jackson, WY. October 19-21.
- BROWN, J.K., and D.G. SIMMERMAN. 1986. Appraisal of fuels and flammability in western aspen: A prescribed fire guide. U.S. For. Ser. Gen. Tech. Rep. INT-205. 48 pp.
- BROWN, J.K., S.F. ARNO, S.W. BARRETT, and J.P. MENAKIS. 1994. Comparing the prescribed natural fire program with presettlement fires in the Selway-Bitterroot Wilderness. *Int. J. Wildland Fire* 4:157-168.
- BRULOTTE, R.K. 1981. Report on preliminary survey ASA permit 81-107. Unpub report on file at Archaeology Survey of Alberta, Edmonton, AB. 49 pp. + appendices.
- BRULOTTE, R.K. 1983. Zooarchaeological interpretations of two sites in southwestern Alberta. M.A. Thesis, University of Alberta, Edmonton, AB. 97 pp.
- BRYANT, L.D., and C. MASER. 1982. Classification and distribution. Pages 1-59 in J.W. Thomas, and D.E. Towell, eds. *Elk of North America: Ecology and management*. Wildlife Management Institute and Stackpole Books, Harrisburg, PA. 698 pp.
- BUDIANSKY, S. 1995. *Nature's keepers: The new science of nature management*. The Free Press, New York, NY. 310 pp.

- BUELL, M.F., and H.F. BUELL. 1959. Aspen invasion of prairie. *Bull. Torrey Bot. Club* 86:264-265.
- BUNNELL, F.L. 1995. Forest-dwelling vertebrate faunas and natural fire regimes in British Columbia: Patterns and implications for conservation. *Conser. Biol.* 9:636-644.
- BUREAU OF LAND MANAGEMENT. 1979a. Historical comparison photography: Missouri Breaks, Montana. Montana State Office, Billings, MT. U.S. Government Printing Office: 1979-699-337. 109 pp.
- BUREAU OF LAND MANAGEMENT. 1979b. Historical comparison photography: Montana foothills, Dillon resource area, Montana. Montana State Office, Billings, MT. U.S. Government Printing Office 698-274. 120 pp.
- BUREAU OF LAND MANAGEMENT. 1984. Historical comparison photography: Headwaters resource area, Butte district. Bureau of Land Management, Butte, MT. 171 pp.
- BUSSEY, B.J. 1981. Archaeological investigations along the Pend D'Oreille River of south-central British Columbia. *Occ. Pap. British Columbia Heritage Conservation Branch* 7:1-158 pp.
- BUSSEY, B.J. 1986. Salvage excavation at EdQa-8, near Invermere, B.C. — a late middle prehistoric camp. Report prepared for Resource Management Division, Heritage Conservation Branch, Victoria BC. by Points West Heritage Consulting Ltd., Langley, BC. 115 pp + appendices.
- BUTZER, K.W. 1992. The Americas before and after 1492: An introduction to current geographical research. *Assoc. Amer. Geographers Annals* 82:345-368.
- BYRNE, A.R. 1968. Man and landscape change in the Banff National Park area before 1911. *Studies in Land Use History and Landscape Changes, National Park Series, No. 1.* University of Calgary, Calgary, AB. 173 pp.
- CAIRNS, A.L., and E.S. TELFER. 1980. Habitat use by 4 sympatric ungulates in boreal mixedwood forest. *J. Wildl. Manage.* 44:849-857.
- CALDER, E.M., and B.O.K. REEVES. 1977. Archaeological investigations Luscar-Sterco Coal Valley project prehistoric sites FgQe-14, 16, and 18 (ASA Permit 76-62). Unpub. consultant's report (Lifeways of Canada Limited) for Luscar Sterco Ltd. Copy on file, Archaeological Survey of Alberta, Edmonton, AB. 50 pp.
- CALLICOTT, J.B. 1991. The wilderness idea revisited: The sustainable development alternative. *Environmental Professional* 13:235-247.
- CAMPBELL, C., I.D. CAMPBELL, C.B. BLYTH, and J.H. MCANDREWS. 1994. Bison extirpation may have caused aspen expansion in western Canada. *Ecography* 17:360-362.
- CAMPBELL, S.K. 1990. Post Columbian cultural history in northern Columbia Plateau A.D. 1500-1900. Garland Publishing, Inc., NY. 228 pp.
- CANADA NATIONAL DEFENSE. 1994. Canadian Forces Base — Winnipeg: Prototype vegetation management plan — Prairie habitats. Unpub. rep. on file Air Command Headquarters, Westwin, Manitoba. March. 39 pp. + appendices.

- CANADIAN FORESTRY SERVICE. 1987. Canadian forest fire danger rating system - users guide. Produced by the Canadian Forestry Service Fire Danger Group, Northern Forest Research Centre, Edmonton, AB. Three-ring binder (unnumbered publication).
- CANADIAN PARKS SERVICE. 1984. Interim wildland fire management plan. Resource Conservation Section, Banff National Park, AB. 104 pp.
- CANADIAN PARKS SERVICE. 1990. Fire preparedness system: 1990 version. Natural Resources Branch, Ottawa, ON. 35 pp.
- CAPRIO, A.C., and T.W. SWETNAM. 1995. Historic fire regimes along an elevational gradient on the west slope of the Sierra Nevada, California. Pages 173-179 in Brown, J.K., R.W. Mutch, C.W. Spoon, and R.H. Wakimoto, eds. Proceedings: Symposium on fire in wilderness and park management. U.S. For. Ser. Gen. Tech. Rep. INT-320. 283 pp.
- CARBYN, L.N. 1974a. Wolf population fluctuations in Jasper National Park, Alberta, Canada. Biol. Conser. 6:94-101.
- CARBYN, L.N. 1974b. Wolf predation and behavioral interactions with elk and other ungulates in an area of high prey diversity. Ph.D. Dissertation. University of Toronto, Toronto, ON. 233 pp.
- CARBYN, L.N. 1980. Ecology and management of wolves in Riding Mountain National Park, Manitoba. Final Report Large Mammal System Studies from September 1975 to March 1979. Report No. 10. Canadian Wildl. Serv., Edmonton, AB. 184 pp.
- CARBYN, L.N., S.M. OOSENBURG, and D.W. ANIONS. 1993. Wolves, bison, and the dynamics related to the Peace-Athabasca Delta in Canada's Wood Buffalo National Park. University of Alberta, Edmonton, AB. Circumpolar Research Series 4. 270 pp.
- CARTWRIGHT, C.W., JR., and D.P. BURNS. 1994. Sustaining our aspen heritage into the twenty-first century. U.S. Forest Service, Southwestern Region. 6 pp.
- CASE, G. 1938. The influence of elk on deer populations. 1st and 2nd Idaho Game Manage. Conf., Univ. Ida., Moscow. Bull. 33(22):25-27.
- CASE, R.A., and G.M. MACDONALD. 1995. A dendroclimatic reconstruction of annual precipitation on the western Canadian prairies since A.D. 1505 from *Pinus flexilis* James. Quat. Res. 44:267-275.
- CASEY, D., and D. HEIN. 1983. Effects of heavy browsing on a bird community in deciduous forest. J. Wildl. Manage. 47:829-836.
- CHADDE, S., and C.E. KAY. 1988. Willows and moose: A study of grazing pressure, Slough Creek enclosure, Montana, 1961-1986. University of Montana, Montana Forest and Conservation Experiment Station Research Note 24. 5 pp.
- CHADDE, S., and C.E. KAY. 1991. Tall willow communities on Yellowstone's northern range: A test of the "natural regulation" paradigm. Pages 231-262 in R.B. Keiter, and M.S. Boyce, eds. The Greater Yellowstone Ecosystem: Redefining America's wilderness heritage. Yale University Press, New Haven, CT. 422 pp.
- CHAMBERLAIN, A.F. 1892. Report on the Kootenay Indians of south-eastern British Columbia. Report of the British Association for the Advancement of Science 62:549-614.

- CHAMBERS, F. 1988. Hayden and his men: Being a selection of 108 photographs by William Henry Jackson of the United States Geological and Geographical Survey of the Territories for the years 1870-1878. Francis Paul, Geoscience Literature, Dillsburg, PA. 6 pp. + 108 plates.
- CHEADLE, W.B. 1971. Cheadle's journal of a trip across Canada in 1862-1863. A.G. Doughty, and G. Lanctot, eds. Graphic Publishers Limited, Ottawa, ON. Reprinted by M.G. Hurtig, Edmonton, AB. 311 pp.
- CHISHOLM, B., J. DRIVER, S. DUBE, AND H.P. SCHWARCZ. 1986. Assessment of prehistoric bison foraging and movement patterns via stable-carbon isotopic analysis. *Plains Anthropol.* 31(116):193-205.
- CHOQUETTE, W.T. 1971. Archaeological salvage operations within the Libby Dam pondage, 1971. Unpub. Rep. on file, Heritage Conservation Branch, Victoria, BC. Permit 1971-19. 13 pp.
- CHOQUETTE, W.T. 1972a. Archaeological site survey in the Kootenay River drainage region. Unpub. Rep. on file, Archaeology Branch, BC Ministry of Tourism and Ministry Responsible for Culture, Victoria, BC. Permit 1972-8. 3 pp.
- CHOQUETTE, W.T. 1972b. Preliminary report, Libby Reservoir archaeological salvage project. Unpub. Rep. on file, Heritage Conservation Branch, Victoria, BC. Permit 1972-9. 22 pp.
- CHOQUETTE, W.T. 1974. Libby pondage archaeological salvage project: 1973 season. Unpub. Rep. on file, Heritage Conservation Branch, Victoria, BC. Permit 1973-3. 11 pp.
- CHOQUETTE, W.T. 1981. The role of lithic raw material studies in Kootenay archaeology. *British Columbia Studies* 48:21-36.
- CHOQUETTE, W.T. 1985a. Archaeological salvage excavations at DjPv-14, the Wild Horse River site, southeastern BC. Unpub. Rep. on file, Heritage Conservation Branch, Victoria, BC. Permit 1984-36. 228 pp.
- CHOQUETTE, W.T. 1985b. A Heritage resource assessment of Top-Of-The-World Provincial Park. Unpub. Rep. to BC Parks and Outdoor Recreation, Southern Interior Regional Office, Kamloops, BC. Copy on file, Archaeology Branch, BC Ministry of Tourism and Ministry Responsible for Culture, Victoria, BC. 66 pp. + appendices.
- CHOQUETTE, W.T. 1993. Archaeological impact assessment of the proposed Toby Creek bridge replacement. Unpub. Rep. on file, Archaeology Branch, BC Ministry of Tourism and Ministry Responsible for Culture, Victoria, BC. Permit 1993-17b. 23 pp.
- CHRISTENSEN, N.L., J.K. AGEE, P.F. BRUSSARD, J. HUGES, D.H. KNIGHT, G.W. MINSHALL, J.M. PEEK, S.J. PYNE, F.J. SWENSON, J.W. THOMES, S. WELLS, S.E. WILLIAMS, and H.A. WRIGHT. 1989. Interpreting the Yellowstone fires of 1888. *Bioscience* 39:678-685.
- CLIFF, E.P. 1939. Relationship between elk and mule deer in the Blue Mountains of Oregon. *Trans. N. Amer. Wildl. Conf.* 4:560-569.
- COHEN, M.N. 1977. *The food crisis in prehistory*. Yale University Press, New Haven, CT. 341 pp.
- COLES, F.H. 1965. The effects of big game and cattle grazing on aspen regeneration. M.S. Thesis, Brigham Young University, Provo, UT. 72 pp.

- COLLINS, W.B., and P.J. URNESS. 1983. Feeding behavior and habitat selection of mule deer and elk on northern Utah summer range. *J. Wildl. Manage.* 47:646-663.
- COOK, N.D., AND W.G. LOVELL, eds. 1992. *Secret judgements of God: Old World disease in colonial Spanish America*. University of Oklahoma Press, Norman, OK. 281 pp.
- COOK, S.F. 1939. Smallpox in Spanish and Mexican California, 1770-1845. *Bull. of the History of Medicine* 7:153-191.
- COOPER, S.V. 1975. Forest habitat types of northwestern Wyoming and contiguous portions of Montana and Idaho. Ph.D. Dissertation, Washington State University, Pullman, WA. 190 pp.
- COUES, E., ed. 1965. *New light on the early history of the greater northwest: The manuscript journals of Alexander Henry and David Thompson 1799-1814*. Reprinted by Ross and Haines, Minneapolis, MN. Originally published by Francis P. Harper, New York, NY. 1897. 1027 pp.
- COVINGTON, W.W., and M.M. MOORE. 1994. Southwestern ponderosa forest structure: Changes since Euro-American settlement. *J. For.* 92:39-47.
- COWAN, I. McT. 1944. Report on game conditions in Banff, Jasper and Kootenay National Parks, 1943. Unpub. rep. on file, Banff Warden Office, Banff National Park, AB. 73 pp.
- COWAN, I. McT. 1947a. Range competition between mule deer and bighorn sheep, and elk in Jasper Park, Alberta. *Trans. N. Amer. Wildl. Conf.* 12:223-227.
- COWAN, I. McT. 1947b. The timber wolf in the Rocky Mountain national parks of Canada. *Can. J. of Res.* 25:139-174.
- COWAN, I. McT. 1950. Some vital statistics of big game on overstocked mountain range. *Trans. N. Amer. Wildl. Conf.* 15:581-588.
- CRETE, M., AND HUOT, J. 1993. Regulation of a large herd of migratory caribou: Summer nutrition affects calf growth and body reserves of dams. *Can. J. Zool.* 71:2291-2296.
- CROUCH, G.L. 1983. Aspen regeneration after commercial clearcutting in southwestern Colorado. *J. For.* 81:316-319.
- CROUCH, G.L. 1986. Aspen regeneration in 6- to 10-year-old clearcuts in southwestern Colorado. *U.S. For. Ser. Res. Note RM-467*. 4 pp.
- CRYER, D.H., AND J.E. MURRAY. 1992. Aspen regeneration and soils. *Rangelands* 14:223-226.
- D'ARRIGO, R., and G.C. JACOBY. 1992. Dendroclimatic evidence from northern North America. Pages 296-311 in R.S. Bradley, and P.D. Jones, eds. *Climate since A.D. 1500*. Routledge, New York, NY.
- DAILEY, T.V., and N.T. HOBBS. 1989. Travel in alpine terrain: Energy expenditures for locomotion by mountain goats and bighorn sheep. *Can. J. Zool.* 67:2368-2375.
- DAILY, G.C., P.R. EHRLICH, and N.M. HADDAD. 1993. Double keystone bird in a keystone species complex. *Proc. Natl. Acad. Sci.* 90:592-594.
- DAVIS, G.P. 1986. *Man and wildlife in Arizona: The American exploration period 1824-1865*. Arizona Game and Fish Dept., Phoenix, AZ. 231 pp.

- DAVIS, K.M., B.D. CLAYTON, and W.C. FISCHER. 1980. Fire ecology of Lolo National Forest habitat types. U.S. For. Ser. Gen. Tech. Rep. INT-79. 77 pp.
- DAY, D., C.A. WHITE, and N. LOPOUKHINE. 1990. Keeping the flame: Fire management in the Canadian Parks Service. In Proceedings of the Interior West Fire Council 1988 Annual Meeting. Forest Can. Int. Rep. NOR-X-309, Northwest Region, Edmonton, AB.
- DEBYLE, N.V. 1985. Animal impacts. Pages 115-123 in DeByle, N.V., and R.P. Winokur, eds. Aspen: Ecology and management in the western United States. U.S. For. Ser. Gen. Tech. Rep. RM-119. 283 pp.
- DEBYLE, N.V., C.D. BEVINS, and W.C. FISHER. 1987. Wildfire occurrence in aspen in the interior western United States. West. J. App. For. 2:73-76.
- DEBYLE, N.V., and R.P. WINOKUR, eds. 1985. Aspen: Ecology and management in the western United States. U.S. For. Ser. Gen. Tech. Rep. RM-119. 283 pp.
- DEKKER, D. 1985a. Elk population fluctuations and their probable causes in the Snake Indian Valley of Jasper National Park: 1970-1985. Alberta Naturalist 15(2):49-54.
- DEKKER, D. 1985b. Wild hunters. Canadian Wolf Defenders, Edmonton, AB. 224 pp.
- DEKKER, D. 1989. Population fluctuations and spatial relationships among wolves, Canis lupus, coyotes, Canis latrans, and red foxes, Vulpes vulpes, in Jasper National Park, Alberta. Can. Field-Nat. 103:261-264.
- DEKKER, D. 1994. Wolf story: From varmit to favourite and the wolves of Jasper. BST Publications, Edmonton, AB. 200 pp.
- DELISLE, G.P., and R.J. HALL. 1987. Forest fire history maps of Alberta, 1931- 1983. Can. For. Ser., Northern Forest Center, Edmonton, AB. 55 pp.
- DEMPSEY, H.A., ed. 1965. Thompson's journey to the Red Deer River. Alberta Historical Review 13(1):1-8.
- DENEVAN, W. 1992. The pristine myth: The landscape of the Americas in 1492. Assoc. Amer. Geographers Annals 82:369-385.
- DESPAIN, D., D. HOUSTON, M. MEAGHER, and P. SCHULLERY. 1986. Wildlife in transition: Man and nature on Yellowstone's northern range. Roberts Rinehart Inc., Boulder, CO. 142 pp.
- DIAMOND, J. 1988. The golden age that never was. Discover 9(12):70-79.
- DIAMOND, J. 1992. The third chimpanzee: The evolution and future of the human animal. Harper Collins Pub., New York, NY. 407 pp.
- DOBYNS, H.F. 1983. Their numbers become thinned: Native American population dynamics in eastern North America. University of Tennessee Press, Knoxville, TN. 378 pp.
- DONNELLY, J.P., ed. 1967. Wilderness kingdom -- Indian life in the Rocky Mountains: 1840-1847; the journals and paintings of Nicolas Point, S.J. Holt, Rinehart and Winston, New York, NY. 274 pp.

- DOUGLAS, D. 1959. Journal kept by David Douglas during his travels in North America, 1823-1827. Reprint in facsimile by Antiquarian Press, New York, NY. 364 pp. Originally published under the direction of the Royal Horticultural Society by William Wesley & Son, London, 1914.
- DRIVER, J.C. 1978. Holocene man and environments in the Crowsnest Pass, Alberta. Ph.D. Dissertation, University of Calgary, Calgary, AB. 230 pp.
- DRIVER, J.C. 1982. Early prehistoric killing of bighorn sheep in the southeastern Canadian Rockies. *Plains Anthropol.* 27(98, part 1):265-271.
- DRIVER, J.C. 1985. Prehistoric hunting strategies in the Crowsnest Pass, Alberta. *Can. J. Archaeol.* 9:109-128.
- DRIVER, J.C. 1988. Late Pleistocene and Holocene vertebrates and palaeoenvironments from Charlie Lake Cave, northeast British Columbia. *Can. J. Earth Sci.* 25:1545-1553.
- DRIVER, J.C. 1993. Early to late prehistoric lithic and faunal assemblages, site DjPp-8, Alberta. *Canad. J. Archaeol.* 17:43-58.
- DUNCAN, R.P. and G.H. STEWART. 1991. The temporal and spatial analysis of tree age distribution. *Canad. J. For. Res.* 21:1703-1710.
- EDGE, W.D., and C.L. MARCUM. 1985. Movements of elk in relation to logging disturbances. *J. Wildl. Manage.* 49:926-930.
- EDGE, W.D., C.L. MARCUM, and S.L. OLSON. 1985a. Elk concentrations in areas closed to hunting. Pages 56-65 in *Proceedings of the 1984 Western States and Provinces Elk Workshop*. Edmonton, AB.
- EDGE, W.D., C.L. MARCUM, and S.L. OLSON. 1985b. Effects of logging activities on home-range fidelity of elk. *J. Wildl. Manage.* 49:741-744.
- EHRlich, P.R., and G.C. DAILY. 1993. Birding for fun: Sapsuckers, swallows, aspen, and rot. *American Birds* 47(1):18-20.
- ENNS, K.A., E.B. PETERSON, and D. MCLENNAN. 1993. Impacts of hardwood management on British Columbia Wildlife: Problem analysis. British Columbia Ministry of Forests and Forestry Canada FRDA Rep. 208. 78 pp.
- EPP, H.T. 1988. Way of the migrant herds: Dual dispersion strategy among bison. *Plains Anthropol.* 33(121):309-320.
- ERMATINGER, E. 1912. Edward Ermatinger's York Factory express journal: Being a record of journeys made between Fort Vancouver and Hudson Bay in the years 1827-1828. *Transactions of the Royal Society of Canada, Third Series* 6(2):67-132.
- ESTES, J.A., D.O. DUGGINS, AND G.B. RATHBUN. 1989. The ecology of extinctions in kelp forest communities. *Conserv. Biol.* 3:252-264.
- FECHNER, G.H., and J.S. BARROWS. 1976. Aspen stands as wildfire fuelbreaks. *Eisenhower Consortium Bulletin* 4., Rocky Mtn. For. and Range Exp. Sta., Fort Collins, CO. 26 pp.

- FEDJE, D. 1986. The second lake site: Archaeological mitigation in Banff National Park. Environment Canada, Canadian Parks Service Microfiche Report Series 234. 112 pp.
- FEDJE, D.W. 1988. The Norquay and Eclipse sites: Trans-Canada Highway twinning mitigation in Banff National Park. Environment Canada, Canadian Parks Service Microfiche Report Series 395. 127 pp.
- FEDJE, D.W., and J.M. WHITE. 1988. Vermilion lakes archaeology and palaeoecology: Trans-Canada Highway mitigation in Banff National Park. Environment Canada, Canadian Parks Service Microfiche Report Series 463. 322 pp.
- FEDJE, D.W., J.M. WHITE, M.C. WILSON, D.E. NELSON, J.S. VOGEL, and J.R. SOUTON. 1995. Vermilion Lakes Site: Adaptations and environments in the Canadian Rockies during the latest Pleistocene and early Holocene. *Amer. Antiq.* 60:81-108.
- FERGUSON, T.A. 1979. Productivity and predictability of resource yield: Aboriginal controlled burning in the boreal forest. M.A. thesis, University of Alberta, Edmonton, AB. 145 pp.
- FEUNEKES, U., and C.E. VAN WAGNER. 1995. A century of fire and weather in Banff National Park. Unpub. rep. on file Banff Warden Office, Banff National Park, Banff, AB. February. 11 pp.
- FEUNEKES, U., M-P. ROGEAU, and C.A. WHITE. 1993. A fire growth model for the Central Rockies Ecosystem. Pages 47-59 in White, C.A., and P.L. Achuff, eds. *Proceedings of the Central Rockies Ecosystem fire management workshop*. Canadian Parks Service, Banff National Park, Banff, AB. 66 pp.
- FIDLER, P. 1991. A look at Peter Fidler's journal: Journal of a journey over land from Buckingham House to the Rocky Mountains in 1792 & 3. B. Haig, ed. *Historical Research Centre*, Lethbridge, AB. 99 pp.
- FINKLIN, A.I. 1986. A climatic handbook for Glacier National Park with data for Waterton Lakes National Park. U.S. For. Ser. Gen. Tech. Rep. INT-204. 124 pp.
- FINNEY, M.A. 1995. The missing tail and other considerations for the use of fire history models. *Int. J. Wildland Fire* 5:197-202.
- FISCHER, W.C., and B.D. CLAYTON. 1983. Fire ecology of Montana forest habitat types east of the continental divide. U.S. For. Ser. Gen. Tech. Rep. INT-141. 83 pp.
- FLACK, J.A.D. 1976. Bird populations of aspen forests in western North America. *Ornithological Monogr.* 19. 97 pp.
- FLANNERY, T.F. 1990. Pleistocene faunal loss: Implications of the aftershock for Australia's past and future. *Archaeology in Oceania* 25:45-67.
- FLANNERY, T.F. 1994. *The future eaters: An ecological history of the Australasian lands and peoples*. Reed Books, Chatswood, NSW, Australia. 423 pp.
- FLANNIGAN, M.D., and B.M. WOTTEN. 1991. Lightning-ignited fires in northern Ontario. *Can. J. For. Res.* 21:277-287.
- FLOOK, D.R. 1959. Analyses of range exclosure plots, Bow Valley, Banff Park, 1958. Unpub. Rep. on file, Banff Warden Office, Banff National Park, AB. 13 pp.

- FLOOK, D.R. 1964. Range relationships of some ungulates native to Banff and Jasper National Parks, Alberta. Pages 119-128 in D.J. Crisp, ed. *Grazing in terrestrial and marine environments*. Blackwell Press, Oxford, UK. 429 pp.
- FLOOK, D.R. 1970. A study of sex differential in the survival of Wapiti. *Can. Wildl. Ser. Rep. Series* 11:1-71.
- FORMAN, R.T., and E.W. RUSSELL. 1983. Evaluation of historical data. *Ecol. Soc. Bull.* 64:5-7.
- FOSTER, D. 1992. Applying the Yellowstone model in America's backyard: Alaska. Pages 363-376 in Birkhead, J., T. DeLacy, and L. Smith, eds. *Aboriginal involvement in parks and protected areas*. Aboriginal Studies Press, Canberra, Australia. 390 pp.
- FOWLER, P.M., AND D.O. ASLESON. 1984. The location of lightning-caused wildland fires, northern Idaho. *Phys. Geog.* 5:240-252.
- FOX, J.F. 1989. Bias in estimating forest disturbance rates and tree lifetimes. *Ecology* 70:1267-1272.
- FRANCHERE, G. 1969. Journal of a voyage on the northwest coast of North America during the years 1811, 1812, 1813, and 1814. W.K. Lamb, ed. The Champlain Society, Toronto, ON. Also published as Franchere, G. 1854. Narrative of a voyage to the northwest coast of America in the years 1811, 1812, 1813 and 1814. R.G. Thwaites, ed. *Early Western Travels 1748-1846*. Vol. 6:167-410. 1966 edition by AMS Press, New York, NY. 330 pp.
- FRANCIS, P.D., ed. 1991. Archaeology of the Echo Creek Site (515R), Banff National Park. Unpub. Rep. on file at Western Region Office, Canadian Parks Service, Calgary, AB. 233 pp. + 97 tables.
- FRISON, G.C. 1978. Prehistoric hunters of the high plains. Academic Press, New York, NY. 457 pp.
- FRISON, G.C. 1987. Prehistoric, plains-mountain, large mammal, communal hunting strategies. Pages 177-223 in M.H. Nitecki, and D.V. Nitecki, eds. *The evolution of human hunting*. Plenum Press, New York, NY. 467 pp.
- FRISON, G.C. 1989a. Experimental use of Clovis weaponry and tools on African elephants. *Amer. Antiq.* 54:766-784.
- FRISON, G.C. 1989b. Hunting strategies and animal mortality data. Paper presented at 54th Annual Meeting Society for Amer. Archaeology. Atlanta, GA. 10 pp.
- FRISON, G.C. 1991. Prehistoric hunters of the high plains. 2nd. ed. Academic Press, New York, NY. 532 pp.
- FROST, L.A., ed. 1979. With Custer in '74: James Calhoun's diary of the Black Hills expedition. Brigham Young University Press, Provo, UT. 140 pp.
- FRYER, G.I., and E.A. JOHNSON. 1988. Reconstructing the fire behavior of effects in a subalpine forest. *J. Applied Ecol.* 25:1063-1072.
- FRYXELL, J.M., J. GREEVER, and A.R.E. SINCLAIR. 1988. Why are migratory ungulates so abundant? *Amer. Nat.* 131:781-798.
- FULE, P.Z., and W.W. COVINGTON. 1995. Changes in fire regimes and forest structures of unharvested Petran and Madrean pine forests. Pages 408-415 in DeBano, L.F., G.J. Gottfried, R.H. Hamre, C.B.

- Edminster, P.F. Ffolliot, and A. Ortega-Rubio, eds. Biodiversity and management of the Madrean Archipelago: The sky islands of southwestern United States and northwestern Mexico. U.S. For. Ser. Gen. Tech. Rep. RM-264. 669 pp.
- GABRIEL, H.W. 1976. Wilderness ecology: The Danaher Creek drainage, Bob Marshall Wilderness, Montana. Ph.D. Dissertation, University of Montana, Missoula, MT. 224 pp.
- GALLOWAY, P. 1991. The archaeology of ethnohistorical narrative. Pages 453-469 in D.H. Thomas, ed. *Columbian Consequences*. Smithsonian Institution Press, Washington, D.C. Vol. 3. 592 pp.
- GASAWAY, W.C., R.D. BOERTJE, D.V. GRANGAARD, D.G. KELLYHOUSE, R.O. STEPHENSON, AND D.G. LARSEN. 1992. The role of predation in limiting moose at low densities in Alaska and Yukon and implications for conservation. *Wildl. Monogr.* 120:1-59.
- GASAWAY, W.C., R.O. STEPHENSON, AND J.L. DAVIS. 1983. Wolf-prey relationships in interior Alaska. Alaska Dep. of Fish and Game Wildl. Tech. Bull. 6. 15 pp.
- GAUTHIER, D.A. 1994. An academic science and research perspective for ecological monitoring in national parks. Pages 155-170 in Skibicki, A., A. Stadel, D. Welch, and J.G. Nelson, eds. *Ecological monitoring and national parks*. University of Waterloo Heritage Resources Centre Working Paper 7. 373 pp.
- GAUTHIER, D.A., D. HODGINS, and P. BENSON. 1995. Science and research in western Canadian National Parks. Pages 454-469 in Herman, T.B., S. Bondrup-Nielsen, J.H.M. Willison, and N.W.P. Munro, eds. *Ecosystem monitoring and protected areas*. Science and Management of Protected Areas Association, Wolfville, NS. 590 pp.
- GEIST, V. 1991. Phantom subspecies: The wood bison Bison bison Athabasca Rhoads 1897 is not a valid taxon, but an ecotype. *Arctic* 44:283-300.
- GIBEAU, M.L. 1993. Use of urban habitats by coyotes in the vicinity of Banff, Alberta. M.S. Thesis, University of Montana, Missoula, MT. 66 pp.
- GLOVER, R., ed. 1962. David Thompson's narrative, 1784-1812. The Champlain Society, Toronto, ON. 410 pp.
- GODDARD, P.E. 1916. The Beaver Indians. *Anthropol. Pap. Amer. Museum of Natural History* 10:201-293.
- GOMEZ-POMPA, A., and A. KAUS. 1992. Taming the wilderness myth. *Bioscience* 42:271-279.
- GOOD, K.R. 1987. Limiting factors in Amazonia ecology. Pages 407-421 in M. Harris, and E.B. Ross, eds. *Food and evolution: Toward a theory of human food habits*. Temple University Press, Philadelphia, PA. 633 pp.
- GORHAM, L., H. MIDDLETON, and G. OETELAAR. 1992. 1991 excavations at the Christensen Site, 360R, Banff National Park. Unpub. Draft Report on file, Archaeological Research Services Unit, Western Region Office, Canadian Parks Service, Calgary, AB. May. 147 pp. + appendices.
- GOTTESFELD, L.M.J. 1994. Aboriginal burning for vegetative management in northwest British Columbia. *Human Ecology* 22:171-188.

- GOULD, R.A. 1982. To have or have not: The ecology of sharing among hunter-gatherers. Pages 69-92 in N.M. Williams, and E.S. Hunn, eds. *Resource managers: North American and Australian hunter-gatherers*. AAAS Selected Symposium 67. 267 pp.
- GOULD, S.J. 1989. *Wonderful life: The Burgess Shale and the nature of history*. W.W. Norton Co., New York, NY. 347 pp.
- GRACE, J., and N. EASTERBEE. 1979. The natural shelter for red deer (*Cervus elaphus*) in a Scottish glen. *J. Appl. Ecol.* 16:37-48.
- GRANT, C. 1980. The desert bighorn and aboriginal man. Pages 7-40 in G. Monson, and L. Sumner, eds. *The desert bighorn*. University of Arizona Press, Tucson, AZ. 370 pp.
- GRANT, M.C. 1993. The trembling giant. *Discover* 14(10):82-89.
- GRANT, M.C., J.B. MITTON, and Y.B. LINHART. 1992. Even larger organisms. *Nature* 360:216.
- GRAYSON, D.K. 1978. Minimum numbers and sample size in vertebrate faunal analysis. *Amer. Antiq.* 43:53-65.
- GRAYSON, D.K. 1981. A critical view of the use of archaeological vertebrates in paleoenvironmental reconstruction. *J. Ethnobiol.* 1:28-38.
- GRAYSON, D.K. 1984. *Quantitative zooarchaeology*. Academic Press, NY. 202 pp.
- GRUELL, G.E. 1973. An ecological evaluation of Big Game Ridge. U.S. Forest Service, Intermountain Region, Ogden, UT. 62 pp.
- GRUELL, G.E. 1980a. Fire's influence on wildlife habitat on the Bridger-Teton National Forest, Wyoming. Vol. 1 - Photographic record and analysis. U.S. For. Ser. Res. Paper INT-235. 207 pp.
- GRUELL, G.E. 1980b. Fire's influence on wildlife habitat on the Bridger-Teton National Forest, Wyoming. Vol. 2 - Changes and causes, management implications. U.S. For. Ser. Res. Paper INT-252. 35 pp.
- GRUELL, G.E. 1983. Fire and vegetative trends in the northern Rockies: Interpretations from 1871-1982 photographs. U.S. For. Ser. Gen. Tech. Rep. INT-158. 117 pp.
- GRUELL, G.E. 1984. To burn or not to burn: A wildlife management dilemma. *Western Wildlands* 10(3):9-15.
- GRUELL, G.E. 1985. Indian fires in the interior West: A widespread influence. Pages 68-74 in J.E. Lotan, B.M. Kilgore, W.C. Fischer, and R.W. Mutch, eds. *Proceedings - symposium and workshop on wilderness fire*. U.S. For. Ser. Gen. Tech. Rep. INT-182. 434 pp.
- GRUELL, G.E. 1994. Understanding Sierra Nevada forests: Historical overview of Sierra Nevada forests provides insights to future. California Forces Projects Commission. 33 pp.
- GRUELL, G.E., AND L.L. LOOPE. 1974. Relationships among aspen, fire and ungulate browsing in Jackson Hole, Wyoming. U.S. For. Ser. Intermountain Region, Ogden, UT. 33 pp.
- GRUMBINE, R.E. 1994. What is ecosystem management? *Conser. Biol.* 8:27-38.

- GYSEL, L.W. 1960. An ecological study of the winter range of elk and mule deer in the Rocky Mountain National Park. *J. For.* 58:696-703.
- HABECK, J.R., and R.W. MUTCH. 1973. Fire dependent forests in the northern Rocky Mountains. *Quaternary Res.* 3:408-421
- HABER, G.C. 1977. Socio-ecological dynamics of wolves and prey in a subarctic ecosystem. Ph.D. Dissertation, University of British Columbia, Vancouver, BC. 786 pp.
- HAINES, A.L. 1974. Yellowstone National Park - its exploration and establishment. U.S. National Park Service, Washington, D.C. 218 pp.
- HAINES, A.L. 1977. The Yellowstone Story. Yellowstone Library and Museum Association in cooperation with Colorado Association University Press, Yellowstone Nat. Park, WY. Vol. 1. 385 pp.
- HALL, C.L. 1976. Archaeological investigations at the Whitehorse Creek rockshelter (FpQi-1): A preliminary report. *Archaeological Society of Alberta Newsletter* 32:1-17.
- HALLAM, S.J. 1975. Fire and hearth. Australian Institute of Aboriginal Studies, Canberra, Australia. 158 pp.
- HAMES, R. 1987. Game conservation or efficient hunting? Pages 92-107 in McCay, B.J., and J.M. Acheson, eds. *The question of commons*. University of Arizona Press, Tucson, AZ. 439 pp.
- HAMES, R.. 1991. Wildlife conservation in tribal societies. Pages 172-199 in Oldfield, M., and Alconn, J., eds. *Biodiversity; culture, conservation and ecodevelopment*. Westview Press, Boulder, CO. 349 pp.
- HAMM, J. 1989. Bows and arrows of the Native Americans. Lyons and Burford, New York, NY. 157 pp.
- HAMM, J., ed. 1992. The traditional bowyer's bible: Volume one. Lyons and Burford, New York, NY. 326 pp.
- HAMM, J., ed. 1993. The traditional bowyer's bible: Volume two. Lyons and Burford, New York, NY. 318 pp.
- HAMM, J., ed. 1994. The traditional bowyer's bible: Volume three. Lyons and Burford, New York, NY. 351 pp.
- HANSEN, H.L., L.W. KREFTING, AND V. KURMIS. 1973. The forest of Isle Royale in relation to fire history and wildlife. *Univ. Minn. Agr. Exp. Sta. Tech. Bull.* 294. 43 pp.
- HANSON, J.R. 1984. Bison ecology in the northern plains and a reconstruction of bison patterns for the North Dakota region. *Plains Anthropol.* 29(104):93-113.
- HARPER, K.T. 1985. Predicting successional rates in Utah aspen forests. Pages 96-100 in *Forester's future: Leaders or followers? - Proceedings of the 1985 Society of American Foresters National Convention*, Fort Collins, Colorado. Society of American Foresters, Bethesda, MD.
- HART, E.J. 1983. The selling of Canada: The CPR and the beginning of Canadian tourism. Altitude Publishing, Banff, AB. 180 pp.

- HART, J.H. 1986. Relationships among aspen, fungi, and ungulate browsing in Colorado and Wyoming. Unpub. Rep., Michigan State University, East Lansing, MI. 71 pp.
- HART, R.H., and W.A. LAYCOCK. 1996. Repeat photography on range and forest lands in the western United States. *J. Range Manage.* 49:60-67.
- HASTINGS, J.R., and R.M. TURNER. 1980. *The changing mile*. University of Arizona Press, Tucson, AZ. 317 pp.
- HAWKES, B.C. 1979. Fire history and fuel appraisal of Kananaskis Provincial Park, Alberta. M.S. Thesis, University of Alberta, Edmonton, AB. 172 pp.
- HAWKES, B.C. 1980. Fire history of Kananaskis Provincial Park-- mean fire return intervals. Pages 42-45 in M.A. Stokes, and J.H. Dieterich, eds. *Proceedings of the fire history workshop*. U.S. For. Ser. Gen. Tech. Rep. RM-81.
- HAWKES, B.C. 1990. Wilderness fire management in Canada: Some new approaches to natural areas. *Western Wildlands* 16(2):30-34.
- HAWKES, K. 1987. How much food do foragers need? Pages 341-355 in M. Harris, and E.B. Ross, eds. *Food and evolution*. Temple University Press, Philadelphia, PA. 394 pp.
- HAWKES, K., and J.F. O'CONNELL. 1981. Affluent hunters? Some comments in light of the Alyawara case. *Amer. Anthropol.* 83:622-626.
- HAWKES, K., J.F. O'CONNELL, K. HILL, and E.L. CHARNOV. 1985. How much is enough? Hunters and limited needs. *Ethnol. and Sociobiol.* 6:3-15.
- HAYDEN, B. 1981. Subsistence and ecological adaptations of modern hunter/gatherers. Pages 344-421 in R.S.O. Harding, and G. Teleki, eds. *Omnivorous primates*. Columbia University Press, NY. 676 pp.
- HAYDEN, F.V. 1872. Preliminary report of the United States geological survey of Montana and portions of adjacent territories; being a fifth annual report of progress. 42nd Congr., 2nd Sess., House Exec. Doc. No. 326. Serial 1520. 570 pp.
- HAYDEN, F.V. 1873. Sixth annual report of the United States geological survey of the territories, embracing portions of Montana, Idaho, Wyoming, and Utah; being a report of progress of the explorations for the year 1872. 42nd Congr., 3rd Sess., House Misc. Doc. No. 112. Serial 1573.
- HEAD, T.H. 1987. Archaeological resource assessments -- Jasper National Park. Environment Canada, Canadian Parks Service Microfiche Report Series 341. 152 pp.
- HEADY, H., and P. ZINKE. 1978. Vegetational changes in Yosemite Valley. National Park Service Occ. Pap. 5. U.S. Government Printing Office, Washington, D.C. 25 pp.
- HEATHCOTT, M.J., and J.C. WIERZCHOWSKI. 1996. Lightning fire in the mountain park window, 50-54°N by 114-120° W, 1961-1994. Unpub. Tech. Rep., Parks Canada, Ottawa, ON. 8 pp.
- HEINEN, J., and B. LOW. 1992. Human behavioral ecology and environmental conservation. *Environ. Conser.* 19:105-116.
- HEINSELMAN, M.L. 1973. Fire in the virgin forests of the Boundary Waters Canoe Area. *Quaternary Res.* 3:408-424.

- HENDRY, A. 1907. York Factory to the Blackfeet Country: The journal of Anthony Hendry, 1754-55. Edited by L.J. Brupee. Transactions of the Royal Society of Canada. Third Series – 1907-1908. Vol. I (Sec. 2):307-364.
- HENRY, J.D., S. MCCANNY, and M. RAILLARD. 1995. The mandate for integrity: Ecological monitoring in the prairie and northern national parks of Canada. Pages 141-153 in Herman, T.B., S. Bondrup-Nielsen, J.H.M. Willison, and N.W.P. Munro, eds. Ecosystem monitoring and protected areas. Science and Management of Protected Areas Association, Wolfville, NS. 590 pp.
- HESS, K., JR. 1993. Rocky times in Rocky Mountain National Park: An unnatural history. University Press of Colorado, Niwot, CO. 167 pp.
- HICKERSON, H. 1965. The Virginia deer and intertribal buffer zones in the upper Mississippi Valley. Pages 43-65 in Leeds, A., and A.P. Vayda, eds. Man, culture and animals: The role of animals in human ecological adjustments. Amer. Assoc. for the Adv. of Sci. Pub. No. 78.
- HIND, H.Y. 1971. Narrative of the Canadian Red River exploring expedition of 1857 and the Assiniboine and Saskatchewan exploring expeditions of 1858. Reprint of 1860 edition by Charles E. Tuttle Co., Rutland, VT. Vol. I:1-494, Vol. II:1-472.
- HINDS, T.E. 1985. Diseases. Pages 87-106 in DeByle, N.V., and R.P. Winokur, eds. Aspen: Ecology and management in the western United States. U.S. For. Ser. Gen. Tech. Rep. RM-119. 283 pp.
- HODGINS, D. 1994. Opportunities or barriers: Science and research issues in Canadian national parks. Pages 203-209 in Skibicki, A., A. Stadel, D. Welch, and J.G. Nelson, eds. Ecological monitoring and national parks. University of Waterloo Heritage Resources Centre Working Paper No. 7. 373 pp.
- HOFFMAN, G.R., AND R.A. ALEXANDER. 1980. Forest vegetation of the Routt National Forest in northwestern Colorado: A habitat type classification. U.S. For. Ser. Res. Paper. RM-221. 42 pp.
- HOLLAND, D.G. 1986. The role of forest insects and diseases in the Yellowstone Ecosystem. Western Wildlands 12(3):19-23.
- HOLLAND, W.D., and G.M. COEN, eds. 1982. Ecological (biophysical) land classification of Banff and Jasper National Parks. Volume II: Soil and vegetation resources. Alberta Institute of Pedology Pub. SS-82-44. 540 pp.
- HOLROYD, G.S., and K.J. VAN TICHEM. 1983. Ecological (biophysical) land classification of Banff and Jasper National Parks. Volume III: The wildlife inventory. Canadian Wildlife Service report to Parks Canada, Calgary, AB. 444 pp.
- HOUSTON, D.B. 1973. Wild fires in northern Yellowstone National Park. Ecology 54:1111-1117.
- HOUSTON, D.B. 1982. The northern Yellowstone elk: Ecology and management. MacMillan Pub., New York, NY. 474 pp.
- HUCKABY, L.S., and W.H. MOIR. 1995. Fire history of subalpine forests at Fraser Experimental Forests, Colorado. Pages 205-210 in Brown, J.K., R.W. Mutch, C.W. Spoon, and R.H. Wakimoto, eds. Proceedings: Symposium on fire in wilderness and park management. U.S. For. Ser. Gen. Tech. Rep. INT-320. 283 pp.

- HUDSON, R.J., and S. FRANK. 1987. Foraging ecology of bison in aspen boreal habitats. *J. Range Manage.* 40:71-75.
- HUDSON'S BAY COMPANY. 1828-1831. Jasper House Journals 1828-1831. Unpublished manuscript journals on file with the Hudson's Bay Company Archives in the Provincial Archives of Manitoba, Winnipeg, MB. B.94/a/1, B.94/a/2, B.94/a/3.
- HUGGARD, D.J. 1993a. Prey selectivity of wolves in Banff National Park. I. Prey species. *Can. J. Zool.* 71:130-139.
- HUGGARD, D.J. 1993b. Prey selectivity of wolves in Banff National Park. II. Age, sex, and condition of elk. *Can. J. Zool.* 71:140-147.
- HUGGARD, D.J. 1993c. Effect of snow depth on predation and scavenging by gray wolves. *J. Wildl. Manage.* 57:382-388.
- JANZ, B., and N. NIMCHUK. 1985. The 500 mb anomaly chart- a useful fire management tool. In *Proceedings Eighth Conference on Fire and Forest Meteorology*. Society of American Foresters Pub. 85-04. Bethesda, MD.
- JELINSKI, D.E., AND W.M. CHELIAK. 1992. Genetic diversity and spatial subdivision of Populus tremuloides (Salicaceae) in a heterogenous landscape. *Amer. J. Bot.* 79:728-736.
- JENKINS, K.J., and R.G. WRIGHT. 1988. Resource partitioning and competition among cervids in the northern Rocky Mountains. *J. Appl. Ecol.* 25:11-24.
- JEZIERSKI, W., and Z. KUCZAWSKI. 1987. The dependence of tapping of deciduous trees on the population density of moose. *Swedish Wildl. Res. Suppl.* 1:757-760.
- JOHNS, B.W. 1993. The influence of grove size on bird species richness in aspen parklands. *Wilson Bull.* 105:256-264.
- JOHNSON, E.A. 1992. *Fire and vegetation dynamics: Studies from the North American boreal forest*. Cambridge University Press, Cambridge, MA. 129 pp.
- JOHNSON, E.A., and C.E. VAN WAGNER. 1985. The theory and use of two fire history models. *Can. J. For. Res.* 15:214-220.
- JOHNSON, E.A., and C.P.S. LARSON. 1991. Climatically induced change in fire frequency in the southern Canadian Rockies. *Ecology* 72:194-201.
- JOHNSON, E.A., and D.R. WOWCHUK. 1993. Wildfires in the southern Canadian Rocky Mountains and their relationship to mid-tropospheric anomalies. *Can. J. For. Res.* 23:1213-1222.
- JOHNSON, E.A., and G.I. FRYER. 1987. Historical vegetation change in the Kananaskis Valley, Canadian Rockies. *Can. J. Bot.* 65:853-858.
- JOHNSON, E.A., and G.I. FRYER. 1989. Population dynamics in lodgepole pine-Engelmann spruce forests. *Ecology* 70:1335-1345.
- JOHNSON, E.A., G.I. FRYER, and M.J. HEATHCOTT. 1990. The influence of man and climate on frequency of fire in the interior wet belt forest, British Columbia. *J. Ecol.* 78:403-412.

- JOHNSON, E.A., K. MIYANISHI, and J.M.H. WEIR. 1995. Old-growth, disturbance, and ecosystem management. *Can. J. Bot.* 73:918-926.
- JOHNSON, E.A., and S.L. GUTSELL. 1994. Fire frequency models, methods and interpretations. *Adv. Ecol. Res.* 25:239-287.
- JOHNSON, K.L. 1987. Rangeland through time. University of Wyoming Agr. Exp. Sta. Misc. Pub. 50. 188 pp.
- JONES, J.R., and N.V. DEBYLE. 1985. Fire. Pages 77-81 in DeByle, N.V., and R.P. Winokur, eds. *Aspen: Ecology and management in the western United States*. U.S. For. Ser. Gen. Tech. Rep. RM-119. 283 pp.
- KANE, P. 1968. Wanderings of an artist among the Indians of North America from Canada to Vancouver's Island and Oregon through the Hudson's Bay Company's territory and back again. Reprinted by M.G. Hurtig, Edmonton, AB. Originally published in 1859 by Longman's, Green, and Co., London, UK. 455 pp.
- KAY, C.E. 1985. Aspen reproduction in the Yellowstone Park-Jackson Hole area and its relationship to the natural regulation of ungulates. Pages 131-160 in G.W. Workman, ed. *Western elk management: A symposium*. Utah State University, Logan, UT. 213 pp.
- KAY, C.E. 1987. Too many elk in Yellowstone? *Western Wildlands* 13(3):39-41, 44.
- KAY, C.E. 1990. Yellowstone's northern elk herd: A critical evaluation of the "natural regulation" paradigm. Ph.D. Dissertation, Utah State University, Logan, UT. 490 pp.
- KAY, C.E. 1992. Book review -- The Jackson Hole elk herd: Intensive wildlife management in North America. *J. Range Manage.* 45:315-316.
- KAY, C.E. 1993. Aspen seedlings in recently burned areas in Grand Teton and Yellowstone National Parks. *Northwest Sci.* 67:94-104.
- KAY, C.E. 1994. Aboriginal Overkill: The role of Native Americans in structuring western ecosystems. *Human Nature* 5:359-396.
- KAY, C.E. 1995a. Aboriginal overkill and native burning: Implications for modern ecosystem management. *West. J. App. For.* 10:121-126.
- KAY, C.E. 1995b. Browsing by native ungulates: Effects on shrub and seed production in the Greater Yellowstone Ecosystem. Pages 310-320 in Roundy, B.A., E.D. McArthur, J.S. Haley, and D.K. Mann, eds. *Proceedings: Wildland shrub and arid land restoration symposium*. U.S. For. Ser. Gen. Tech. Rep. INT-GRR-315. 384 pp.
- KAY, C.E. 1996. The condition and trend of aspen communities in Kootenay and Yoho National Parks: Implications for ecosystem management and ecological integrity. Unpub. report on file Kootenay Warden Office, Kootenay National Park, Radium Hot Springs, BC and Yoho Warden Office, Yoho National Park, Field, BC. 173 pp. + appendices.
- KAY, C.E. In Press a. An alternative interpretation of the historical evidence relating to the abundance of wolves in the Yellowstone Ecosystem. Paper presented at the Second North American symposium on wolves: Their status, biology, and management. University of Alberta, Edmonton, AB. August 25-27, 1992.

- LEWIS, M., and W. CLARK. 1893. The history of the Lewis and Clark expedition. Edited by E. Coues originally published by Francis P. Harper, New York, NY. Republished in 1964 by Dover Publications, NY. Vol. I:1-352, Vol. II:353-820, Vol. III:821-1364.
- LIBERMAN, K. 1990. The native environment: Contemporary perspectives of southwestern Oregon's Native Americans. Pages 85-93 in Hannon, N., and R.K. Olmo, eds. *Living with the land: The Indians of southwest Oregon*. Southern Oregon Historical Society, Medford, OR. 153 pp.
- LIEBERMAN, L.S. 1987. Biocultural consequences of animals versus plants as sources of fats, proteins, and other nutrients. Pages 225-258 in M. Harris, and E.B. Ross, eds. *Food and evolution: Toward a theory of human food habits*. Temple University Press, Philadelphia, PA. 633 pp.
- LIEFF, B.C. 1992. A new direction for science in the Canadian Parks Service, Western Region. Pages 203-204 in Willison, J.H.M., S. Bondrup-Nielsen, C. Drysdale, T.B. Herman, N.W.P. Munro, and T.L. Pollock, eds. *Science and the management of protected areas*. Elsevier, New York, NY. 548 pp.
- LIGHT, J.A. 1985. Final report: Excavations at FgQe-11, mitigation of the Luscar Sterco Coal Valley mine disturbance in pit 42-1 (ASA permit 85-70). Unpub. consultant's report (Aresco Ltd.) on file at Archaeology Survey of Alberta, Edmonton, AB. 25 pp.
- LOPOUKHINE, N. 1985. Guiding philosophy in fire and vegetation management in Canadian parks. Pages 16-20 in Lotan, J.E., B.M. Kigore, W.C. Fischer, and R.W. Mutch, eds. *Proceedings: Symposium and workshop on wilderness fire*. U.S. Forest Service Gen. Tech. Rep. INT-182. 434 pp.
- LOPOUKHINE, N. 1993. A Canadian approach to fire management in national parks. *Renewable Res. J.* 17:17-18.
- LORIMER, C.G. 1985. Methodological considerations in the analysis of forest disturbance history. *Can. J. For. Res.* 15:200-213.
- LOSCHIEDER, M.A. 1977. Use of fire in interethnic and intraethnic relations on the northern plains. *Western Canadian J. Anthropol.* 7(4):82-96.
- LOVESETH, B.A., B.O.K. REEVES, and T. SMITH. 1979. Archaeological test excavations and evaluations proposed Alaska gas pipeline system southeastern British Columbia. Unpub. Rep. on file, Heritage Conservation Branch, Victoria, BC. Permit 1978-28. 166 pp.
- LUCKMAN, B.H. 1990. Mountain areas and global change - a view from the Canadian Rockies. *Mountain Research and Development* 10:183-195.
- LUCKMAN, B.H. 1992. Glacier and dendrochronological records for the Little Ice Age in the Canadian Rocky Mountains. Pages 78-80 in T. Mikami, ed., *Proceedings of the international conference on the Little Ice Age climate*. Tokyo Metropolitan University, Tokyo, Japan.
- LUCKMAN, B.H. 1993. Glacier fluctuation and tree-ring records for the last millennium in the Canadian Rockies. *Quaternary Science Reviews* 16:441-450.
- LUCKMAN, B.H., and E.D. SEED. 1995. Fire-climate relationships and trends in the mountain national parks. Unpub. rep. on file with Fire Management Office, Parks Canada, Hull, ON. June 22nd. 204 pp.

- LUDLOW, W. 1875. Report of a reconnaissance of the Black Hills of South Dakota made in the summer of 1874. Engineer Dep., U.S. Army. Government Printing Office, Washington, D.C. 121 pp.
- LYMAN, R.L. 1982. Archaeofaunas and subsistence studies. *Advances in Archaeol. Method and Theory* 5:331-343.
- LYMAN, R.L. 1987a. Archaeofaunas and butchery studies: A taphonomic perspective. *Advances in Archaeol. Method and Theory* 10:249-337.
- LYMAN, R.L. 1987b. Zooarchaeology and taphonomy: A general consideration. *J. Ethnobiol.* 7:93-117.
- LYNCH, D. 1955. Ecology of the aspen groveland in Glacier County, Montana. *Ecol. Monogr.* 25:321-344.
- LYON, L.J. 1979a. Habitat effectiveness for elk as influenced by roads and cover. *J. For.* 77:658-660.
- LYON, L.J. 1979b. Influences of logging and weather on elk distribution in western Montana. U.S. For. Ser. Res. Paper INT-236. 11 pp.
- LYON, L.J. 1980. Coordinating forestry and elk management. *Trans. N. Amer. Wildl. and Nat. Res. Conf.* 45:278-286.
- LYON, L.J. 1983. Road density models describing habitat effectiveness for elk. *J. For.* 81:592-595.
- LYON, L.J., T.N. LONNER, J.P. WEIGAND, C.L. MARCUM, W.D. EDGE, J.D. JONES, D.W. MCCLEEREY, and L.L. HICKS. 1985. Coordinating elk and timber management. Final report of the Montana cooperative elk-logging study, 1970-1985. Montana Department of Fish, Wildlife, and Parks, Helena, MT. 53 pp.
- MCCABE, R.E. 1982. Elk and Indians: Historical values and perspective. Pages 61-123 J.W. Thomas, and D.E. Towell, eds. *Elk of North America: Ecology and management*. Wildlife Management Institute and Stackpole Books, Harrisburg, PA. 698 pp.
- MCCABE, R.E., and T.R. MCCABE. 1984. Of slings and arrows: A historical retrospection. Pages 19-72 in L.K. Halls, ed. *White-tailed deer: Ecology and management*. Wildlife Management institute and Stackpole Books, Harrisburg, PA. 870 pp.
- MCCARTNEY, D.H. 1993. History of grazing research in the aspen parkland. *Can. J. Anim. Sci.* 73:749-763.
- MCCAY, B.J., AND J.M. ACHESON, eds. 1987. *The question of the commons: The culture and ecology of communal resources*. University of Arizona Press, Tucson, AZ. 439 pp.
- MCCORMACK, P.A. 1992. The political economy of bison management in Wood Buffalo National Park. *Arctic* 45:367-380.
- MCCORQUODALE, S.M. 1987a. The desert elk of Washington. *Bugle* 4(2):30-31.
- MCCORQUODALE, S.M. 1987b. Fall-winter habitat use by elk in the shrub-steppe of Washington. *Northwest Sci.* 61:171-173.
- MCCORQUODALE, S.M. 1991. Energetic considerations and habitat quality for elk in arid grasslands and coniferous forests. *J. Wildl. Manage.* 55:237-242.

- MCCORQUODALE, S.M. 1993. Winter foraging behavior of elk in the shrub-steppe of Washington. *J. Wildl. Manage.* 57:881-890.
- MCCORQUODALE, S.M. 1995. The formula for trophy elk. *Bugle* 12(4):27-32.
- MCCORQUODALE, S.M., K.J. RAEDEKE, AND R.D. TABER. 1986. Elk habitat use patterns in the shrub-steppe of Washington. *J. Wildl. Manage.* 50:664-669.
- MCCORQUODALE, S.M., K.J. RAEDEKE, AND R.D. TABER. 1989a. Home ranges of elk in an arid environment. *Northwest Sci.* 63:29-34.
- MCCORQUODALE, S.M., L.E. EBERHARDT, AND G.A. SARGEANT. 1989b. Antler characteristics in a colonizing elk population. *J. Wildl. Manage.* 53:618-621.
- MCCORQUODALE, S.M., L.L. EBERHARDT, AND L.E. EBERHARDT. 1988. Dynamics of a colonizing elk population. *J. Wildl. Manage.* 52:309-313.
- MCCULLAGH, C.B. 1987. The truth of historical narratives. *History and Theory (Beiheft)* 26:30-45.
- MCCULLOUGH, D.R. 1971. The tule elk: Its history, behavior, and ecology. *Univ. Calif. Publ. Zool.* 88. 191 pp.
- MCCULLOUGH, E.J., and G.J. FEDIRCHUK. 1986. Organizing eastern slopes prehistory: A suggested method. *Archaeol. Survey of Alberta Occ. Pap.* 30:21-24.
- MCCUNE, B. 1983. Fire frequency reduced two orders of magnitude in the Bitterroot Canyons, Montana. *Can. J. For. Res.* 13:212-218.
- MCDONALD, J.N. 1981. North American bison: Their classification and evolution. University of California Press, Berkeley, CA. 316 pp.
- MCDONOUGH, W.T. 1979. Quaking aspen seed germination and early seedling growth. *U.S. For. Ser. Res. Paper INT-234.* 13 pp.
- MCDONOUGH, W.T. 1985. Sexual reproduction, seeds and seedlings. Pages 25-28 in N.V. DeByle, and R.P. Winokur, eds. *Aspen: Ecology and management in the western United States.* U.S. For. Ser. Gen Tech. Rep. RM-119. 283 pp.
- MACGREGOR, J.G. 1966. Peter Fidler: Canada's forgotten surveyor 1769-1822. McClelland and Stewart Ltd., Toronto, ON. 265 pp.
- MCINNES, P.F., R.J. NAIMAN, J. PASTOR, AND Y. COHEN. 1992. Effects of moose browsing on vegetation and litter of the boreal forest, Isle Royale, Michigan, U.S.A. *Ecology* 73:2059-2075.
- MCKENZIE, G.A. 1973. The fire ecology of the forests of Waterton Lakes National Park. M.S. Thesis, University of Calgary, Calgary, AB. 199 pp.
- MCKENZIE, K.H. 1976a. Report of archaeological investigations of two southeastern British Columbia sites, near the headwaters of the Columbia River. Unpub. Rep. on file, Heritage Conservation Branch, Victoria, BC. Permit 1975-12. 50 pp.
- MCKENZIE, K.H. 1976b. Preliminary report of archaeological investigation at site EcPx-5. Unpub. Rep. on file, Heritage Conservation Branch, Victoria, BC. Permit 1976-16. 40 pp.

- MCLEAN, H. 1993. Romancing the clone. *Amer. Forests* 99(3):8.
- MCNAMEE, K. 1994. Ecological monitoring in national parks: The perspective of the Canadian Nature Federation. Pages 171-174 in Skibicki, A., A. Stadel, D. Welch, and J.G. Nelson, eds. *Ecological monitoring and national parks*. University of Waterloo Heritage Resources Centre Working Paper No. 7. 373 pp.
- MADSEN, D.B. In press. The Silver Lake expedition: Anthropological archaeology in the Bonneville Basin. *University of Utah Anthropological Papers*.
- MAINI, J.S. 1960. Invasion of grassland by Populus tremuloides in the northern Great Plains. Ph.D. Thesis, University of Saskatchewan, Saskatoon, SK. 231 pp.
- MARSHALL, F., and T. PILGRAM. 1993. NISP vs. MNI in quantification of body-part representation. *Amer. Antiquity* 58:261-269.
- MASTERS, A.M. 1989. Forest fire history of Kootenay National Park, British Columbia. Unpub. report on file at Warden Office, Kootenay National Park, Radium BC. 55 pp. + maps.
- MASTERS, A.M. 1990. Changes in forest fire frequency in Kootenay National Park, Canadian Rockies. *Can. J. Bot.* 68:1763-1767.
- MAXIMILLIAN, PRINCE OF WEID. 1966. Travels in the Interior of North America, 1832-1834. In Thwaites, R.G., ed. *Early western travels*. Reprint of 1906 edition by AMS Press, NY. Vol. 22:1-393, Vol. 23:1-305, Vol. 24:1-346, Vol. 25:81 plates.
- MEAGHER, M.M. 1973. The bison of Yellowstone National Park. *National Park Service Science Monogr. Series No. 1*. 161 pp.
- MECH, L.D. 1970. The wolf: The ecology and behavior of an endangered species. *Natural History Press*, Garden City, NY. 384 pp.
- MECH, L.D. 1977. Wolf-pack buffer zones as prey reservoirs. *Science* 198:320-321.
- MERK, F., ed. 1931. Fur trade and empire: George Simpson's journal -- remarks connected with the fur trade in the course of a voyage from York Factory to Fort George and back to York Factory 1824-25; together with accompanying documents. *Harvard University Press*, Cambridge, MA. 370 pp.
- MERRIAM, H.R. 1964. The wolves of Coronation Island. *Proc. Alaska Sci. Conf.* 15:27-32.
- MESSIER, F. 1989a. Towards understanding the relationship between wolf predation and moose density in southwestern Quebec. Pages 13-25 in *Wolf-prey dynamics and management*. Wildlife Branch, British Columbia Ministry of Environment, Victoria. Wildlife Working Report WR-40. 180 pp.
- MESSIER, F. 1989b. Effect of bison population changes on wolf-prey dynamics in and around Wood Buffalo National Park. Report prepared on behalf of Federal Environmental Assessment Review Office, Environment Canada and Northern Diseased Bison Environmental Assessment Panel. Oct 5. 29 pp.
- MESSIER, F. 1991. The significance of limiting and regulating factors on the demography of moose and white-tailed deer. *J. Animal Ecol.* 60:377-393.

- MESSIER, F. 1994. Ungulate population models with predation: A case study with the North American moose. *Ecology* 75:478-488.
- METCALFE, D., and K.T. JONES. 1988. A reconsideration of animal body-part utility indices. *Amer. Antiq.* 53:486-504.
- METCALFE, D., and K.R. BARLOW. 1992. A model for exploring the optimal trade-off between field processing and transport. *Amer. Anthropol.* 94:340-356.
- MILLAR, W.N. 1915. Game preservation in the Rocky Mountains Forest Reserve. Department of the Interior, Canada. Forestry Branch Bull. No. 51. 69 pp.
- MILLS, L.S., M.E. SOULE, and D.F. DOAK. 1993. The keystone-species concept in ecology and conservation. *Bioscience* 43:219-224.
- MILNER, B.J. 1977. Vegetation analysis of ungulate range exclosures, Elk Island National Park. Canadian Wildlife Service, Edmonton, AB. 95 pp.
- MILTON, W.F., AND W.B. CHEADLE. 1865. The north-west passage by land. Cassell, Petter and Galpin, London, UK. Reprinted by Coles Pub., Toronto, ON. 1970. 400 pp.
- MINNICH, R.A., M.G. BARBOUR, J.H. BURK, and R.F. FERNAU. 1995. Sixty years of change in Californian conifer forests of the San Bernardino Mountains. *Conser. Biol.* 9:902-914.
- MITTON, J.B., and M.C. GRANT. 1996. Genetic variation and the natural history of quaking aspen. *Bioscience* 46:25-31.
- MIYAGAWA, R.S. 1974. Fire incidence 1961-1970. Alberta Energy and Natural Resources, Edmonton, AB. Forest Service Res. Note 14. 28 pp.
- MOBERLY, W. 1871-1872. Manuscript diary July 25, 1871 to January 21, 1872. Unpublished manuscript diary on file with the Provincial Archives of British Columbia, Victoria, BC.
- MOBERLY, W. 1872-1873. Manuscript diary April 19, 1872 to February 16, 1873. Unpublished manuscript diary on file with the Provincial Archives of British Columbia, Victoria, BC.
- MOEN, A.N. 1982. The biology and management of wild ruminants. Part V: Meteorology and thermal relationships of wild ruminants. Cornerbook Press, Lansing, NY. 147 pp.
- MOEN, A.N., and F.L. JACOBSEN. 1974. Changes in radiant temperature of animal surfaces with wind and radiation. *J. Wildl. Manage.* 38:366-368.
- MOHS, G. 1981. Archaeological investigation of a Kutenai Indian encampment. Unpub Rep. on file, Heritage Conservation Branch, Victoria, BC. Permit 1980-5. 109 pp.
- MOODIE, D.W., AND A.J. RAY. 1976. Buffalo migrations in the Canadian plains. *Plains Anthropol.* 21(71):45-52.
- MORGAN, R.G. 1980. Bison movement patterns on the Canadian plains: An ecological analysis. *Plains Anthropol.* 25(88 part 1):143-160.
- MORGANTINI, L.E. 1995. The Ya Ha Tinda: An ecological overview. Unpub. rep. on file Canadian Heritage, Parks Canada Alberta Regional Office, Calgary, AB. June. 110 pp.

- MOSS, E.H. 1932. The vegetation of Alberta. 4. The poplar association and related vegetation of central Alberta. *J. Ecol.* 20:380-415.
- MUEGGLER, W.F. 1976. Type variability and succession in Rocky Mountain aspen. Pages 16-20 in Utilization and marketing as tools for aspen management in the Rocky Mountains. U.S. For. Ser. Gen. Tech. Rep. RM-29. 120 pp.
- MUEGGLER, W.F. 1985. Vegetation associations. Pages 45-55 in DeByle, N.V., and R.P. Winokur, eds. Aspen: Ecology and management in the western United States. U.S. For. Ser. Gen. Tech. Rep. RM-119. 283 pp.
- MUEGGLER, W.F. 1988. Aspen community types of the Intermountain region. U.S. For. Ser. Gen. Tech. Rep. INT-250. 135 pp.
- MUEGGLER, W.F. 1989. Age distribution and reproduction of Intermountain aspen stands. *West. J. Appl. For.* 4:41-45.
- MUEGGLER, W.F., and D.L. BARTOS. 1977. Grindstone Flat and Big Flat exclosures - a 41-year record of changes in clearcut aspen communities. U.S. For. Ser. Res. Paper INT-195. 16 pp.
- MUEGGLER, W.F., and R.B. CAMPBELL, JR. 1982. Aspen community types on the Caribou and Targhee National Forests in southeastern Idaho. U.S. For. Ser. Res. Paper INT-294. 32 pp.
- MUEGGLER, W.F., and R.B. CAMPBELL, JR. 1986. Aspen community types in Utah. U.S. For. Ser. Res. Paper INT-362. 69 pp.
- MURIE, A. 1934. The moose of Isle Royale. University of Michigan Museum of Zoology Misc. Pub. 25. 44 pp.
- MURIE, A. 1940. Ecology of the coyote in the Yellowstone. National Park Service Fauna Series 4. 206 pp.
- MURPHY, P.J. 1985a. History of forest and prairie fire control policy in Alberta. Alberta Energy and Natural Resources Forest Service, Edmonton, AB. ENR Report T/77. 408 pp.
- MURPHY, P.J. 1985b. Methods for evaluating the effects of forest fire management in Alberta. Ph.D. Dissertation, University of British Columbia, Vancouver, BC. 167 pp.
- NASH, C.H. and E.A. JOHNSON. 1993. Temporal and spatial distribution of cloud-to-ground lightning strikes in the southern Canadian Rocky Mountains and adjacent plains as related to the fire season. *Bull. Ecol. Soc. of Amer.* 74:372.
- NELSON, J.G. 1969a. Some observations on animals, landscape, and man, in the Bow Valley Area: c. 1750-1885. Pages 219-237 in J.G. Nelson, and M.J. Chambers, eds. Vegetation, soils, and wildlife. Methuen, Toronto, ON.
- NELSON, J.G. 1969b. Land use history, landscape change and planning problems in Banff National Park. *I.U.C.N. Bull.* 2(10):80-82.
- NELSON, J.G. 1970. Man and landscape change in Banff National Park: A national park problem in perspective. Pages 63-96 in J.G. Nelson, ed. The Canadian parks in perspective. Harvest House, Montreal, PQ.

- NELSON, J.G., L.D. CORDES, and W.J. MASYK. 1972. The proposed plans for Banff National Park: Some criticisms and an alternative. *Canadian Geographer* 16(1):29-49.
- NELSON, J.R., and T.A. LEEGE. 1982. Nutritional requirements and food habits. Pages 323-367 in J.S. Thomas, and D.E. Towell, eds. *Elk of North America: Ecology and management*. Stackpole Books, Harrisburg, PA. 698 pp.
- NIMCHUK, N. 1983. Wildfire behavior associated with upper ridge breakdown. Alberta Energy and Natural Resources Tech. Rep. T/50. Edmonton, AB. 45 pp.
- NOBLE, I.R., and R.O. SLATYER. 1980. The use of vital attributes to predict successional changes in plant communities subject to recurrent disturbances. *Vegetatio* 43:5-21.
- NORTON, H.H. 1979. The association between anthropogenic prairies and important food plants in western Washington. *Northwest Anthropol. Res. Notes* 13:175-200.
- NORTON-GRIFFITHS, M. 1979. The influence of grazing, browsing, and fire on the vegetation dynamics of the Serengeti. Pages 310-352 in Sinclair, A.R.E., and M. Norton-Griffiths, eds. *Serengeti: Dynamics of an ecosystem*. University of Chicago Press, Chicago, IL. 389 pp.
- OAKLEAF, R.J., C. MASSER, and T. NAPPE. 1983. Livestock and nongame wildlife. Pages 95-102 in J.W. Menke, ed. *Proceedings of the workshop on livestock and wildlife-fisheries relationships in the Great Basin*. University of California Special Pub. 3301. 173 pp.
- O'BRIEN, D.M. 1969. Occurrence of lightning caused fires in Glacier National Park, 1910-1968. U.S. National Parks Service, West Glacier, MT. 28 pp.
- O'CONNELL, J.F., K. HAWKES, and N. BLURTON-JONES. 1988. Hadza hunting, butchering, and bone transport and their archaeological implications. *J. Anthropol. Res.* 44:113-161.
- O'CONNELL, J.F., K. HAWKES, and N. BLURTON-JONES. 1990. Reanalysis of large mammal body part transport among the Hadza. *J. Archaeol. Sci.* 17:301-316.
- OLMSTED, C.E. 1977. The effect of large herbivores on aspen in Rocky Mountain National Park. Ph.D. Dissertation, University of Colorado, Boulder, CO. 136 pp.
- OLMSTED, C.E. 1979. The ecology of aspen with reference to utilization by large herbivores in Rocky Mountain National Park. Pages 89-97 in Boyce, M.S., and L.D. Hayden-Wing, eds. *North American elk: Ecology, behavior, and management*. University of Wyoming, Laramie, WY. 294 pp.
- OLSON, B.D. 1994. Alberta's prairie vegetation: Past and present use. *Rangelands* 16:58-62.
- OLSON, D.L. 1983. A descriptive analysis of the faunal remains from the Miller site, Franklin County, Washington. M.A. Thesis, Washington State University, Pullman, WA. 147 pp.
- OMI, P.N. 1989. Lessons from fires of 1988. *Forum Appl. Res. Publ. Policy* 4:41-45.
- OMI, P.N., and K.D. KALABOKIDIS. 1991. Fire damage on extensively vs. intensively managed forest stands within the North Fork Fire, 1988. *Northwest Sci.* 65:149-157.
- OSBORN, G.D., and B.H. LUCKMAN. 1988. Holocene glacier fluctuations in the Canadian Cordillera (Alberta and British Columbia). *Quaternary Science Reviews* 7:115-128.

- PACAS, C., J. GREEN, and S. BAYLEY, eds. 1995. Ecological outlook: Cumulative effects assessment and futures modeling – Workshop 1, summary report. Banff-Bow Valley Task Force, Banff, AB. 27 pp.
- PAGE, J.L., N. DODD, T.O. OSBORNE, and J.A. CARSON. 1978. The influence of livestock grazing on non-game wildlife. *Cal.-Nev. Wildl.* 1978:159-173.
- PALLISER, J. 1863. The journals, detailed reports, and observations relative to the exploration by Captain Palliser of a portion of British North America, which in latitude, lies between the British boundary line and the height of land or watershed of the northern or frozen ocean respectively and longitude between the western shore of Lake Superior and the Pacific Ocean during the years 1857, 1858, 1859, and 1860. London, UK.
- PALLISER, J. 1969. Solitary rambles and adventures of a hunter in the prairies. Charles E. Tuttle Co., Rutland, VT. 326 pp.
- PAQUET, P.C. 1993. Summary reference document: Ecological studies of recolonizing wolves in the Central Canadian Rocky Mountains. John/Paul and Associates report to Parks Canada, Banff National Park, Banff, AB. 215 pp.
- PARKER, K.L., C.T. ROBBINS, and T.A. HANLEY. 1984. Energy expenditures for locomotion by mule deer and elk. *J. Wildl. Manage.* 48:474-488.
- PASTOR, J., AND R.J. NAIMAN. 1992. Selective foraging and ecosystem processes in boreal forests. *Amer. Nat.* 139:690-705.
- PASTOR, J., B. DEWEY, R.J. NAIMAN, P.F. MCINNES, AND Y. COHEN. 1993. Moose browsing and soil fertility in the boreal forests of Isle Royale National Park. *Ecology* 74:467-480.
- PASTOR, J., R.J. NAIMAN, AND B. DEWEY. 1987. A hypothesis of the effects of moose and beaver foraging on soil carbon and nitrogen cycles, Isle Royale. *Alces* 23:107-124.
- PASTOR, J., R.J. NAIMAN, B. DEWEY, AND P. MCINNES. 1988. Moose, microbes and the boreal forest. *Bioscience* 38:770-776.
- PATTEN, D.T. 1991. Human impacts in the Greater Yellowstone Ecosystem: Evaluating sustainability goals and eco-redevelopment. *Conserv. Biol.* 5:405-411.
- PATTEN, D.T. 1993. Herbivore optimization and overcompensation: Does herbivory on western rangelands support these theories? *Ecol. Applications* 3:35-36.
- PATTON, B. *In press.* *The Great Divide: The early exploration of the Canadian Rockies.* Altitude Publishing, Banff, AB.
- PECK, V.R. 1980. The Muskwa-Liard elk herd: A historical and economic perspective. Pages 57-66 in *Proceedings of the western states elk workshop*, Cranbrook, BC.
- PECK, V.R. 1988. Response of elk and vegetation to prescribed fire, Tughodi River area of northeastern British Columbia. M.S. Thesis, University of Idaho, Moscow, ID. 206 pp.
- PECK, V.R., and J. PEEK. 1991. Elk, *Cervus elaphus*, habitat use related to prescribed fire, Tughodi River, British Columbia. *Canad. Field-Nat.* 105:354-362.

- PENGELLY, I. 1993. Canadian Parks Service policy and Pandora's Box. Unpub. Rep. on file, Banff Warden Office, Banff National Park, AB. 24 pp.
- PERRY, W. 1987. Archaeological resources impact assessment, snowshed and avalanche chute construction, Mt. Stephen, Yoho National Park. Environment Canada, Canadian Parks Service Microfiche Rep. Series 343. 39 pp.
- PETERSON, E.B., and N.M. PETERSON. 1992. Ecology, management and use of aspen and balsam poplar in the prairie provinces, Canada. For. Can. North. For. Cent. Spec. Rep. 1. 252 pp.
- PETERSON, E.B., and N.M. PETERSON. 1995. Aspen managers' handbook for British Columbia. British Columbia Ministry of Forests and Canadian Forest Service FRDA Rep. 230. 110 pp.
- PETERSON, E.B., N.M. PETERSON, and K.A. ENNS. 1995. Guidelines for old forest management in Elk Island, Jasper, Yoho, Kootenay, Banff and Waterton Lakes National Parks. Unpub. rep. prepared for Canadian Heritage, Parks Canada, Alberta Region, Calgary, AB by Western Ecological Services, Victoria, BC and Larkspur Biological Consultants, Victoria, BC. March. 78 pp. + appendices.
- PETERSON, R.O. 1977. Wolf ecology and prey relationships on Isle Royale. National Park Service Sci. Monogr. 11. 210 pp.
- PETERSON, R.O., AND R.E. PAGE. 1988. The rise and fall of Isle Royale wolves, 1975-1986. J. Mamm. 69:89-99.
- PETERSON, R.O., R.E. PAGE, AND K.M. DODGE. 1984. Wolves, moose, and the allometry of population cycles. Science 224:1350-1352.
- PICKARD, R. 1985. The site of Jasper House: An archaeological assessment. Environment Canada, Canadian Parks Service Microfiche Rep. Series 268. 240 pp.
- PICKARD, R. 1987. Archaeological resource description -- Canadian National Railway corridor, Jasper National Park. Environment Canada, Canadian Parks Service Microfiche Rep. Series 337. 170 pp.
- PICKARD, R., and H. D'AMOUR. 1987. Archaeological investigations at the national historic site of Jasper House. Unpub. Rep. on file at Archaeological Research Library, Western Regional Office, Canadian Parks Service, Calgary, AB. Vol. I: 1-216, Vol. II: 217-440.
- POJAR, R.A. 1995. Breeding bird communities in aspen forests of the sub-boreal spruce (dk subzone) in the Prince Rupert forest region. British Columbia Ministry of Forests Land Manage. Handbook 33. 59 pp.
- POLE, G. 1991. The Canadian Rockies: A history in photographs. Altitude Publishing, Banff, AB. 112 pp.
- POLL, D.M. 1989. Wildlife mortality on the Kootenay Parkway, Kootenay National Park -- Final report. Parks Canada, Kootenay National Park, Radium, BC. 105 pp.
- POLL, D.M., M.M. PORTER, G.L. HOLROYD, R.M. WERSHLER, and L.W. GYUG. 1984. Ecological land classification of Kootenay National Park. Vol. II: Wildlife resource Environment Canada, Canadian Wildlife Service, Edmonton, AB. 260 pp.
- POPE, S.T. 1923. A study of bows and arrows. Univ. of Calif. Pub. in Amer. Archaeol. and Ethnol. 13:329-414.

- POTTER, J.M. 1995. The effects of sedentism on the processing of hunted carcasses in the southwest: A comparison of two Pueblo IV sites in central New Mexico. *Kiva* 60:411-428.
- PRICE, B.J. 1980. The truth is not in accounts but in account books: On the epistemological status of history. Pages 155-180 in Ross, E.B., ed. *Beyond the myths of culture*. Academic Press, New York, NY. 422 pp.
- PROGULSKE, D.R. 1974. Yellow ore, yellow hair, yellow pine: A photographic study of a century of forest ecology. *South Dakota State University Agr. Exp. Sta. Bull.* 616. 169 pp.
- PROGULSKE, D.R., and F.J. SHIDELER. n.d. *Following Custer*. Agricultural Experiment Station Bull. 674. South Dakota State University, Brookings, SD. 139 pp.
- PURVES, H.D., C.A. WHITE, and P.C. PAQUET. 1992. Wolf and grizzly bear habitat use and displacement by human use in Banff, Yoho, and Kootenay National Parks: A preliminary analysis. Canadian Parks Service, Banff National Park, Banff, AB. 54 pp.
- PUTMAN, R.J., P.J. EDWARDS, J.C.E. MANN, R.C. HOW, and S.D. HILL. 1989. Vegetational and faunal changes in an area of heavily grazed woodland following relief of grazing. *Biol. Conser.* 47:13-32.
- PYKE, G., H. PULLIAM, and E. CHARNOV. 1977. Optimal foraging: A selective review of theories and tests. *Quart. Rev. Biol.* 52:137-154.
- PYNE, S.J. 1982. *Fire in America: A cultural history of wildland and rural fire*. Princeton University Press, Princeton, NJ. 654 pp.
- PYNE, S.J. 1984. *Introduction to wildland fire*. Wiley-Interscience, New York, NY. 455 pp.
- PYNE, S.J. 1989. The summer we let wild fires loose. *Natural History* 98(8):45-49.
- PYNE, S.J. 1991. *Burning bush: A fire history of Australia*. Henry Holt and Co., New York, NY. 520 pp.
- PYNE, S.J. 1993. Keeper of the flame: A survey of anthropogenic fire. Pages 245-266 in P.J. Crutzen, and J.G. Goldammer, eds. *Fire in the environment: Its ecological, climatic, and atmospheric chemical importance*. John Wiley and Sons, New York, NY.
- PYNE, S.J. 1994. Maintaining focus: An introduction to anthropogenic fire. *Chemosphere* 29:889-911.
- PYNE, S.J. 1995a. Vestal fires and virgin lands: A reburn. Pages 15-21 in Brown, J.K., R.W. Mutch, C.W. Spoon, and R.H. Wakimoto, eds. *Proceedings: Symposium on fire in wilderness and park management*. U.S. For. Ser. Gen. Tech. Rep. INT-320. 283 pp.
- PYNE, S.J. 1995b. *World fire: The culture of fire on Earth*. Henry Holt and Company, New York, NY. 379 pp.
- QUINTILIO, D., M.E. ALEXANDER, and R.L. PONTO. 1989. Spring fires in a semi-mature aspen stand, central Alberta. *For. Can. Inf. Rep.*, Northern Forest Research Center, Edmonton, AB.
- RAMENOFISKY, A.F. 1987. *Vectors of death: The archaeology of European contact*. University New Mexico Press, Albuquerque, NM. 300 pp.
- RATZ, A. 1995. Long-term spatial patterns created by fire: A model oriented towards boreal forests. *Int. J. Wildland Fire* 5:25-34.

- RAWLEY, E.V. 1985. Early records of wildlife in Utah. Utah Division of Wildlife Resources Pub. 86-2. 102 pp.
- REDFORD, K.H. 1992. The empty forest. *Bioscience* 42:412-422.
- REED, W.J. 1994. Estimating the historic probability of stand-replacement fire using the age-class distribution of undisturbed forest. *For. Sci.* 40:104-119.
- REEVES, B.O.K. 1980. Final report: Historical resources impact assessment Gregg River coal project (ASA permit 80-135). Unpub. consultant's report (Lifeways of Canada Ltd.) on file at Archaeology Survey of Alberta, Edmonton, AB. 28 pp.
- REEVES, B.O.K. 1983a. Culture change in the northern plains: 1000 B.C. - A.D. 1000. *Archaeol. Survey of Alberta Occ. Pap.* 20. 370 pp.
- REEVES, B.O.K. 1983b. Six millennia of buffalo kills. *Sci. Amer.* 249(4):120-135.
- REEVES, B.O.K. 1986. Northern Rocky Mountain archaeology: A bibliography. *Archaeol. Survey of Alberta Occ. Pap.* 30:353-405.
- REEVES, B.O.K., and J. DORMAAR. 1972. A partial Holocene pedological and archaeological record from the southern Alberta Rocky Mountains. *Arctic and Alpine Res.* 4:325-336.
- REID, D.K. 1987. Fire and habitat modification: An anthropological inquiry into the use of fire by indigenous peoples. M.A. Thesis, University of Alberta, Edmonton, AB. 169 pp.
- REID, K.C. 1988. Downey Gulch archaeology and the Hill 5230 Game Drive. Center for Northwest Anthropology, Washington State University Contrib. in Cultural Resource Manage. 22. 146 pp.
- REID, K.C., and G. CAULK. 1986. Ungulate zooarchaeology in northeastern Oregon: A review of the evidence. Paper presented at the Northwest Section meeting of The Wildlife Society, Coos Bay, OR. March 19-21st. 15 pp.
- RENKIN, R.R., and D.G. DESPAIN. 1992. Fuel moisture, forest type and lightning-caused fire in Yellowstone National Park. *Can. J. For. Res.* 22:37-45.
- RINGROSE, T.J. 1993. Bone counts and statistics: A critique. *J. Archaeol. Sci.* 20:121-157.
- RISBRUDT, C.D. 1995. Ecosystem management: A framework for management of our national forests. *Natural Resources and Environmental Issues* 5:91-96.
- RISENHOOVER, K.L., AND S.A. MAASS. 1987. The influence of moose on the composition and structure of Isle Royale forests. *Can. J. For. Res.* 17:357-364.
- ROBERTSON, E.O., and L.A. JOSZA. 1988. Climate reconstruction from tree rings at Banff. *Can. J. For. Res.* 18:888-900.
- ROGEAU, M-P. 1996. Understanding age-class distributions in the southern Canadian Rockies. M.S. Thesis, University of Alberta, Edmonton, AB. 139 pp.
- ROGEAU, M-P., and D. GILBRIDE. 1994. Forest stand original mapping of Banff National Park. Unpub. rep. on file Banff Warden Office, Banff National Park, Banff, AB. September. 72 pp. + appendices.

- ROGERS, G.F. 1982. Then and now. University of Utah Press, Salt Lake City, UT. 152 pp.
- ROGERS, G.F., H.E. MALDE, and R.M. TURNER. 1984. Bibliography of repeat photography for evaluating landscape change. University of Utah Press, Salt Lake City, UT. 179 pp.
- ROMME, W.H. 1982. Fire and landscape diversity in subalpine forests of Yellowstone National Park. *Ecol. Monogr.* 52:199-221.
- ROMME, W.H., and D.G. DESPAIN. 1989a. Historical perspective on the Yellowstone fires of 1988. *Bioscience* 39:695-699.
- ROMME, W.H., and D.G. DESPAIN. 1989b. The Yellowstone fires. *Sci. Amer.* 261(5):37-46.
- ROMME, W.H., and D.G. DESPAIN. 1989c. The long history of fire in the Greater Yellowstone Ecosystem. *Western Wildlands* 15(2):10-17.
- RONAGHAN, B. 1986. The status of prehistoric research in Alberta's Eastern Slopes. *Archaeol. Survey of Alberta Occ. Pap.* 30:269-352.
- RONAGHAN, B. 1993. The James Pass project: Early Holocene occupation in the front ranges of the Rocky Mountains. *Canad. J. Archaeol.* 17:85-91.
- RONAGHAN, B.M., and A.B. BEAUDOIN. 1988. An archaeological survey in the upper North Saskatchewan River Valley. *Archaeol. Survey of Alberta Occ. Pap.* 32:25-45.
- RONAGHAN, B., A. LANDALS, and G. LANGEMAN. 1982. Final report: Conservation excavations at DjPq-2, a stratified campsite in the upper Crowsnest Pass. Report submitted to Alberta Natural Gas Company Ltd. by Lifeways of Canada Ltd. Unpub. report on file at Archaeology Survey of Alberta, Edmonton, AB. 188 pp.
- ROSTLUND, E. 1957. The myth of a natural prairie belt in Alabama: An interpretation of historical records. *Annals of the Association of American Geographers* 47:392-411.
- ROSTLUND, E. 1960. The geographic range of the historic bison in the southeast. *Annals of the Association of American Geographers* 50:395-407.
- RUSCO, M. 1976. Fur trappers in Snake country: An ethnohistorical approach to recent environmental change. Pages 152-173 in Elston, R., and P. Headrick, eds. *Holocene environment change in the Great Basin*. Nevada Archaeological Survey Research Paper 6. 394 pp.
- RYLATT, R.M. 1991. Surveying the Canadian Pacific: Memoir of a railroad pioneer. University of Utah Press, Salt Lake City, UT. 246 pp.
- SAHLINS, M.D. 1972. Stone age economics. Aldine Press, Chicago, IL. 348 pp.
- SAVAGE, M., and T.W. SWETNAM. 1990. Early 19th-century fire decline following sheep pasturing in Navajo ponderosa pine forest. *Ecology* 71:2374-2378.
- SCHALK, R.F., and R.R. MIERENDORF, eds. 1983. Cultural resources of the Rocky Reach of the Columbia River. Center for Northwest Anthropology, Washington State University Project Rep. No. 1. Vol. 1 and 2. 752 pp.

- SCHIER, G.A., W.D. SHEPPERD, and J.R. JONES. 1985. Regeneration. Pages 197-208 in DeByle, N.V. and R.P. Winokur, eds. 1985. *Aspen: Ecology and management in the western United States*. U.S. For. Ser. Gen. Tech. Rep. RM-119. 283 pp.
- SCHULLERY, P. 1989a. Yellowstone fires: A preliminary report. *Northwest Sci.* 63:44-54.
- SCHULLERY, P. 1989b. The fires and fire policy. *Bioscience* 39:686-694.
- SCHULMAN, E. 1956. *Dendroclimatic changes in semiarid America*. University of Arizona Press, Tucson, AZ. 142 pp.
- SEIP, D.R., ed. 1989a. Proceedings wolf-prey dynamics and management. Wildlife Working Report WR-40. Wildlife Branch, British Columbia Ministry of Environment, Victoria, B.C. 180 pp.
- SEIP, D.R. 1989b. Caribou-moose-wolf interactions in central British Columbia. Pages 57-69 in Wolf-prey dynamics and management. Wildlife Branch, British Columbia Ministry of Environment, Victoria, B.C. Wildlife Working Report WR-40. 180 pp.
- SEIP, D.R. 1991. Predation and caribou populations. *Rangifer* (Special Issue) 7:46-52.
- SEIP, D.R. 1992a. Factors limiting woodland caribou populations and their interrelationships with wolves and moose in southeastern British Columbia. *Can. J. Zool.* 70:1494-1503.
- SEIP, D.R. 1992b. Wolf control and the management of ungulate populations. Pages 331-340 in D.M. McCullough, and R. Barrett, eds. *Wildlife 2001: Populations*. Elsevier Applied Science, New York, NY. 1163 pp.
- SHEPPERD, W.D. 1993. Initial growth, development, and clonal dynamics of regenerated aspen in the Rocky Mountains. U.S. For. Ser. Res. Paper RM-312. 8 pp.
- SHEPPERD, W.D., and F.W. SMITH. 1993. The role of near-surface lateral roots in the life cycle of aspen in the central Rocky Mountains. *For. Ecol. and Manage.* 61:157-170.
- SHEPPERD, W.D., and M.L. FAIRWEATHER. 1994. Impact of large ungulates in restoration of aspen communities in a southwestern ponderosa pine ecosystem. Pages 344-347 in Covington, W.S., and L.F. DeBano, eds. *Sustainable ecological systems: Implementing an ecological approach to land management*. U.S. For. Ser. Gen. Tech. Rep. RM-247. 363 pp.
- SHINN, D.E. 1980. Historical perspectives on range burning in the inland Pacific Northwest. *J. Range Manage.* 33:415-423.
- SHIPEK, F. 1993. Kumeyaay plant husbandry: Fire, water, and erosion control systems. Pages 379-388 in Blackburn, T.G., and K. Anderson, eds. *Before the wilderness: Environmental management by native Californians*. Ballena Press, Menlo Park, CA. 476 pp.
- SHRADER-FRECHETTE, K.S., and E.D. MCCOY. 1995. Natural landscapes, natural communities, and natural ecosystems. *Forest and Conservation Hist.* 39:138-142.
- SHROEDER, M.J., and C.C. BUCK. 1970. Fire weather: A guide for application of meteorological information to forecast forest fire control operation. U.S. Dept. of Agr. Handbook 360. 229 pp.
- SILSBY, S. 1994. Stone points. Pages 275-326 in Hamm, J., ed. *The traditional bowyer's bible: Volume three*. Lyons and Burford, New York, NY. 351 pp.

- SIMMS, S.R. 1984. Aboriginal Great Basin foraging strategies: An evolutionary analysis. Ph.D. Dissertation, University of Utah, Salt Lake City, UT. 286 pp.
- SIMMS, S.R. 1992. Wilderness as a human landscape. Pages 183-201 in S.I. Zeveloff, L.M. Vause, and W.H. McVaugh, eds. *Wilderness tapestry*. University of Nevada Press, Reno, NV. 306 pp.
- SIMPSON, G. 1841. Manuscript journals -- 1841; D. 3/2. Unpublished manuscript journals on file with Hudson's Bay Company Archives in the Provincial Archives of Manitoba, Winnipeg, MB.
- SKIBICKI, A., A STADEL, L D. WELCH, and J.G. NELSON, eds. 1994. Ecological monitoring and national parks. University of Waterloo Heritage Resources Centre Working Paper No. 7. Waterloo, ON. 373 pp.
- SKJONSBERG, T. 1993. Eastern slopes wildlife study 1984-1987. Canadian Parks Service, Banff National Park, Banff, AB. Final Report. 138 pp.
- SKOVLIN, J.M., and J.W. THOMAS. 1995. Interpreting long-term trends in Blue Mountain ecosystems from repeat photography. U.S. Forest Service Res. Paper PNW-315. 102 pp.
- SMITH, A.H. 1984. Kutenai Indian subsistence and settlement patterns, northwest Montana. Technical Report, U.S. Army Corps of Engineers, Seattle, WA. 291 pp.
- SMITH, E.A. 1983. Anthropological applications of optimal foraging theory: A critical review. *Curr. Anthropol.* 24:625-651.
- SMITH, E.A. and B. WINTERHALDER, eds. 1992. *Evolutionary ecology and human behavior*. Aldine de Gruyter, New York, NY. 470 pp.
- SMITH, J.H.G. 1981. Fire cycles and management alternatives. Pages 511-531 in Mooney, H.A., T.M. Bonnicksen, N.L. Christensen, J.E. Lotan, and W.A. Reiners, eds. *Fire regimes and ecosystem properties*. U.S. Forest Service Gen. Tech. Rep. WO-26.
- SMITH, K.G., M.A. URQUHART, AND M. FESTA-BIANCHET. 1992. Preliminary observations of timing and causes of mountain goat kid mortality in west-central Alberta. *Bienn. Symp. North. Wild Sheep and Goat Council* 8:293-304.
- SNEED, P.G. 1979. Kootenay River diversion: Cultural heritage resources, phase 1 impact statement. Unpub. Rep. on file, Heritage Conservation Branch, Victoria, BC. Rep. No. SE-907.
- SOUTHESK, J.C. 1969. *Saskatchewan and the Rocky Mountains: A diary and narrative of travel, sport, and adventure, during a journey through the Hudson's Bay Company's territories, in 1859 and 1860*. Charles E. Tuttle Co., Rutland, Vermont. 448 pp. Originally published by Edmonston and Douglas, Edinburgh, UK. 1875. Also reprinted by M.G. Hurtig, Edmonton, AB. in 1969.
- SPETH, J.D. 1983. Bison kill and bone counts: Decision making by ancient hunters. University of Chicago Press, Chicago, IL. 237 pp.
- SPETH, J.D. 1987. Early hominid subsistence strategies in seasonal habitats. *J. Archaeol. Sci.* 14:13-29.
- SPETH, J.D., and K.A. SPIELMANN. 1983. Energy source, protein metabolism, and hunter-gatherer subsistence strategies. *J. Anthropol. Archaeol.* 2:1-31.

- SPRY, I.M., ed. 1968. The papers of the Palliser Expedition 1857-1860. The Champlain Society, Toronto, ON. 694 pp.
- STANNARD, D.E. 1992. American holocaust. Oxford University Press, New York, NY. 358 pp.
- STEADMAN, D.W. 1995. Prehistoric extinctions of Pacific island birds: Biodiversity meets zooarchaeology. *Science* 267:1123-1131.
- STEARNS, E.W., AND A.E. STEARNS. 1945. The effect of smallpox on the density of the Amerindian. Bruce Humphries, Inc., Boston, MA. 153 pp.
- STEELE, R., S.F. ARNO, and K. GEIER-HAYES. 1986. Wildfire patterns changes in central Idaho's ponderosa pine-Douglas-fir forest. *West. J. Applied For.* 1:16-18.
- STEFFIAN, A.F. 1991. Territorial stability as a factor in the occurrence and perpetuation of inter-group buffer zones. *Michigan Discussions in Anthropology Hunter-Gatherer Studies* 10:89-105.
- STELFOX, J.B., ed. 1995. Relationship between stand age, stand structure, and biodiversity in aspen mixedwood forests in Alberta. Jointly published by Alberta Environmental Centre, Vegreville, AB and Canadian Forest Service, Edmonton, AB. 308 pp.
- STELFOX, J.G. 1969. Wolves in Alberta: A history 1800-1969. *Alberta Lands -- Forest, Parks, and Wildlife.* 12:18-27.
- STELFOX, J.G. 1971. Bighorn sheep in the Canadian Rockies: A history 1800-1970. *Can. Field-Nat.* 85:101-122.
- STELFOX, J.G. 1974. Range ecology of bighorn sheep in relation to self-regulation theories. Pages 67-76 in *Northern Wild Sheep and Goat Council Biennial Proceedings*. April 23-25.
- STELFOX, J.G. 1976. Range ecology of Rocky Mountain bighorn sheep. *Can. Wildl. Ser. Rep.* 39. 50 pp.
- STEPHENS, D.W., and J.R. KREBS. 1986. Foraging theory. Princeton University Press, Princeton, NJ. 247 pp.
- STEVENS, D.R. 1980. The deer and elk of Rocky Mountain National Park: A 10-year study. *Rocky Mountain National Park ROMO-N-13.* 163 pp.
- STEWART, O.C. 1956. Fire as the first great force employed by man. Pages 115-133 in W.L. Thomas, ed. *Man's role in changing the face of the earth*. University of Chicago Press, Chicago, IL.
- STOCKTON, C.W., and H.C. FRITTS. 1973. Long-term reconstruction of water level changes for Lake Athabasca by analysis of tree-rings. *Water Resources Bulletin* 9:1006-1027.
- STROBECK, C. 1993. Molecular genetic research and DNA repository: Final report -- May 1993. Unpub. rep. Dep. of Zoology, University of Alberta to Canadian Parks Service. Report on file in Banff Warden Office, Banff, AB. 60 pp.
- SUMPTER, I.D., and B. PERRY. 1987. Archaeological resource impact assessments Yoho National Park 1984, 1985, and 1986. Environment Canada, Canadian Parks Service, Microfiche Rep. Series 385. 60 pp.
- SWETNAM, T.W. 1993. Fire history and climate change in giant sequoia groves. *Science* 262:885-889.

- SWETMAN, T.W., and J.L. BETANCOURT. 1990. Fire-southern oscillation relations in the southwestern United States. *Science* 249:1017-1020.
- TANDE, G.F. 1977. Forest fire history around Jasper townsite, Jasper National Park, Alberta. M.S. Thesis, University of Alberta, Edmonton, AB. 169 pp.
- TANDE, G.F. 1979. Fire history and vegetation pattern of coniferous forests in Jasper National Park, Alberta. *Can. J. Bot.* 57:1912-1931.
- TAYLOR, D.M. 1986. Effects of cattle grazing on passerine birds nesting in riparian habitat. *J. Range Manage.* 39:254-258.
- TAYLOR, J.F. 1977. Sociocultural effects of epidemics on the northern plains: 1734-1850. *Western Canad. J. Anthropol.* 78:55-81.
- TAYLOR, R.J. 1984. Predation. Chapman and Hill, New York, NY. 166 pp.
- TEIT, J.H. 1906. The Lillooet Indians. *Memoirs of the American Museum of Natural History* 4:193-300.
- TEIT, J.H. 1908. The Thompson Indians of British Columbia. *Memoirs of the American Museum of Natural History*. Vol. I, Part 4:165-392.
- TEIT, J.H. 1909. The Shuswap. *Memoirs of the American Museum of Natural History* 2:448-813.
- TELFER, E.S., and A. CAIRNS. 1979. Bison-wapiti interrelationships in Elk Island National Park, Alberta. Pages 114-121 in Boyce, M.S., and L.D. Hayden-Wing, eds. *North American elk: Ecology, behavior, and management*. University of Wyoming, Laramie, WY. 294 pp.
- TELFER, E.S., and J.P. KELSALL. 1984. Adaptation of some large North American mammals for survival in snow. *Ecology* 65:1828-1834.
- THOMPSON, D. 1800-1812. Unpublished manuscript journals on file at the Provincial Archives of Ontario, Toronto, ON. Microfilm copy on file with Glenbow Museum, Calgary, AB.
- TIMBROOK, J., J.R. JOHNSON, and D.D. EARLE. 1982. Vegetation burning by the Chumash. *J. Calif. Great Basin Anthropology* 4:163-186.
- TIMMERMAN, H.R. 1991. Ungulates and aspen management. Pages 99-110 in Navratil, S., and P.B. Chapman, eds. *Aspen management for the 21st century*. Forestry Canada, Northwest Region and Poplar Council of Canada, Edmonton, AB. 174 pp.
- TOUCHAN, R., T.W. SWETNAM, and H.D. GRISSINO-MAYER. 1995. Effects of livestock grazing on pre-settlement fire regimes in New Mexico. Pages 268-272 in Brown, J.K., R.W. Mutch, C.W. Spoon, and R.H. Wakimoto, eds. *Proceedings: Symposium on fire in wilderness and park management*. U.S. For. Ser. Gen. Tech. Rep. INT-320. 283 pp.
- TRIMBLE, M.K. 1985. Epidemiology on the northern plains: A cultural perspective. Ph.D. Dissertation, University of Missouri-Columbia, Columbia, MO. 331 pp.
- TROTTIER, G.C. 1976. Big game range exclosures in the national parks of western Canada. Canadian Wildlife Service, Edmonton, AB. June 30. 160 pp.

- TROTTIER, G.C., and A. FEHR. 1982. Re-evaluation of four range enclosures in Banff National Park, 1981. Canadian Wildlife Service, Edmonton, AB. May. 49 pp.
- TURNER, N.J. 1991. Burning mountain sides for better crops: Aboriginal landscape burning in British Columbia. *Archaeology in Montana* 32:57-73.
- TURNER-HIGH, H. 1941. Ethnography of the Kutenai. *American Anthropological Association Memoir* 56:1-202.
- TYMSTRA, C. 1988. Fire history report — Volume 1: An historical review of wildland fires in Yoho National Park. Unpub. rep. on file Yoho Warden Office, Yoho National Park, Field, BC. September 16th. 114 pp. + appendices.
- TYMSTRA, C. 1989. Fire history report — Volume 2: Analysis of fire report and fire behavior data for Yoho National Park. Unpub. rep. on file Yoho Warden Office, Yoho National Park, Field, BC. 98 pp. + appendices.
- TYMSTRA, C. 1991. Fire history of Yoho National Park. M.S. Thesis, University of Alberta, Edmonton, AB. 151 pp.
- TYRRELL, J.B., ed. 1916. David Thompson's narrative of his exploration in western America 1784-1812. The Champlain Society, Toronto, ON. 582 pp.
- USDA FOREST SERVICE. 1988. The Canyon Creek fire. Videotape production, Lolo National Forest, Missoula, MT.
- U.S. FOREST SERVICE. 1993a. Vegetation changes on the Manti-LaSal National Forest: A photographic study using comparative photographs from 1902-1992. Manti-LaSal National Forest, Price, UT. 128 pp.
- U.S. FOREST SERVICE. 1993b. Snapshot in time: Repeat photography on the Boise National Forest 1870-1992. Boise National Forest, Boise, ID. 239 pp.
- VALE, T.R. 1987. Vegetation change and park purposes in the high elevations of Yosemite National Park, California. *Assoc. Amer. Geographers Annals* 77:1-18.
- VAN EGMOND, T.D. 1990. Forest succession and range conditions in elk winter habitat in Kootenay National Park. M.S. Thesis, University of Manitoba, Winnipeg, MB. 163 pp.
- VANKAT, J., and J. Major. 1978. Vegetation changes in Sequoia National Park, California. *J. Biogeog.* 5:377-402.
- VAN WAGNER, C.E. 1972. Duff consumption by fire in eastern pine stands. *Can. J. For. Res.* 2:34-39.
- VAN WAGNER, C.E. 1978. Age-class distribution and the forest fire cycle. *Can. J. For. Res.* 8:220-227.
- VAN WAGNER, C.E. 1985. Does nature really care who lights the fire? Pages 98-100 in Lotan, J.E., B.M. Kilgore, W.C. Fischer, and R.W. Mutch, eds. *Proceedings — symposium and workshop on wilderness fire*. U.S. For. Ser. Gen. Tech. Rep. INT 182. 434 pp.
- VAN WAGNER, C.E. 1988. The historical pattern of annual burned area in Canada. *For. Chronicle* 64:182-185.

- VAN WAGNER, C.E. 1995. Analysis of fire history for Banff, Jasper, and Kootenay National Parks. Unpub. report on file Banff Warden Office, Banff National Park, Banff, AB. January. 19 pp.
- VAN WAGTENDONK, J.W. 1991. Spatial analysis of lightning strikes in Yosemite National Park. Pages 605-611 in Proceedings 11th conference on fire and forest meteorology, April 16-19, Missoula, Montana. Society of American Foresters Pub. 91-04.
- VEBLEN, T.T., and D.C. LORENZ. 1991. The Colorado front range: A century of ecological change. University of Utah Press, Salt Lake City, UT. 186 pp.
- VEHICK, S.C. 1977. Bone fragments and bone grease manufacturing: A review of their archaeological use and potential. *Plains Anthropol.* 22(No. 77):169-182.
- WAGNER, F.H., and C.E. KAY. 1993. "Natural" or "healthy" ecosystems: Are U.S. national parks providing them? Pages 257-270 in McDonnell, M.J., and S.T. Pickett, eds. *Humans as components of ecosystems*. Springer-Verlag, New York, NY. 364 pp.
- WAGNER, F.H., R. FORESTA, R.B. GILL, D.R. MCCULLOUGH, M.P. PELTON, W.F. PORTER, and H. SALWASSER. 1995. *Wildlife policies in the U.S. national parks*. Island Press, Washington, D.C. 242 pp.
- WALKER, D.N. 1987. Late Pleistocene/Holocene environmental changes in Wyoming: The mammalian record. Pages 334-393 in Graham, R.W., H.A. Semken, and M.A. Graham, eds. *Late quaternary mammalian biogeography and environments of the Great Plains and prairies*. Illinois State Museum Scientific Papers Vol 22. 491 pp.
- WALKER, S.C. 1993. Effects of cattle and big game on the secondary succession of aspen-conifer understory following fire. M.S. Thesis, Brigham Young University, Provo, UT. 44 pp.
- WALTERS, C.J. 1986. *Adaptive management of renewable resources*. McMillan Press, New York, NY.
- WALTERS, C.J., M. STOCKER, AND G.C. HABER. 1981. Simulation and optimization models for a wolf-ungulate system. Pages 317-337 in Fowler, C.W., and T.D. Smith, eds. *Dynamics of large mammal populations*. John Wiley and Sons, New York, NY.
- WARRE, H.J. 1845. Unpublished manuscript journal. National Archives of Canada, Ottawa, ON. MG 24, F71, Vol. 1:1035-1053.
- WAYNE, R.K., N. LEHMAN, D. GIRMAN, P.J.P. GOGAN, D.A. GILBERT, K. HANSEN, R.O. PETERSON, U.S. SEAL, A. EISENHAWER, L.D. MECH, AND R.J. KRUMENAKER. 1991. Conservation genetics of the endangered Isle Royale gray wolf. *Conserv. Biol.* 5:41-51.
- WEAVER, J.L. 1994. Ecology of wolf predation amidst high ungulate diversity in Jasper National Park, Alberta. Ph.D. Dissertation, University of Montana, Missoula, MT. 183 pp.
- WEBB, R. 1957. Range studies in Banff National Park, Alberta, 1953. National Parks Branch, Canadian Wildlife Service, Canada Department of Northern Affairs and National Resources. Wildlife Management Bull. Series 1, No. 13. Ottawa, ON. 24 pp.
- WEBSTER, D., and G. WEBSTER. 1984. Optimal hunting and Pleistocene extinction. *Human Ecol.* 12:275-289.
- WEBSTER, G.S. 1985. Susquehannoch animal economy. *N. Amer. Archaeol.* 6:41-62.

- WEIR, J.M.H., K.J. CHAPMAN, and E.A. JOHNSON. 1995. Wildland fire management and the fire regime in the southern Canadian Rockies. Pages 275-280 in Brown, J.K., R.W. Mutch, C.W. Spoon, and R.H. Wakimoto, eds. *Proceedings: Symposium on fire in wilderness and park management*. U.S. For. Ser. Gen. Tech. Rep. INT-320. 283 pp.
- WEST, P., and S. BRECHLIN. 1991. National parks, protected areas and resident peoples: A comparative assessment and integration. Pages 363-400 in P. West, and S. Brechlin, eds. *Resident peoples and national parks*. University of Arizona Press, Tucson, AZ. 443 pp.
- WESTERN, D., and H. GICHOHI. 1993. Segregation effects and the impoverishment of savanna parks: The case for ecosystem viability analysis. *Afr. J. Ecol.* 31:269-281.
- WESTMAN, W.E. 1991. Restoration projects: Measuring their performance. *Environmental Professional* 13:207-215.
- WESTWORTH, D.A., and E.S. TELFER. 1993. Summer and winter bird populations associated with five age-classes of aspen forest in Alberta. *Can. J. For. Res.* 23:1830-1836.
- WHITE, C.A. 1985a. Wildland fires in Banff National Park 1880-1989. Occ. Pap. 3. National Parks Branch, Parks Canada, Environment Canada, Ottawa, ON. 106 pp.
- WHITE, C.A. 1985b. Fire and biomass in Banff National Park's closed forests. Warden Service, Banff National Park, Banff, AB. 203 pp.
- WHITE, C.A. 1989. Vegetation and fire management in Banff National Park. Pages 84-86 in *Final Program: The art and science of fire management*. First Annual Meeting and Workshop, Interior West Fire Council, Kananashis Country, AB. Oct. 24-27, 1988.
- WHITE, C.A. 1990. Field trip notes: Vegetation and fire management in Banff National Park, Alberta. Pages 194-195 in M.E. Alexander, and G.F. Bisgrove, eds. *Proceedings Interior West Fire Council Annual Meeting*, Oct. 24-27, 1988, Kananaskis Village, Alberta. Can. For. Serv., N. For. Res. Centre Info. Rep. NOR-X-309. Edmonton, AB. 333 pp.
- WHITE, C.A., and I.R. PENGELLY. 1992. Fire as a natural process and a management tool: The Banff National Park experience. Paper presented at Society of Grassland Naturalists Cypress Hills Forest Management Workshop, Medicine Hat, AB. Oct. 2-4, 1992. 16 pp.
- WHITE, C.A., P.C. PAQUET, AND H.D. PURVES. 1994. Nursing Humpty's syndrome: Bow Valley ecosystem restoration. Pages 31-44 in Lopoukhine, N., ed. *Ecological restoration of national parks: Proceedings of a symposium at the fourth annual conference of the Society for Ecological Restoration* 10-14 August 1992, University of Waterloo, Waterloo, Ontario. Parks Canada, Ottawa, ON. 73 pp.
- WHITE, C.M., ed. 1950. *David Thompson's journals relating to Montana and adjacent regions, 1808-1812*. Montana State University Press, Missoula, MT. 345 pp.
- WHITE, R. 1975. Indian land use and environmental change: Island County, Washington: A case study. *Arizona and the West* 17:327-338.
- WHITE, R. 1991. *It's your misfortune and none of my own: A history of the American West*. University of Oklahoma Press, Norman, OK. 644 pp.

- WHITE, T.E. 1952. Observations on the butchering technique of some aboriginal peoples No. 1. *Amer. Antiq.* 17:337-338.
- WHITE, T.E. 1953a. A method of calculating the dietary percentage of various food animals utilized by aboriginal peoples. *Amer. Antiq.* 18:396-398.
- WHITE, T.E. 1953b. Observations on the butchering technique of some aboriginal peoples No. 2. *Amer. Antiq.* 18:160-164.
- WHITE, T.E. 1954. Observations on the butchering technique of some aboriginal peoples No. 3, 4, 5, and 6. *Amer. Antiq.* 19:254-264.
- WIERZCHOWSKI, J.L. 1995. An evaluation of prescribed burning program in Banff National Park and application of remote sensing in assessing effects of prescribed burning. M.S. Thesis, University of Calgary, Calgary, AB. 196 pp.
- WIERZCHOWSKI, J.L., C.A. WHITE, and I.R. PENGELLY. 1995. Evaluation of the Banff National Park planned ignition prescribed fire program. Pages 281-283 in Brown, J.K., R.W. Mutch, C.W. Spoon, and R.H. Wakimoto, eds. *Proceedings: Symposium on fire in wilderness and park management*. U.S. For. Ser. Gen. Tech. Rep. INT-320. 283 pp.
- WINTERHALDER, B. 1981a. Optimal foraging strategies and hunter-gatherer research in anthropology: Theory and models. Pages 13-35 in B. Winterhalder, and E.A. Smith, eds. *Hunter-gatherer strategies*. University of Chicago Press, Chicago, IL. 273 pp.
- WINTERHALDER, B. 1981b. Foraging strategies in the boreal forest: An analysis of Cree hunting and gathering. Pages 66-98 in B. Winterhalder, and E.A. Smith, eds. *Hunter-gatherer foraging strategies*. University of Chicago Press, Chicago, IL. 273 pp.
- WINTERHALDER, B. 1994. Concepts in historical ecology: The view from evolutionary ecology. Pages 17-43 in Crumley, C.L., ed. *Historical ecology*. School of American Research Press, Santa Fe, NM. 284 pp.
- WINTERNITZ, B.L. 1980. Birds in aspen. Pages 247-257 in Degraff, R.M., ed. *Workshop proceedings on management of western forests and grasslands for nongame birds*. U.S. For. Ser. Gen. Tech. Rep. INT-86.
- WOODLEY, S.J. 1992. Developing ecosystem goals for Canadian national parks. Canadian Parks Service Internal Report. C.P.S. Documentation Centre, 25 Eddy Street, Hull, PQ. K1A 0H3. 15 pp.
- WOODLEY, S.J. 1993. *Assessing and monitoring ecological integrity in parks and protected areas*. Ph.D. Dissertation, University of Waterloo, Waterloo, ON. 167 pp.
- WOODLEY, S.J. 1995. Playing with fire: Vegetation management in the Canadian Parks Service. Pages 30-33 in Brown, J.K., R.W. Mutch, C.W. Spoon, and R.H. Wakimoto, eds. *Proceedings: Symposium on fire in wilderness and park management*. U.S. For. Ser. Gen. Tech. Rep. INT-320. 283 pp.
- WOODLEY, S.J. and G. FORBES. 1995. Ecosystem management and protected areas: Principles, problems, and practicalities. Pages 50-58 in Herman, T.B., S. Bondrup-Nielsen, J.H.M. Willison, and N.W.P. Munro, eds. *Ecosystem monitoring and protected areas*. Science and Management of Protected Areas Association, Wolfville, NS. 590 pp.

- WOODLEY, S.J., J. KAY, AND G. FRANCIS, eds. 1993. Ecological integrity and the management of ecosystems. St. Lucie Press, Del Ray Beach, FL. 220 pp.
- WOODLEY, S.J., and J. THEBERGE. 1992. Monitoring for ecosystem integrity in Canadian national parks. Pages 369-377 in Willison, J.H.M., S. Bondrup-Nielsen, C. Drysdale, T.B. Herman, N.W.P. Munro, and T.L. Pollock, eds. Science and the management of protected areas. Elsevier, New York, NY. 548 pp.
- WOODS, J.G. 1988. Effectiveness of fences and underpasses on the Trans-Canada Highway and their impact on ungulate populations project – second progress report – September 1985 to May 1988. Western Region, Canadian Parks Service, Calgary, AB. 97 pp.
- WOODS, J.G. 1991. Ecology of a partially migratory elk population. Ph.D. Dissertation, University of British Columbia, Vancouver, BC. 149 pp.
- WOODWARD, M.B. 1993. Land of dreams: A history in photographs of the British Columbia interior. Altitude Publishing, Banff, AB. 112 pp.
- WORK, J. 1945. Fur brigade to the Bonaventura: John Work's California expedition 1832-1833 for the Hudson's Bay Company. A.B. Maloney, ed. California Historical Society, San Francisco, CA. 111 pp.
- WRIGHT, G.A. 1979. Homage to Gustavus Cheney Doane: Science in our national parks. Pages 887-892 in R.M. Linn, ed. First Conference on Scientific Research in the National Parks. U.S. National Park Service, Washington D.C. 942 pp.
- WRIGHT, G.A. 1984. People of the high country: Jackson Hole before the settlers. Peter Lang, New York, NY. 181 pp.
- WRIGHT, H.A., and A.W. BAILEY. 1982. Fire ecology: United States and southern Canada. John Wiley & Sons, New York, NY. 501 pp.
- WYOMING STATE HISTORICAL SOCIETY. 1976. Re-discovering the Big Horns: A pictorial study of 75 years of ecological change. U.S. For. Ser., Bighorn National Forest, Sheridan, WY. 79 pp.
- YESNER, D.R. 1981. Archaeological applications of optimal foraging theory: Harvest strategies of Aleut hunter-gatherers. Pages 148-170 in B. Winterhalder, and E.A. Smith, eds. Hunter-gatherer foraging strategies. University of Chicago Press, Chicago, IL. 273 pp.
- YESNER, D.R. 1989. Moose hunters of the boreal forest? A re-examination of subsistence patterns in the western subarctic. Arctic 42:97-108.
- YIP, J. 1982. Archaeological investigations at the Columbia Lake site, EbPw-1. Unpub Rep. on file, Heritage Conservation Branch, Victoria, BC. Permit M.O. 1981-14. 188 pp.
- YOUNG, J.L. 1973. Breeding bird populations and habitat utilization in aspen stands of upper Logan Canyon. M.S. Thesis, Utah State University, Logan, UT. 38 pp.
- YOUNG, J.L. 1977. Density and diversity responses of summer bird populations to the structure of aspen and spruce-fir communities on the Wasatch Plateau, Utah. Ph.D. Dissertation, Utah State University, Logan, UT. 79 pp.

- YOUNG, V.H. 1994. Closing commentary and recommendations arising from the workshop. Pages 277-280 in Skibicki, A., A. Stadel, D. Welch, and J.G. Nelson, eds. Ecological monitoring and national parks. University of Waterloo Heritage Resources Centre Working Paper No. 7. 373 pp.
- YOUNGBLOOD, A.P., and W.F. MUEGGLER. 1981. Aspen community types on the Bridger-Teton National Forest in western Wyoming. U.S. For. Ser. Res. Paper INT-272. 34 pp.