Aspen: A New Perspective—Implications For Park Management And Ecological Integrity

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Introduction

Aspen *(Populus tremuloides)* communities are deteriorating throughout western North America, including in national parks such as Yellowstone, Rocky Mountain, Banff, Jasper, Yoho, and Kootenay (Olmsted 1979, Kay 1996a), and based on repeat photographs, the area occupied by aspen has declined by up to 90% or more since European settlement (Kay 1990; Kay et al. 1994; Kay and White 1995). Many aspen stands contain old-age or single-age trees and have not successfully regenerated for 80 years or longer (Mueggler 1989a, 1989b). Moreover, many western aspen stands are being replaced by shade-tolerant conifers. These changes are usually attributed to the "fact" that aspen is a seral species, which has declined due to fire suppression (Cartwright and Burns 1994). I believe, though, that this view is incorrect, and I offer a new perspective on aspen ecology in the Intermountain West.

Aspen is Not Seral

Since there are no known instances of aspen clones having established from seed anywhere in the West during the period of recorded history (Kay 1993), aspen is not "seral" as that term is commonly used. It is thought that environmental conditions have not been conducive to seedling growth and clonal establishment since shortly after the glaciers retreated 10,000 or more years ago (McDonough 1985; Jelinski and Cheliak 1992; Mitton and Grant 1996). This means that aspen clones found in the West today have likely maintained their presence for thousands of years via vegetative regeneration (Grant 1993; Mitton and Grant 1996). Some clones in the southern Rockies are thought "to be as much as a million years old" (Cartwright and Burns 1994:2). Thus, in a sense, western aspen represents old-growth ancient forests (Peterson et al. 1995:14-17), not seral plant communities. Aspen, in fact, may be among the longest-lived organisms on Earth (Mitton and Grant 1996).

Western aspen clones are also generally quite large. In Yellowstone, for example, randomly selected aspen stands averaged more than an acre in size and larger clones are common (Kay 1990). One clone in southern Utah contains an estimated 47,000 stems, covers 106 acres, and weighs approximately 6,000 tons, making it the largest living organism on Earth (McLean 1993). This has led some to call aspen "charismatic mega*flora.*" If aspen is lost to advancing forest succession or overbrowsing (see below), there are no proven means of re-establishing those clones.

Although individual trees within clones are relatively short-lived (usually < 150 years), the long-lived aspen clones are often dependent on periodic disturbance such as fire to stimulate vegetative regeneration via root suckering and to reduce conifer competition (Bartos et al. 1991; 1994; Shepperd 1993; Shepperd and Smith 1993). Aspen will "appear" after a fire, though, only if it is already present; i.e., if the clones are already established—it will not seed onto the site. So, aspen is not really "seral"; instead, the presence of aspen indicates a long history of past disturbance, primarily frequent fire. Fire-return intervals of 20-130 years are necessary to maintain aspen, and, as fire cycles lengthen, aspen is eliminated (Noble and Slatyer 1980).

DeByle et al. (1987:75) reported that, at current rates of burning, "it would require about 12,000 years to burn the entire aspen type in the West," so something is clearly different today than at any point in the past, and if current trends are allowed to continue, much of the aspen in the Intermountain West will be lost. It should be noted, however, that approximately one-third of western aspen may be potentially climax—these stands lack invading conifers, and even in the absence of fire or other disturbance, they will successfully regenerate producing multi-stem-age stands (Mueggler 1988, 1989a, 1989b; Peterson and Peterson 1992, 1995; Stelfox 1995), if browsing is not excessive (see below).

Fire Ecology

Fire-history studies indicate that, prior to European settlement, aspen burned at frequent intervals throughout the West, and it is generally assumed that those fires were started by lightning (Houston 1982). Research and experience, though, have proven that aspen is extremely difficult to burn (Brown and Simmerman 1986). Terms such as "asbestos type" and "firebreak" are often used to describe aspen (DeByle et al. 1987:75). Even raging crown fires in coniferous forests seldom burn adjacent aspen communities (Fechner and Barrows 1976).

Research has demonstrated that aspen communities will readily burn only when aspen is leafless and when understory plants are dry, conditions that occur only in early spring and late in the fall (Brown and Simmerman 1986). Prior to May 15th and after September 15th, when aspen is normally dry enough to burn, however, there are few lightning strikes and virtually no lightning fires in the northern Rockies (Figures 1 and 2). So, if aspen burned at frequent intervals in the past, as fire-frequency data and historical photographs indicate it did, then the only logical conclusion is that those fires had to have been set by Native Americans (Lewis 1985; Kay 1995a, 1996a, 1996b; Pyne 1993, 1995; Kay and White 1995).

Ungulate Browsing

Single-age aspen stands are also generally considered normal, but exclosure studies indicate that is not the case. Kay (1990:84-122), for instance, measured 14 aspen-containing exclosures in the Yellowstone ecosystem where elk *(Cervus elaphus)* are the dominant herbivore, and found that aspen stands protected from ungulates all successfully regenerated and developed multi-age structures. Where native ungulates or domestic livestock have been excluded, aspen invariably produce multi-aged stems (Gysel 1960; Coles 1965; Milner 1977; Mueggler and Bartos 1977; Olmsted 1979; Kay et al. 1994). That is to say, stands dominated by old-age or single-age trees are an artifact of excessive browsing and not a biological attribute of aspen.

Even when burned by wildfire or prescribed fire, aspen clones across the West often fail to successfully regenerate due to excessive browsing. This is especially true in national parks and wildlife areas (Bartos and Mueggler 1981; Kay 1990; Bartos et al. 1991, 1994; Kay et al. 1994; Kay and White 1995; Romme et al. 1995). In Arizona, for instance, the Forest Service has had to fence treated aspen stands to keep elk from consuming all the new suckers, and when the fencing was removed after several year's protection, elk still killed the new aspen trees by browsing and stem breakage (Shepperd and Fairweather 1994). In fact, burning plus repeated browsing only hastens the elimination of aspen clones (Kay 1990; Bartos et al. 1994; Kay et al. 1994; Kay and White 1995; Kay and Wagner 1996).

Since it is often assumed that large numbers of elk and other ungulates inhabited the Intermountain West before game populations were decimated by Europeans, this raises the question of how aspen was able to survive for the last 10,000± years. First, historical photographs show that aspen were virtually unbrowsed during the 1800s, unlike conditions today (Kay and Wagner 1994). Second, historical journals indicate that elk and other ungulates were rare ca. 1800-1870. Between 1835 and 1876, for instance, explorers spent 765 days in the Yellowstone Ecosystem on foot or horseback, yet reported seeing elk only once every 18 days—today there are nearly 100,000 elk in that ecosystem (Kay 1990, 1995b). Similarly, between 1792 and 1872, 26 different expeditions spent 369 days traveling through the Canadian Rockies, yet reported seeing elk only 12 times, or once every 31 party-days (Kay and White 1995). Elk were also rarely seen in Utah, Arizona, New Mexico, or Colorado (Rawley 1985; Davis 1986; Allen 1996; Truett 1996). Third, archaeological data indicate that

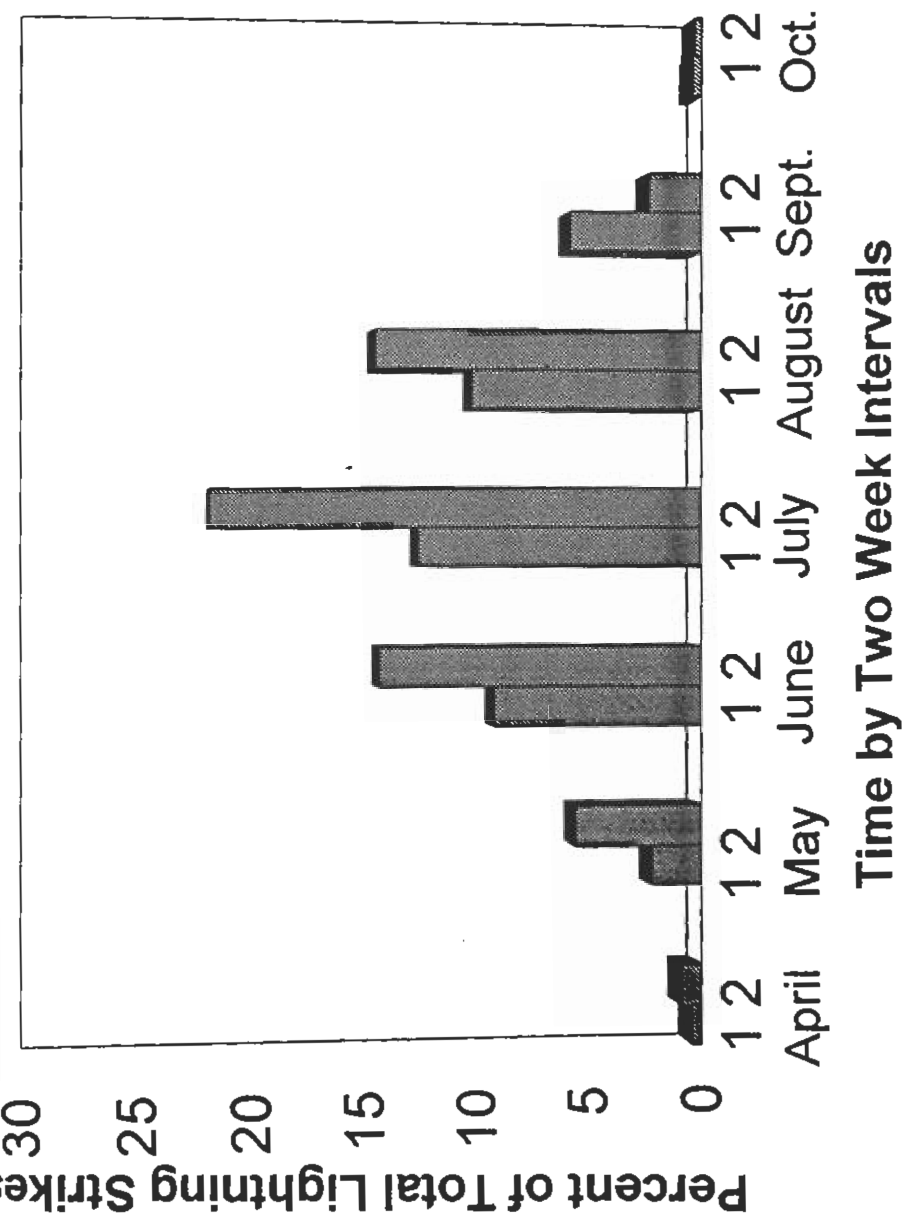

Figure 1. Frequency distribution of lightning strikes in the Centennial Mountains along the Montana-Idaho border. When aspen is normally dry enough to burn in early spring and late in the fall, there are few lightning strikes. This is true throughout western North America. Graphed are 8,908 lightning strikes that occurred from 1985 through 1993. Lightning data from the Bureau of Land Management's Automatic Lightning Strike Detection System, Boise, ID.

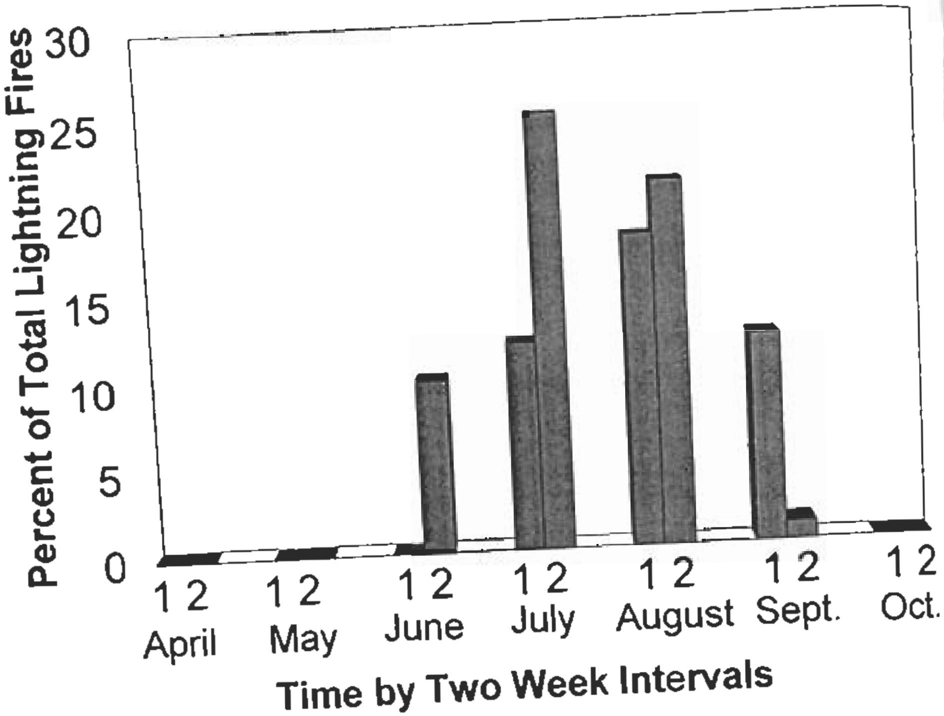

Figure 2. Frequency distribution of lightning-caused fires in the Centennial Mountains along the Montana-Idaho border. When aspen is normally dry enough to burn in early spring and late in the fall, not only are there few lightning strikes (see Figure 1), but there are virtually no lightning-started fires. During the 29 years (1965-1993) for which data are available, there were no lightning fires before June 15 and only one lightning fire after September 15. Although, there are virtually no lightning fires capable of burning aspen, historical photographs indicate that aspen in the Centennials burned frequently during the early 1800s (Kay unpub. repeat photos—work in progress for the Agricultural Research Service). This suggests that those fires had to have been set by Native Americans, as this area was not settled by Europeans until around 1876. Again, this pattern is common throughout western North America. Forest fire data from the Targhee National Forest, St. Anthony, ID.

the elk and other ungulates were rare in pre-Columbian times, as well (Kay 1990; Kay et al. 1994; Kay and White 1995; Allen 1996; Truett 1996). Of over 60,000 ungulate bones unearthed in more than 400 archaeological sites throughout the Rockies, elk composed only 3% (Kay 1990; Kay et al. 1994). Even in areas where elk dominate present ungulate fauna, elk are rarely recovered from archaeological sites (Kay 1990; Allen 1996; Truett 1996). Thus, there are more elk in the Rocky Mountains today than at any time in the last 10,000 years.

Aboriginal Overkill

Predation by carnivores is one factor that could conceivably have limited ungulate populations in the past, but data indicate that wolves *(Canis lupus)*, bears *(Ursus* spp.), and mountain lions *(Felis concolor)* are less-efficient predators than Native Americans (Kay 1994, 1995a, 1996b, 1997). Unlike carnivores which tend to kill the young, the old, the unfit, and males, Native Americans killed a predominance of prime-age females. I suggest that prior to European influences, predation by Native Americans kept elk and other ungulates at low densities throughout the Intermountain West which, in turn, permitted aspen to flourish, especially in areas burned by native peoples.

As I have presented my "aboriginal overkill" hypothesis elsewhere (Kay 1994, 1995a, 1996b,1997), I will not elaborate on its details here except to note that Native American preferences for prime-age females runs counter to any conservation strategy. It is often claimed, however, that Native Americans' religious belief system prevented those peoples from over-utilizing their resources. Native Americans tended to view wildlife as their spiritual kin where success in the hunt was obtained by following prescribed rituals and atonement after the kill (e.g., Feit 1987). A scarcity of animals or failure in the hunt were not viewed as biological or ecological phenomena, but rather as a spiritual consequence of social events or circumstances. If a Native American could not find any game, it was not because his people had overharvested the resource, but because he had done something to displease his gods. Since Native Americans saw no connection between their hunting and game numbers, their system of religious beliefs actually fostered the over-exploitation of ungulate populations. Religious respect for animals does not equal conservation (Kay 1994, 1995a, 1996b, 1997).

Instead, native hunters were essentially opportunistic and tended to take high-ranking ungulates regardless of the size of the prey populations or the likelihood of those animals becoming extinct (Kay 1994, 1995a, 1996b,1997). Native Americans had no concept of maximum sustained yield and did not manage ungulate populations to produce the greatest off-take. In addition, human predation and predation by carnivores are additive and worked in concert to reduce ungulate numbers (Kay and White 1995). Moreover, competition from carnivores tended to negate any possible conservation practices. Because Native Americans could prey-switch to small animals, vegetal foods, and fish, they could take their preferred ungulate prey to low levels or extinction without having any adverse effect on human populations. In fact, once Native Americans killed off most ungulates, human populations actually rose (Hawkes 1991, 1992, 1993).

There are, however, exceptions to aboriginal overkill (Kay 1994, 1995a, 1996b, 1997). According to predator–prey theory, prey populations will increase if they have a refugium where they are safe from predation. So, ungulates that could escape aboriginal hunters in time or 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. This explains why there were larger numbers of ungulates on the Great Plains and in the Arctic. By undertaking long-distance migrations, bison and caribou were able to outdistance most of their human and carnivorous predators (Kay 1994, 1995a, 1996b). Ungulates were also able to survive in buffer zones between tribes at war. Lewis and Clark (1893:1197), for instance, noted that "with regard to game in general, we observe that the greatest quantities of wild animals are usually found in the country lying between nations at war."

Native Americans, though, had no immunological resistance to European diseases, such as smallpox, and epidemics usually reduced aboriginal numbers by 50% to 90% at each passing. Moreover, aboriginal populations had declined by at least 90% before the first European chroniclers arrived in the West ca. 1800—this was due to disease transmission between native peoples in advance of actual white contact (Dobyns 1983; Ramenofsky 1987; Campbell 1990). Based on this and other information, pre-Columbian aboriginal numbers for North America have been revised upward to 100 million or more (Stannard 1992). 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 (Denevan 1992; Gomez-Pompa and Kaus 1992; Simms 1992; Cronon 1995).

Management Considerations

Aspen, then, is an excellent indicator of ecological integrity (Woodley and Theberge 1992; Woodley et al. 1993) because its condition provides information on long-term ecosystem states and processes. And, 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).

Aspen, for instance, indicates that aboriginal burning was once widespread; 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 green-up, or late in the fall when burning conditions were not severe (Turner 1991; Gottesfeld 1994). 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 (Kay 1995a). Moreover, aboriginal burning reduces or eliminates the number of high-intensity, lightning-generated fires. Once aboriginal fires opened up the vegetation, then subsequent lightning fires behaved like those set by Native Americans (Kay 1995a).

Aspen also indicates that Intermountain ecosystems developed with relatively low levels of ungulate herbivory. This, in turn, suggests that today's land managers will have to control browsing intensity if western aspen communities are to survive, and that high elk and deer *(Odocoileus hemionus* and *O. virginianus)* populations, common on many western ranges and in most national parks today, are not within the range of historical variability. Aspen in the past was perpetuated and probably enhanced by aboriginal land management, so the only way to maintain or restore western aspen communities is through active management. Creating a wilderness area or park and then allowing nature to take its course, often called "hands-off" or "natural regulation" management, will only consign most aspen to extinction.

Maintaining and restoring aspen communities is important because they have exceedingly high biodiversity, second only to riparian areas on western ranges, and because aspen covers millions of acres across the West (DeByle and Winokur 1985). Bird communities, for instance, vary with the size, age, and grazing history of aspen clones (Daily et al. 1993; Ehrlich and Daily 1993; Johns 1993; Westworth and Telfer 1993; Stelfox 1995). Moreover, aspen provide an "outstanding visual resource" especially during fall (Cartwrightand Burns 1994:2). So, the decline of aspen has ramifications far beyond the loss of a single species, which makes it an excellent indicator of ecological integrity, forest health, and protected area management.

References

Allen, C. D. 1996. Elk response to the La Mesa fire and current status in the Jemez Mountains. Pages 179-195 in Allen, C.D., ed. Fire effects in southwestern forests: Proceedings of the second La Mesa fire symposium. U.S. Forest Service Gen. Tech. Rep. RM-286. 216 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. 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.

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.

Campbell, S. K. 1990. Post Columbian cultural history in northern Columbia Plateau A.D. 1500-1900. Garland Publishing, New York, NY. 228 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.

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.

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

Cronon, W. 1995. The trouble with wilderness: Or, getting back to the wrong nature. Pages 69-90 in Cronon, W., ed. Uncommon ground: Toward reinventing nature. W. W. Norton and Co., New York, NY. 561 pp.

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.

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.

Denevan, W. 1992. The pristine myth: The landscape of the Americas in 1492. Assoc. Amer. Geographers Annals 82:369-385.

Dobyns, H. F. 1983. Their numbers become thinned: Native American population dynamics in eastern North America. University of Tennessee Press, Knoxville, TN. 378 pp.

Ehrlich, P. R., and G. C. Daily. 1993. Birding for fun: Sapsuckers, swallows, aspen, and rot. American Birds 47(1):18-20.

Fechner, G. H., and J. S. Barrows. 1976. Aspen stands as wildfire fuel breaks. Eisenhower Consortium Bull. 4:1-26. U.S. For. Ser. Rocky Mtn. For. and Range Exp. Sta., Ft. Collins, CO.

Feit, H. A. 1987. North American native hunting and management of moose populations. Swedish Wildl. Res. Suppl. 1:25-42.

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.

Grant, M. C. 1993. The trembling giant. Discover 14(10):83-89.

Gysel, L. W. 1960. An ecological study of the winter range of elk and mule deer in the Rocky Mountain National Park. J. For. 58:696-704.

Hawkes, K. 1991. Showing off: Tests of a hypothesis about men's foraging goals. Ethol. and Sociobiol. 12:29-54.

———. 1992. On sharing and work. Curr. Anthropol. 33:404-407.

———. 1993. Why hunter-gatherers work. Curr. Anthropol. 34:341-361.

Houston, D. B. 1982. The northern Yellowstone elk: Ecology and management. Macmillan, NY. 474 pp.

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.

Johns, B. W. 1993. The influence of grove size on bird species richness in aspen parklands. Wilson Bull. 105:256-264.

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.

———. 1993. Aspen seedlings in recently burned areas in Grand Teton and Yellowstone National Parks. Northwest Science 67:94-104.

———. 1994. Aboriginal overkill: The role of Native Americans in structuring western ecosystems. Human Nature 5:359-398.

———. 1995a Aboriginal overkill and native burning: Implications for modern ecosystem management. West. J. App. For. 10:121-126.

———. 1995b. An alternative interpretation of the historical evidence relating to the abundance of wolves in the Yellowstone Ecosystem. Pages 77-84 in Carbyn, L.D., S. H. Fritts, and D. R. Seip, eds. Ecology and conservation of wolves in a changing world. Canadian Circumpolar Institute, Edmonton, AB. 642 pp.

———. 1996a 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.

———. 1996b. Ecosystems then and now: A historical-ecological approach to ecosystem management. Pages 79-87 in Willms, W. D., and J. F. Dormaar, eds. Proceedings of the fourth prairie conservation and endangered species workshop. Provincial Museum of Alberta Natural History Occ. Paper 23. 337 pp.

———. 1997. Aboriginal overkill and the biogeography of moose in western North America. Alces 32: In press.

Kay, G. 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. Resource Conservation, Parks Canada, Banff National Park, Banff, AB. 405 pp.
Kay C. E., and C. A. White. 1995. Long-term ecosystem states and processes in the central Canadian Rockies: A new perspective on ecological integrity and ecosystem management. Pages 119-132 in Linn, R. M., ed. Sustainable society and protected areas. The George Wright Society, Hancock, MI. 300 pp.
Kay, C. E., and F. H. Wagner. 1994. Historic condition of woody vegetation on Yellowstone's northern range: A critical test of the "natural regulation" paradigm. Pages 151-169 in Despain, D.G., ed. Plants and their environments'—Proceeding of the first biennial scientific conference on the Greater Yellowstone Ecosystem. U.S. National Park Service, Denver, CO. Tech. Rep. NPS/NRYELL/NRTR-93/XX. 347 pp.
Kay, C. E., and F. H. Wagner. 1996. The response of shrub-aspen to Yellowstone's 1988 wildfires: Implications for "natural regulation" management. Pages 107-111 in Greenlee, J. M., ed. Ecological implications of fire in Greater Yellowstone: Proceedings of the second biennial conference on the Greater Yellowstone Ecosystem. International Association of Wildland Fire, Fairfield, WA. 235 pp.
Lewis, H. T. 1985. Why Indians burned: Specific versus general reasons. Pages 75-80 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.
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.
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.
McLean, H. 1993. Romancing the clone. Amer. Forests 99(3):8.
Milner, B. J. 1977. Vegetation analysis of ungulate range exclosures, Elk Island National Park. Canadian Wildlife Service, Edmonton, AB. 95 pp.
Mitton, B. J. and M. C. Grant. 1996. Genetic variation and the natural history of quaking aspen. Bioscience 46:25 - 31.
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. 1989a. Age distribution and reproduction of Intermountain aspen stands. West. J. Appl. For. 4:41-45.
Mueggler, W. F. 1989b. Status of aspen woodlands in the West. Pages 32-37 in Pendleton, B.G., ed. Western Raptor Management Symposium and Workshop. National Wildlife Federation Scientific and Tech. Series No. 12. Washington, D.C.
Mueggler, W. F., and D. L. Bartos. 1977. Gridstone 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.
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.
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.
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.
———. 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. Report 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.
Pyne, S. J. 1993. Keeper of the flame: A survey of anthropogenic fire. Pages 245-266 in Crutzen, P. J., and J. G. Goldammer, eds. Fire in the environment: Its ecological, climatic, and atmospheric chemical importance. John Wiley and Sons, New York, NY.
———. 1995. 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.
Ramenofsky, A. F. 1987. Vectors of death: The archaeology of European contact. University of New Mexico Press, Albuquerque, NM. 300 pp.
Rawley, E. V. 1985. Early records of wildlife in Utah. Utah Division of Wildlife Resources Pub. 86-2. 102 pp.
Romme, W. H., M. G. Turner, L. L. Wallace, and J. S. Walker. 1995. Aspen, elk, and fire in northern Yellowstone National Park. Ecology 76:2097-2106.
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.
Simms, S. R. 1992. Wilderness as a human landscape. Pages 183-201 in Zeveloff, S. I., L. M. Vause, and W. H. McVaugh, eds. Wilderness tapestry. University of Nevada Press, Reno, NV. 306 pp.
Stannard, D. E. 1992. American holocaust. Oxford University Press, New York, NY. 358 pp.
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.
Truett, J. 1996. Bison and elk in the American southwest: In search of the pristine. Environ. Manage. 20:195-206.
Turner, N. J. 1991. Burning mountain sides for better crops: Aboriginal landscape burning in British Columbia. Archaeology in Montana 32:57-73.
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.
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.

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