Long-Term Ecosystem States and Processes in the Central Canadian Rockies: A New Perspective on Ecological Integrity and Ecosystem Management

Charles E. Kay
Institute of Political Economy, Utah State University
Logan, Utah 84322-0725
and
Clifford A. White
Heritage Resource Conservation, Parks Canada, Banff National Park
P.O. Box 900, Banff, Alberta T0L 0C0

Introduction

According to legislative directives, Canada is to manage her national parks "so as to leave them unimpaired for ... future generations [and] ... ecological integrity ... of natural resources shall be [given] first priority ...."(Woodley 1993). To comply with these legal mandates, Banff National Park implemented ecosystem-style management and began a study of the states and processes that structured the Central Canadian Rockies Ecosystem over the last several thousand years. For as Aldo Leopold noted over 40 years ago, "if we are serious about restoring [or maintaining] ecosystem health and ecological integrity, then we must know what the land was like to begin with" (Covington and Moore 1994:45). Banff was established as Canada's first national park in 1885 and is often regarded as the flagship of that country's national park system.

Aspen (*Populus tremuloides*), elk (*Cervus elaphus*), wolves (*Canis lupus*), fire, and humans were selected as key indicators 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, Angermeier and Karr 1994). We then developed a simplified model linking these elements in the Banff Ecosystem (Figure 1). The elements and linkages in the model all have value as indicators of ecological integrity (Kay 1991a, 1991b; Woodley and Theberge 1992), and are understood, at least to some degree, from previous research and monitoring (White et al. 1994).

The Questions

Observations suggest that the area occupied by aspen has decreased since Banff National Park was established, but are the park's aspen declining 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 in other ecosystems (Despain et al. 1986).

Aspen rarely grows from seed due to its demanding seed bed requirements, and there are no known instances of aspen clones having established from seed on natural substrates anywhere in the Intermountain West (Kay 1993). It is thought that environmental conditions have not been conducive to clonal establishment since shortly after the glaciers retreated 10,000 or more years ago (McDonough 1985, Jelinski and Cheliak 1992). So, the aspen clones found in the central Canadian Rockies today have likely maintained their presence on those sites for thousands of years via vegetative regeneration. If aspen are lost due to advancing forest succession or overgrazing, there are no known means of reestablishing those stands.

Elk are now the most abundant ungulate in Banff's Bow Valley and

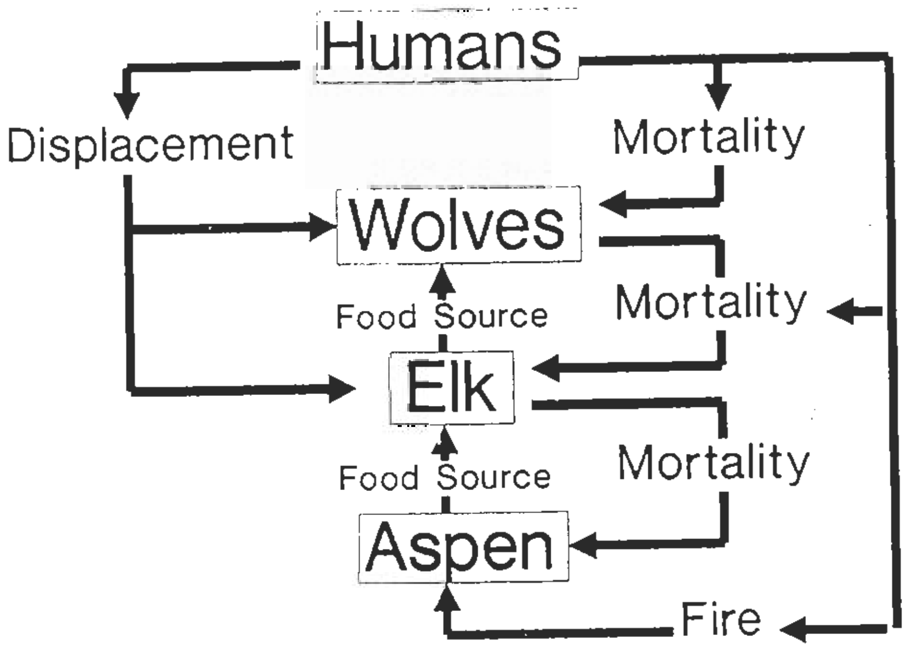

Figure 1. A simple model for Banff's lower Bow Valley and other montane areas in the central Canadian Rockies that incorporates elk, aspen, wolves, fire, and humans as key ecosystem components.

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?

According to some researchers, fires set by Native Americans are thought to have been unimportant and not to have substantially contributed to the area burned in prehistoric times (Byrne 1968, Johnson et al. 1990, Johnson and Larsen 1991). Others, though, have presented evidence that aboriginal burning was widespread and important throughout western North America (Lewis 1973, 1980b, 1982a, 1990a, 1990b, 1992, 1993; Barrett 1980a, 1980b, 1981; Barrett and Arno 1982; Arno 1985; Gruell 1985; Boyd 1986; Reid 1987). In northern Alberta, for instance, anthropologists reported that native peoples set fires for at least 17 different reasons (Lewis 1977, 1980a, 1982b; Ferguson 1979; Lewis and Ferguson 1988). Even in British Columbia with its wetter climate, aboriginal burning was still 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 provincial 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 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. Unlike lightning fires, which tend to be infrequent high-intensity infernos, 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 1993). Moreover, aboriginal burning reduces or eliminates the number of high-intensity, lightning-generated fires (Pyne 1982, 1989, 1991, 1993; 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 utilized in those fields. If these varied types of evidence support a single conclusion or a single set of conclusions, our findings will be very robust because the individual data sets are independent, termed consilience (Gould 1989:282-284).

Many people have used selected quotes from historical journals as evidence that certain ungulates were or were not abundant during the late 1700s and early 1800s (Byrne 1968; Nelson 1969a, 1969b, 1970). With selective quotations, however, there is always a question of whether or not the author included only those passages that supported some 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 1792 to 1873. We then tabulated those data in three ways (Kay 1990, in press). First, animals seen; second, game sign encountered or referenced; and third, animals shot or killed. For this analysis, we divided the Central Canadian Rockies Ecosystem into three geographic regions–the Alberta Foothills, the Rocky Mountains, and the Columbia Trench. Thus, we developed three historical wildlife sightings tables for each region or a total of nine tables (Kay et al. 1994).

To determine the relative abundance of ungulate species in pre-Columbian times, we reviewed all available reports for archaeological sites in the southern Canadian Rockies. This included the Alberta Foothills from the U.S. border north to the Smoky River, the Rocky Mountains from Montana to Jasper National Park, and the entire Columbia Trench including the Kootenay, Columbia, and Canoe River valleys. 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 peoples who inhabited the Canadian Rockies and the Intermountain West at historical contact.

Next, we reviewed over 500 historical photographs of the central Canadian Rockies obtained from the Whyte Museum of the Canadian Rockies, the Glenbow Museum, the Geologic Survey of Canada Photograph Archives, and Canada's National Air Photograph Library. To obtain a regional perspective, we then selected 14 historical photographs for paired comparison with current retakes of montane ecoregions along the North Saskatchewan, Red Deer, Bow, and Columbia Rivers. The repeat photosets were analyzed using established techniques to evaluate long-term vegetation changes and fire history parameters (Rogers et al. 1984).

To quantify the fire component of our ecosystem model, we first developed a submodel of fire activity in the Rocky Mountains which we then used as a framework for a detailed review of fire history research conducted in Wyoming, Montana, Idaho, Alberta, and British Columbia. We consulted studies on dendrochronology, written records (explorer diaries and fire reports), historical photographs, stand age analysis, fire frequency, ignition sources, burn patterns, and native ethnographies.

Finally, we surveyed and photographed aspen stands throughout Banff National Park, plus we evaluated aspen at three locations adjacent to the park, Kootenay Plains, the Ya Ha Tinda, and the area from Eastgate to Canmore, Alberta. This allowed us to compare aspen stand dynamics 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, but where the general climate is similar (Kay 1985, 1990). In addition, we rephotographed existing aspen exclosures and surveyed all aspen burned under Banff's prescribed fire program (White and Pengelly 1993, White et al. 1994), before measuring representative stands.

Results and Discussion

Based on repeat photographs, aspen in Banff's Bow Valley has declined precipitously since that national park was established. Immediately outside the park where elk numbers are lower, however, aspen continues to flourish. Aspen has also successfully regenerated inside Banff's exclosures while it has declined on adjacent outside plots suggesting that repeated elk browsing, not climatic change, is responsible. Aspen has also declined with advancing forest succession, but even when burned, aspen has failed to successfully regenerate due to repeated elk browsing. While aspen is often thought to be a seral species, successional replacement of aspen by conifers is not normal because aspen does not commonly reproduce from seed. Although aspen has maintained its presence in Banff's vegetation mosaic for thousands of years, it is now disappearing from the park. Clearly, something is different today than in earlier times. Moreover, the very persistence of aspen in the central Canadian Rockies over the millennium, indicates that ungulate use, and especially elk browsing, was not as intense in the past as it is now.

The ecology of aspen also suggests that aboriginal burning may have been more important than lightning fires in structuring pre-Columbian vegetation communities. Historical photographs and fire frequency studies indicate that aspen burned at frequent intervals in Banff's Bow Valley prior to park establishment. Aspen, however, will carry fire only when it is leafless and when understory fuels are dry, conditions which occur only in early spring or late fall (Fechner and Barrows 1976, DeByle et al. 1987). During both those periods, though, there are few lightning strikes and virtually no lightning fires in the Canadian Rockies (White 1985, Johnson and Larsen 1991), 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.

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

Worldwide patterns of aboriginal burning 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 the product, primarily, 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 valleys would have spread upslope and burned higher-elevation forests more frequently than lightning fires alone. That is to say, the vegetation as first seen by Europeans ca. 1800 was not as it had been crafted by God, but as it had been created by native peoples (Hallam 1975, Schule 1990, Martinez 1993).

Repeat photographs, aspen ecology, historical observations, and archaeological data, 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. Between 1792 and 1872, for instance, 26 different expeditions spent 369 days traveling through the Canadian Rockies on foot or horseback yet reported seeing elk on only 12 occasions or once every 31 party-days (Table 1). Similarly, few elk bones have been recovered from archaeological sites in the Canadian Rockies (Table 2), a pattern that is true throughout western North America (Kay 1990, 1992). Moreover, archaeological data suggest that all ungulate species were relatively rare in pre-Columbian times (Kay 1994).

Predation by wolves and grizzly bears (*Ursus arctos*) is one factor that would have limited ungulate numbers in pre-Columbian time, but recent predation has not lowered elk populations enough in Banff or Jasper National Parks to permit widespread aspen regeneration, even in large areas burned by prescribed fire. We recognize, though, that extensive human development in many park areas is impacting predator-prey relationships. Unhunted elk have habituated to high human use levels, but wolves and grizzly bears remain wary of developments, or habituated individuals have a high mortality rate if they frequent highways, campgrounds, or townsites (Purves et al. 1992, Paquet 1993, White et al. 1994).

Since aspen are not regenerating in remote areas where wolves and grizzly populations have not been substantially impacted, however, we suggest that another factor helped limit past ungulate numbers—Native Americans. 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 have suggested. Instead, the mountains, foothills, and the Columbia Trench have always been home to substantial numbers of native peoples.

It has long been known, however, that Native Americans lacked

Figure 2a. Hoodoos near Banff townsite viewed southeast in ca. 1890 and 1981. The south-facing grassy slopes above the Bow River; the open, widely-scattered, mature Douglas fir (*Pseudotsuga menziesii*); and the dead snags suggest that low-intensity ground fires were common prior to establishment of Banff National Park. There is no evidence of recent crown fires as would be the cas if the Bow Valley had been heavily forested only to have been ravaged by fires associated with early railroad construction or European settlement. So, 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 courtesy of the Whyte Museum of the Canadian Rockies (WMCR-NG5-22).*

Figure 2b. 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 ungulate winter range. 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. These slopes are among the driest in the park and conifer encroachment has been even more severe on other sites. A 1981 retake is shown instead of a 1994 photo because the conifers now completely obscure the Hoodoos and block the original photopoint. *Banff Warden Office photo (BNP-81A-18).*

Observer	Date	Trip Length (days)	Size of party	Elk	Bison	Deer	Goat	Bighorn Sheep	Moose	Caribou	Wolf	Cougar	Grizzly Bear	Black Bear	Bear
1. Peter Fidler															
12/31-1/1	1792-93	1	43+	-	-	-	-	-	-	-	-	-	-	-	-
2. David Thompson															
a. 6/12-6/14	1801	3	11	-	1	-	-	1	-	-	-	-	-	-	-
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. 6/17-6-19	1810	3	8-11	-	1	-	-	-	-	-	-	-	-	-	-
h. 12/30-1/19	1810-11	21	13	-	3	-	-	2	3	-	-	-	-	-	-
i. 5/8-5/13	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 Ermatinger															
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

Table 1. Animals observed by early explorers to the Canadian Rockies from 1792 to 1872. Dashes appear instead of zeros for species that were not reported. For details and citations to the original historical journals see Kay et al. (1994).

Table 2. Ungulate remains recovered from archaeological sites in Banff National Park. Included are data from six sites in the Bow Valley that date from 10,700 to 100 BP. Today, free-ranging bison are absent while elk make up rouoghly 50% of the ungulate population. Moose and mountain goats are still rare but deer have increased relative to bighorn sheep, which are still common. For details and citations to the original archaeological reports see Kay et al. (1994).

Measure	Elk	Bison	Deer	Bighorn	Moose	Goat
			Percent of identified specimens			
NISP* (n=566)	7	47	7	39	<1	<1
MNI** (n=78)	6	42	12	37	1	1

*NISP = Number of identified specimens
**MNI = Minimum number of individuals.

Bison (*Bison bison*), Deer (*Odoicoileus heminus* and *O. virginianus*), Bighorn (*Ovis canadensis*), Moose (*Alces alces*), and goat (*Oreamus americanus*).

immunological resistance to European diseases and that many epidemics reduced aboriginal numbers by 50% to 90% at each passing. Only recently, though, 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). 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 millions of aboriginal peoples before European-introduced diseases decimated their numbers (Bowden 1992, Gomez-Pompa and Kaus 1992, Simms 1992, Birkedal 1993, Martinez, 1993).

Another common misconception is that Native Americans were original conservationists who were too wise and knowledgeable to over-exploit 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), Alvard (1993a, 1993b, 1994), and others, however, have concluded that for humans conservation is seldom an evolutionary stable strategy. More specifically, Kay (1994) 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 those animals becoming extinct. Moreover, native hunting and predation by carnivores are additive and once worked in concert to reduce ungulate numbers (Figure 3).

Conclusions

The Banff of today is not the Banff of the 1880s, and neither are

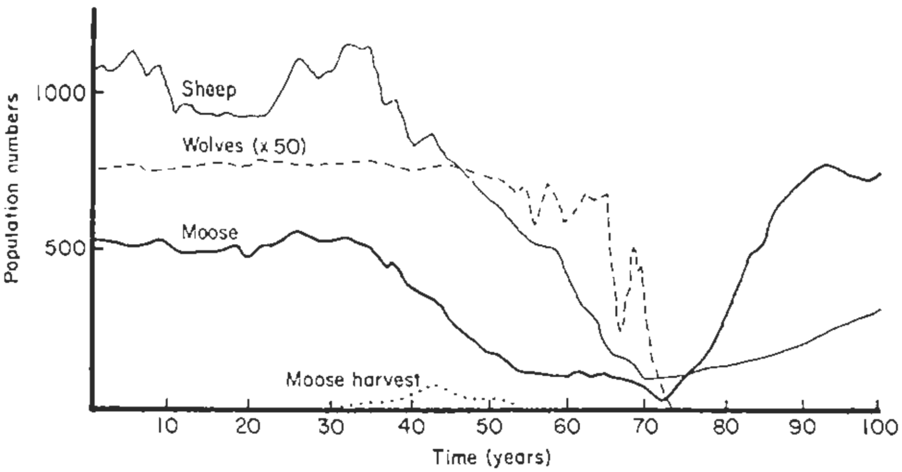

Figure 3. Model of Alaskan wolf-ungulate interactions simulated under circumstances in which human harvest of moose triggered a catastrophic decline in both predator and prey. Without hunting, wolves, moose and Dall shee0 (*Ovis dalli*) numbers are low, but relatively stable. The addition of a small amount of human moose harvest, however, destabilizes the entire system. Even after hunting is halted, wolves continue to drive the moose population downward. The wolves then switch to Dall sheep and drive those numbers down as well. In this simulation, wolves go extenct before they can kill the few remaining ungulates, allowing prey populations to recover. This would not be the case, though, if humans continued to prey on the ungulates. Grizzly bear (*Ursus arctos*) 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 Walters et al. (1981). Se suggest that in pre-Columbian times, the combined effect of carnivorous predation and native hunting kept ungulate populations at very low levels, except where the prey had refugia in time (long-distant migrations) or space (Kay 1994).

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 past. If we measure present ecological integrity by the state of the ecosystem that existed before European arrival, as others have proposed (Kay 1991a, 1991b; Woodley and Theberge 1992; Woodley 1993; Woodley et al. 1993; Angermeier and Karr 1994; Wagner et al. in press), then Banff's Bow Valley and much of the central Canadian Rockies today lack ecological integrity. But what Banff should Parks Canada manage for? 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). We suggest, however, that defining ecological integrity based on pre-Columbian ecosystem states and processes will keep personal biases and politics to a minimum, as well as preserve biodiversity within the environment to which it is best adapted.

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 (Wagner et al. in press). In Banff, for instance, following the status quo means, among other things, that (1) elk will continue to dominate the ungulate community especially in Banff townsite and developed areas avoided by wolves and other predators, (2) aspen will eventually be eliminated from most of the Bow Valley along with other species, (3) biodiversity will continue to decline as the forests age and replace grasslands in the absence of frequent low-intensity fires, 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 could also create burn patterns unlike any previously seen in Banff.

Throughout North America, most national parks, wilderness areas, and nature reserves are 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 in combination with other predators 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 (Martinez 1993, Wagner and Kay 1993, Wagner et al. in press). Moreover, Canada, like many 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). But again, what is natural? If ecological conditions in Canada's national parks are changing due to reduced predation on ungulates and lack of aboriginal burning, as we have argued, then are those parks the proper standard with which to measure ecosystem health and ecological integrity in other areas?

Clearly, the only hope in answering these and similar questions rests with studies that focus on historical ecology and how ecosystem states and processes have changed over time (Wagner et al. in press). 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).

Literature Cited

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.

Angermeier, P.L., and J.R. Karr. 1994. Biological integrity versus biological diversity as policy directives. Bioscience 44:690-697.

Arno, S.F. 1985. Ecological effects and management implications of Indian fires.

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.

Barrett, S.W. 1981. Relationship of Indian-caused fires to the ecology of western Montana forests. M.S. Thesis, University of Montana, Missoula. 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.

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. 1993. Before the wilderness: Environmental management by native Californians. Ballena Press, Menlo Park, CA. 476 pp.

Bowden, M.J. 1992. The invention of American tradition. J. of Historical Geography 18:3-26.

Boyd, T. 1986. Strategies of Indian burning in the Wilamette Valley. Can. J.Anthropol. 5:65-86.

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.

Covington, W.W., and M.M. Moore. 1994. Southwestern ponderosa forest structure: Changes since Euro-American settlement. J. For. 92:39-47.

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.

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.

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.

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.

Gomez-Pompa, A., and A. Kaus. 1992. Taming the wilderness myth. Bioscience 42:271-279.

Gottesfeld, L.M.J. 1994. Aboriginal burning for vegetative management in northwest British Columbia. Human Ecology 22:171-188.

Gould, S.J. 1989. Wonderful life: The Burgess Shale and the nature of history. W.W. Norton Co., New York, NY. 347 pp.

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.

Hallam, S.J. 1975. Fire and hearth. Australian Institute of Aboriginal Studies, Canberra, Australia. 158 pp.

Heinen, J., and B. Low. 1992. Human behavioral ecology and environmental conservation. Environ. Conser. 19:105-116.

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.

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., C.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.

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 Workman, G.W., ed. Western elk management: A symposium. Utah State University, Logan, UT. 213 pp.

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 5:359-398.

Kay, C.E. In Press. 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.

Kay, C.E., B. Patton, and C.A. White. 1994. Assessment of long-term terrestrial ecosystem states and processes in Banff National Park and the central Canadian Rockies. Heritage Resource Conservation Branch, Parks Canada, Banff National Park, Banff, AB. 405 pp.

Kay, J.J. 1991a. A non-equilibrium thermodynamic framework for discussing ecosystem integrity. Envir. Manage. 15:483-495.

Kay, J.J. 1991b. The concept of ecological integrity, alternative theories of ecology, and implications for decision support indicators. Pages 23-58 in Canadian Environmental Advisory Council. Economic, ecological and decision theories: Indicators of sustainable development. Canadian Environmental Advisory Council, Ottawa, ON. 121 pp.

Lewis, H.T. 1973. Patterns of Indian burning in California: Ecology and ethno-history. Anthropological Papers No. 1. Ballena Press, Ramona, CA. 101 pp.

Lewis, H.T. 1977. Maskuta: The ecology of Indian fires in northern Alberta. West. Can. J. Anthropol. 7:15-52.

Lewis, H.T. 1980a. Indian fires of spring. Natural Hist. 89(1):76-83.

Lewis, H.T. 1980b. Hunter-gatherers and problems for fire history. Pages 115-119 in M.A. Stokes, and J.H. Dieterich, eds. Proceedings of the fire history workshop. U.S. For. Ser. Gen. Tech. Rep. RM-81. 142 pp.

Lewis, H.T. 1982a. Fire technology and resource management in aboriginal North America and Australia. Pages 46-67 in N.M. Williams, and E.S. Hunn, eds. Resource managers: North American and Australian hunter-gatherers. AAAS Selected Symposium No. 67. 267 pp.

Lewis, H.T. 1982b. A time for burning. University of Alberta, Boreal Institute for Northern Studies Occ. Pub. 17. 62 pp.

Lewis, H.T. 1985. Why Indians burned: Specific versus general reasons. Pages 75-80 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.

Lewis, H.T. 1990a. Traditional ecological knowledge of fire in northern Alberta: Something old, something new, something different. Pages 222-227 in P.A. McCormack, and R.G. Ironside, eds. Proceedings of the Fort Chipewyan and Fort Vermilion Bicentennial Conference. 319 pp.

Lewis, H.T. 1990b. Reconstructing patterns of Indian burning in southwestern Oregon. Pages 80-84 in Hannon, N., and R. Olmo, eds. Living with the land: The Indians of southwestern Oregon. Southern Oregon Historical Society, Medford, OR. 153 pp.

Lewis, H.T. 1992. The technology and ecology of nature's custodians: Anthropological perspectives on aborigines and national parks. Pages 15-28 in Birckhead, J., T. Delacy, and L. Smith, eds. Aboriginal involvement in parks and protected areas. Aboriginal Studies Press, Canberra, Australia. 390 pp.

Lewis, H.T. 1993. In retrospect. Pages 389-400 in Blackburn, T.C., and K. Anderson, eds. Before the wilderness: Environmental management by native Californians. Ballena Press, Menlo Park, CA. 476 pp.

Lewis, H.T., and T.A. Ferguson. 1988. Yards, corridors and mosaics: How to burn a boreal forest. Human Ecol. 16:57-77.

Lewis, M., and W. Clark. 1893. The history of the Lewis and Clark expedition. Edited by E. Coues originally published by Francis P. Harper, NY. Republished in 1964 by Dover Publications, NY. Vol. I:1-352, Vol. II:353-820, Vol. III:821-1364.

Lotan, J. E., B. M. Kilgore, W. C. Fisher, and R. W. Mutch (eds.) Pages 81-86 in: Proceedings -- symposium and workshop on wilderness fire. U.S. For. Ser. Gen. Tech. Rep. INT-182. 434pp.

Martinez, D. 1993. Managing a precarious balance: Wilderness versus sustainable forestry. Winds of change 8(3):23-28.

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.

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, QU.

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.

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. Parks Canada, Banff National Park, Banff, AB. 54 pp.

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. 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., 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, NY.

Ramenofsky, A.F. 1987. Vectors of death: The archaeology of European contact. University New Mexico Press, Albuquerque, NM. 300 pp.
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.
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.
Schule, W. 1990. Landscapes and climate in prehistory: Interaction of wildlife, man and fire. Pages 273-318 in Goldammer, J., ed. Fire in the tropical biota. Springer-Verlag, NY. 497 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.
Turner. N.J. 1991. Burning mountain sides for better crops: Aboriginal landscape burning in British Columbia. Archaeology in Montana 32(2):57-73.
U.S. Forest Service. Pages 35-41 in: Proceedings of fire history workshopl. U.S. For. Ser. Gen. Tech. Rep. RM-81. 147 pp.
Wagner, F.H., R. Foresta, R.B. Gill, D.R. McCullough, M.R. Pelton, W.P. Porter, and H. Salwasser. In Press. Wildlife policies in the U.S. national parks–[An independent review originally commissioned by The Wildlife Society]. Island Press, Washington, D.C.
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, NY. 364 pp.
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, NY.
White, C.A. 1985. Wildland fires in Banff National Park 1880-1989. Occ. Pap. 3. National Parks Branch, Parks Canada, Environment Canada, Ottawa. 106 pp.
White, C.A., and I.R. Pengelly. 1993. Fire management in Banff National Park. Pages 30-43 in White, C.A., and P.L. Anchuff, eds. Proceedings of the central Rockies ecosystem interagency fire management workshop. Parks Canada, Banff, AB. 66 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.
White, R. 1975. Indian land use and environmental change: Island County, Washington: A case study. Arizona and the West 17:327-338.
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., 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, NY. 548 pp.

❖

Sustainable Society and Protected Areas

Contributed Papers
of the
8th Conference on Research and Resource Management in Parks and on Public Lands

April 17–21, 1995
Portland, Oregon

Edited by Robert M. Linn

Sponsored by
The George Wright Society

Co-Sponsored by: U.S. National Park Service · U.S. National Biological Service · National Oceanic and Atmospheric Administration, Coastal Ocean Office · U.S. Fish and Wildlife Service · National Park Foundation · Bureau of Land Management, Oregon-Washington State Office · Fort Clatsop Historical Association · Eastern National Park & Monument Association · Richard A. Brichetto and Sherry Wright Brichetto · Northwest Interpretive Association

Cooperating Organizations: Advanced Data Concepts, Inc. · Bonneville Power Administration · Columbia River Gorge Commission · The Museum at Warm Springs · Oregon Historical Society · Oregon State University · Portland Parks & Recreation Department · USDA–Forest Service

❖

The George Wright Society
Hancock, Michigan
1995