ARE LIGHTNING FIRES UNNATURAL? A COMPARISON OF ABORIGINAL AND LIGHTNING IGNITION RATES IN THE UNITED STATES

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ABSTRACT

It is now widely acknowledged that frequent, low-intensity fires once structured many plant communities. Despite an abundance of ethnographic evidence, however, as well as a growing body of ecological data, many professionals still tend to minimize the importance of aboriginal burning compared to that of lightning-caused fires. Based on fire occurrence data (1970–2002) provided by the National Interagency Fire Center, I calculated the number of lightning fires/million acres (400,000 ha) per year for every national forest in the United States. Those values range from a low of <1 lightning-caused fire/400,000 ha per year for eastern deciduous forests, to a high of 158 lightning-caused fires/400,000 ha per year in western pine forests. Those data can then be compared with potential aboriginal ignition rates based on estimates of native populations and the number of fires set by each individual per year. Using the lowest published estimate of native people in the United States and Canada prior to European influences (2 million) and assuming that each individual started only 1 fire per year—potential aboriginal ignition rates were 2.7–350 times greater than current lightning ignition rates. Using more realistic estimates of native populations, as well as the number of fires each person started per year, potential aboriginal ignition rates were 270–35,000 times greater than known lightning ignition rates. Thus, lightning-caused fires may have been largely irrelevant for at least the last 10,000 y. Instead, the dominant ecological force likely has been aboriginal burning.

keywords: aboriginal burning, Indian burning, lightning-caused fires, lightning-fire ignition rates, potential aboriginal ignition rates.

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INTRODUCTION

It is now widely acknowledged that frequent, low-intensity fires once structured many plant communities in the United States. Anderson (2005), Stewart (1956, 1963, 2002), Zybach (2003), Lewis (1973, 1977, 1985), Pyne (1982, 1993, 1994, 1995), and others (Blackburn and Anderson 1993, Kay and Simmons 2002, Carloni 2005, Gassaway 2005) contend that, historically, most fires were set by native people to manage their environment. Vale (2002), Baker (2002), and their colleagues (Houston 1973, Loope and Gruell 1973), however, maintain that the case for aboriginal burning has been overstated and that most fires, historically, were started by lightning. According to Baker (2002:41–42), ''Ignitions by Indians were . . . probably numerically insignificant relative to lightning ignitions . . . [and] Indians were a small part of a large Rocky Mountain wilderness, with a fire regime . . . essentially free of human influence for millennia.'' However, neither Vale (2002) nor Baker (2002) presented data on actual lightning ignition rates nor compared known lightning ignition rates with potential aboriginal ignition rates. In this paper, I present data on lightning-fire ignition rates for every national forest in the contiguous United States and then compare those figures with potential aboriginal ignition rates based on hypothetical estimates of native populations and the number of fires accidentally and purposefully set by each individual per year.

LIGHTNING-FIRE IGNITION RATES

The National Interagency Fire Center in Boise, Idaho, provided data on the number of known lightning-caused fires that occurred on individual national forests from 1970 to 2002. Based on the area of each forest, I then calculated lightning-fire ignition rates/million acres (400,000 ha) per year (Table 1). Those data range from a low of <1 fire/400,000 ha per year to 158 fires/400,000 ha per year on the Plumas National Forest in California. Ponderosa pine (*Pinus ponderosa*)–dominated forests in Arizona and New Mexico also have high lightning-fire ignition rates but, surprisingly, most national forests have relatively low lightning-fire ignition rates—this is especially true of national forests in the East (Figures 1, 2). Even the majority of western national forests, though, have relatively low lightning ignition rates (Figures 1, 2). Several national forests in Montana, Wyoming, and Colorado have <10 lightning-caused fires/400,000 ha per year (Table 1). National forests also have higher lightning-fire ignition rates than surrounding, lower-elevation, Bureau of Land Management (BLM), state, and private land (Barrows 1978). When those data are included, the mean lightning-fire ignition rate on all lands in the western United States is approximately 19 fires/400,000 ha per year (Table 2).

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These data then do not support the idea that the United States, or even the West, is awash in lightning-started fires. Popular misconceptions regarding the frequency of lightning fires may be due to media coverage during recent extreme fire seasons, as well as the fact that many fire-history studies have been done on the few national forests in California, Arizona, and New Mexico that have relatively high lightning-fire ignition rates.

POTENTIAL ABORIGINAL IGNITION RATES

Any estimate of aboriginal ignition rates must consider at least three factors—the number of landscape fires started inadvertently per person per year, the number of fires purposefully set per person per year, and the number of people. Unfortunately, how many people there were in the Americas prior to Columbus' landfall is not a settled issue. In fact, the entire subject is exceedingly contentious and highly charged, as it impinges directly on various national creation beliefs, charges of genocide by remaining indigenous inhabitants, and core environmental values, such as the idea of wilderness (Stannard 1992, 1998; Loewen 1995; Churchill 1997; Kay and Simmons 2002; Vale 2002; Mann 2005). Then, too, there is the problem that European-introduced diseases, such as smallpox, decimated native populations well in advance of actual European contact.

Smallpox, to which Native Americans had no acquired or genetic immunity, entered the Americas around 1520 and, according to Dobyns (1983), native people attempting to escape Spanish domination in Cuba fled to Florida in ocean-going canoes and brought smallpox to the mainland. Dobyns postulated that at least three major pandemics swept North America and reduced aboriginal populations by 90% or more before the Pilgrims arrived at Plymouth Rock. Needless to say, Dobyns' hypothesis has caused a great deal of debate, but recent archaeological work by Ramenofsky (1987), Campbell (1990), and Kornfield (1994) has documented a major aboriginal population collapse in the northern Rockies and on the northern Great Plains ca. 1550—250 y before explorers like Lewis and Clark (1804–1806) set foot in the West. Thus, we are left with a range of estimates—from a low of only a few million aboriginal inhabitants to a high of 200–300 million in the Americas ca. 1491 (Mann 2005). The only certainty is that Europeans have consistently underestimated the antiquity of aboriginal occupation, as well as the political and technical sophistication of America's original inhabitants (Mann 2005).

To be conservative in my evaluation of potential aboriginal ignition rates, I started with the lowest, published and commonly accepted estimate that I could find, namely 2 million native people in the continental United States and Canada ca. 1491 (Mann 2005). As there are approximately 1.5 billion ha north of Mexico, this yields a density estimate of 428 people/400,000 ha. Assuming there were only 500,000 natives in that area, as Alroy (2001) calculated for the end of the Pleistocene, then the density estimate is 107 people/400,000 ha. Both seemingly insignificant figures.

Escaped Campfires—Inadvertent Landscape Burning

Another thing that can be stated with certainty is that no one has ever found a Smokey Bear poster in an archaeological site anywhere in North or South America. In fact, no evidence exists that native people ever purposefully extinguished their heating or cooking fires. Most likely, they simply walked away and left their campfires burning.

> In a very extensive search of the literature, I discovered almost no reference that natives anywhere carefully extinguished fires. . . . Everywhere that man traveled, he made campfires and left them to ignite any and all vegetation in the vicinity [Stewart 1956:118].

If native people routinely used water or soil to put out campfires, we would expect to find large pieces of charcoal in archaeologically recovered fire pits, but charcoal is rare or absent from such features—all that is commonly found is white ash or exceedingly fine charcoal particles. Wright (1984:20–21), who conducted extensive archaeological research in the Yellowstone ecosystem, noted:

> We have recorded nearly three dozen archeological sites spanning about 4000 years of occupation. Rock broken from the heat of campfires is abundant, but charcoal is virtually absent. Even though it requires only four grams of charcoal for a C-14 analysis, on not one site has enough been collected for a date. There is obvious evidence of extensive cooking, so what has happened to the burned wood? At Blacktail Butte the firepits were shallow and the wind blows hard. No doubt much of the charcoal was dispersed by the wind, quite probably as still burning embers. The chance of accidental fires was quite high.

The only cases in which large pieces of charcoal have routinely been unearthed in archaeological settings are where habitation structures were set on fire, and this is usually interpreted as a sign of conflict or warfare (William Hildebrandt, Far Western Anthropological Research Group, personal communication).

Similarly, anthropologists who work with modern-day hunter–gatherers living in South America, Australia, and Africa report that their subjects never extinguish heating or cooking fires unless under duress by Europeans (Jim O'Connell, University of Utah, personal communication; William Preston, California Polytechnic State University, personal communication; Richard Chacon, Winthrop University, personal communication). Peter Fidler, who traveled with a band of Piegan natives in what is today central and southern Alberta during the winter of 1792–1793, reported how

Table 1. Lightning-fire ignition rates on national forest lands in the United States. Fire occurrence data (1970–2002) provided by the National Interagency Fire Center, Boise, ID.

National forest	Number of lightning fires/400,000 ha per year
Western United States	
Arizona	
Apache-Sitgreaves	81
Coconino	150
Coronado	49
Kaibab	97
Prescott	43
Tonto	61
California	
Angeles	26
Cleveland	17
Eldorado	49
Inyo	31
Klamath	64
Lassen	52
Los Padres	8
Mendocino	23
Modoc	51
Plumas	158
San Bernardino	121
Sequoia	75
Shasta-Trinity	38
Sierra	65
Six Rivers	18
Stanislaus	57
Tahoe	56
Colorado	
Arapaho-Roosevelt	12
Grand Mesa–Uncompahgre–Gunnison	8
Pike–San Isabel	25
Rio Grande	5
Routt	7
San Juan	32
White River	7
Idaho	
Boise	47
Caribou	14
Challis	16
Clearwater	70
Nez Perce	65
Panhandle	27
Payette	49
Salmon	31
Sawtooth	12
Targhee	12
Montana	
Beaverhead	8
Bitterroot	65
Custer	46
Deerlodge	13
Flathead	16
Gallatin	8
Helena	21
Kootenai	39
Lewis and Clark	9
Lolo	45
Nebraska	
Nebraska	73
Nevada	
Humboldt	7
Toiyabe	25
New Mexico	
Carson	22
Cibola	38
Gila	105
Lincoln	35
Santa Fe	55

Table 1. Continued.

National forest	Number of lightning fires/400,000 ha per year
Oregon	
Deschutes	54
Fremont	43
Malheur	83
Mount Hood	20
Ochoco	79
Rogue River	68
Siskiyou	14
Siuslaw	1
Umpqua	59
Wallowa–Whitman	50
Willamette	43
Winema	45
Umatilla	59
South Dakota	
Black Hills	64
Utah	
Ashley	22
Dixie	34
Fishlake	28
Manti-La Sal	33
Uinta	16
Wasatch-Cache	10
Washington	
Gifford Pinchot	14
Mount Baker–Snoqualmie	7
Okanogan	35
Olympic	6
Wenatchee	27
Wyoming	
Bighorn	8
Bridger–Teton	11
Medicine Bow	18
Shoshone	6
Eastern United States	
Alabama	
All national forests	6
Arkansas	
Ouachita	9
Ozark–St. Francis	4
Florida	
All national forests	51
Georgia	
Chattahoochee–Oconee	3
Illinois	
Shawnee	0.3
Kentucky	
Daniel Boone	1
Louisiana	
Kisatchie	2
Michigan	
Hiawatha	1
Huron–Manistee	1
Ottawa	1
Minnesota	
Chippewa	1
Superior	6
Mississippi	
All national forests	1
Missouri	
Mark Twain	1
New Hampshire	
White Mountain	1
North Carolina	
All national forests	2

Table 1. Continued.

National forest	Number of lightning fires/400,000 ha per year
Ohio–Indiana	
Wayne–Hoosier	0.1
Pennsylvania	
Allegheny	0.1
South Carolina	
Sumter–Francis Marion	3
Tennessee	4
Cherokee	
Texas	
All national forests	3
Vermont	
Green Mountain	0.3
Virginia	
George Washington–Jefferson	2
West Virginia	
Monongahela	0.4
Wisconsin	
Chequamegon	1
Nicolet	1

aboriginal attitudes toward fire differed from those of Europeans:

> 2 Tents [of Piegan] joined us that was tenting ¾ mile to the Eastward of us. They did not put out their fire when they left it, which spread amongst the dry grass and ran with great velocity and 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 [Haig 1992:58].

This observation was recorded on 18 January, a time of year when lightning-started fires are nonexistent on the northern Great Plains (Higgins 1984).

So, to begin with a simple and conservative assumption that there was only 1 escaped campfire/y per adult aboriginal inhabitant, and using the previous estimate of 428 native people/400,000 ha, this produces an estimate of 428 escaped fires/400,000 ha per year, which is 2.7 times the highest known lightning ignition rate in the West or 350 times the lightning ignition rate for national forests in the East (Table 1). If, on the other hand, we assume there were 20 million native inhabitants, possibly a more realistic figure (Dobyns 1983, Mann 2005), then the estimated escaped-campfire ignition rate is 27 times higher than the highest known lightning ignition rate and 3,500 times higher than the lightning ignition rate in much of the eastern United States. If we assume 10 escaped campfires/y per aboriginal inhabitant, instead of 1, then the accidental ignition rate is 270 times the highest lightning-started rate and 35,000 times the lightning-fire ignition rate in the East.

Unlike Europeans, aboriginal people without metal cutting instruments, which included all the Americas before 1492, tended to build relatively small cooking and warming fires. First, it took work to collect the necessary firewood and second, because large fires were more likely to be detected by enemies. Thus, no more than 6–8 native people usually sat around a single campfire (Binford 1978, Kelly 1995, Hill and Hurtado 1996). Assuming that 8 people shared a single campfire, that there were 2 million aboriginal inhabitants north of Mexico, and that each group of 8 lit only 1 campfire/d, this calculates out to 19,500 fires/400,000 ha per year—all of which were presumably left burning. This is 124 times the highest known lightning ignition rate (Table 1). However, it should be noted that some large villages of native peoples did occur in the East in the 1500s and were associated with extensive agriculture, such as near present-day Tallahassee in North Florida (Masters et al. 2003). This would likely decrease the potential for escapes in our hypothetical example.

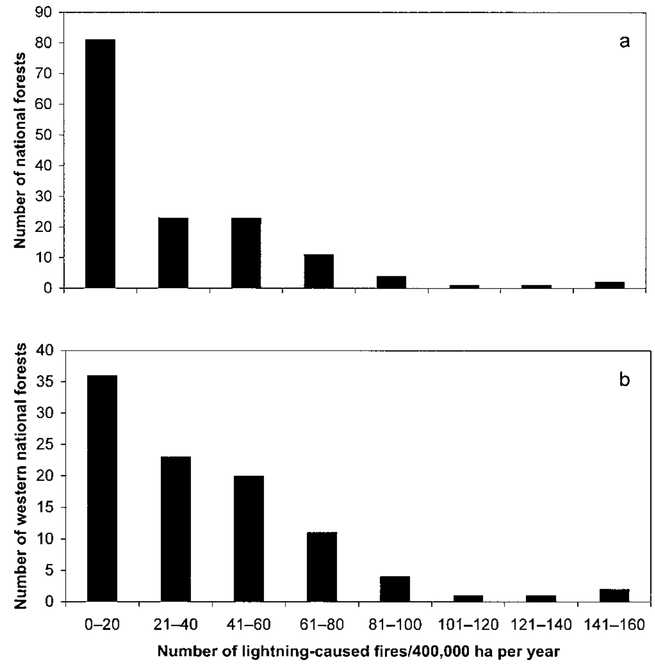

Fig. 1. Lightning-fire ignition rates on national forests in the contiguous United States (not including national grasslands). (a) All national forests (not including Alaska). (b) National forests west of the 100th Meridian (not including the Chugach and Tongass national forests, Alaska).

Baker (2002:41) dismissed aboriginal burning as a significant ecological force, in part because he contended that ''only about 30,000'' native people inhabited the northern Rockies. Baker did not define what he considered the northern Rockies but if we assume this includes one-half of Colorado, one-half of Montana, one-half of Wyoming, and one-third each of Idaho and Utah, we have an area of 610,000 km^2 (235,000 mi^2) or 1 aboriginal inhabitant/19 km^2 (7.3 mi^2). Again, a seemingly insignificant figure. A number, however, that translates to 212 people/400,000 ha. The mean lightning ignition rate for national forests in the northern Rockies, though, is only 17.6 fires/400,000 ha per year (Table 1). Assuming only 1 escaped campfire/aboriginal person per year, the accidental ignition rate is still 12 times the lightning ignition rate. Any other assumptions, as to the number of escaped campfires, only put more fire on the landscape. Thus, this hypothetical example does not support Baker's (2002:

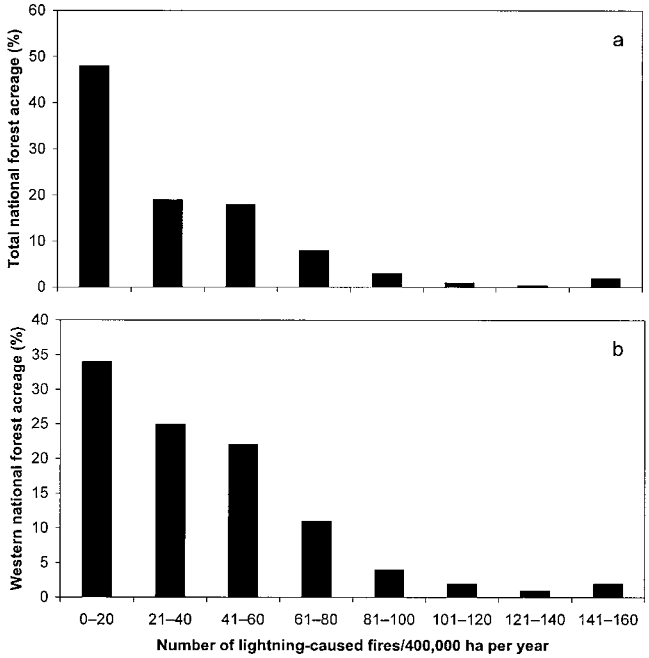

Fig. 2. Lightning-fire ignition rates by area for national forests in the contiguous United States (not including national grasslands). (a) All national forests. (b) National forests west of the 100th Meridian (not including the Chugach and Tongass national forests, Alaska).

41) conclusions that aboriginal fires were ''insignificant'' or that the Rockies were a wilderness untouched by the hand of man.

Similarly, Griffin (2002:81) suggested that there may have been no more than 1 native person/23 km^2 (8.9 mi^2) in the Great Basin and therefore aboriginal burning was unimportant compared to lightning-started fires. Griffin's aboriginal population estimate translates to 176 people/400,000 ha. For comparison, national forests in Nevada have a lightning ignition rate of only 17.8 fires/400,000 ha per year (Table 1). Using the conservative assumption of 1 escaped campfire/person per year, the accidental aboriginal ignition rate was 10 times the known lightning ignition rate. Thus, available data suggest that accidentally started aboriginal fires were 1, 2, or 3 orders of magnitude greater than known lightning ignition rates in the United States—depending on location and vegetation type (Fechner and Barrows 1976:19). For other reviews of the methodology used by Vale (2002), Baker (2002), and Griffin (2002), see LaLande (2003) and Pyne (2003). Finally, despite an extremely successful anti-fire public relations campaign, fire bans, and other measures, including closing entire national forests during high fire danger, 49% of the fires recorded in the National Forest System from 1940 to 2000 were caused by humans, not by lightning—and those human-set fires accounted for 57% of the area burned (Stephens 2005).

Purposeful Burning—Management-Set Fires

Although there is little doubt that Native Americans used fire to purposefully modify their environment (Stewart 1963, 2002; Lewis 1973, 1977, 1985; Anderson 2005), ethnographers have failed to record the number of fires set/person per year. The only data that I have been able to locate on this subject come from Australia where, in a few locations, aboriginal people still use fire to purposefully modify the vegetation as their ancestors are thought to have done for the last 45,000–50,000 y (Hallam 1975, Lewis 1989, Flannery 1994, Fensham 1997, Russell-Smith et al. 1997, Bowman 1998, Bowman et al. 2004, Vigilante and Bowman 2004). In Australia, most of the aboriginal-set management fires are started by men and each individual sets 100 or more fires/y, mostly at the end of the wet season and the beginning of the dry season—a time when lightning-fires are rare to nonexistent. This creates a vegetation mosaic that not only is more productive for the indigenous inhabitants but which also prevents large-scale, high-intensity, lightning-caused fires during the height of the dry season. Aboriginal-managed areas have also been shown to have higher plant and animal biodiversity than adjacent national parks, where lightning-caused fires are allowed to burn unchecked but where aboriginal burning is prohibited (Yibarbuk et al. 2001, Fraser et al. 2003).

So if we conservatively assume that each Native American purposefully set only 1 fire/person per year, and that there were only 2 million native people north of Mexico, the aboriginal burning rate would have been 2.7–350 times greater than known lightning ignition rates (Table 1). If 10 fires/person per year were set, possibly a more realistic assumption (Boyd, T., 1986; Turner 1991; Gottesfeld 1994; Boyd, R., 1999; Anderson 2005), the aboriginal burning rate would have been 27–3,500 times greater than known lightning ignition rates. If there were 20 million Native Americans, instead of 2 million, that would add another order of magnitude to the estimated rate of purposefully set fires. Finally, if estimates of accidentally started aboriginal fires are combined with estimates of purposefully set management fires, the overall aboriginal burning rate would have been 2–5 orders of magnitude greater than known lightning ignition rates. Even if we assume there were no more than 500,000 native people in the United States and Canada, aborig-

Table 2. Average lightning-fire ignition rates on protected state, private, and federal lands in the western United States, 1960–1975 (Barrows 1978:4).

State	Number of lightning fires/400,000 ha per year
Arizona	46
New Mexico	21
Colorado	11
Wyoming	6
Idaho	25
Montana	17
Nevada	3
Utah	7
California	28
Oregon	30
Washington	19
All western states	19

inal ignition rates would still have overshadowed lightning fires. Thus, there have been more than enough people in the Americas for the past 10,000 or so years to completely alter fire regimes and vegetation patterns.

Moreover, widespread aboriginal burning, by consuming fuels and creating patches of burned and unburned vegetation, limited the spread and extent of any lightning fires that may have started, similar to what has been documented in Australia (Kay 1998, 2000). This would suggest that lightning-caused fires have been largely irrelevant in structuring plant communities throughout many areas in North America. It also turns out that it does not require very many native people to completely alter fire regimes because lightning ignition rates were so low and aboriginal ignition rates so high.

EXTENT OF ABORIGINAL BURNING AND VEGETATION MODIFICATION

There are several ecological examples that suggest aboriginal burning not only structured a wide range of plant communities but actually created many of the vegetation associations heretofore thought to be ''natural.'' Perhaps the most compelling evidence is from eastern United States forests.

For the last 8,000–10,000 y, much of the east-central United States was dominated by oaks (*Quercus* spp.), American chestnut (*Castanea dentata*), and pines (*Pinus* spp.), all fire-tolerant, early to mid-successional species (Delcourt et al. 1986, 1998; Clark and Royall 1995; Cowell 1995, 1998; Olson 1996; Delcourt and Delcourt 1997, 1998; Bonnicksen 2000). Since European settlement, however, oaks and pines have increasingly been replaced by late-successional, fire-sensitive species, such as maples (*Acer* spp.), even in protected areas (Botkin 1990:51–71; Abrams 1998, 2003, 2005; Batch et al. 1999; Bonnicksen 2000; Rodewald 2003; Roovers and Shifley 2003; Aldrich et al. 2005; Rentch and Hicks 2005). This and related fire-history studies suggest that the species composition of eastern forests had been maintained for thousands of years by frequent landscape-level burning (Black et al. 2006, Stambaugh and Guyette 2006). Now, this portion of the United States does have one of the highest lightning-strike densities in North America (Orville and Huffines 2001, Orville et al. 2002) but as noted in Table 1, these forests have the lowest lightning-fire ignition rates in the country. This is because when most lightning strikes occur during June, July, and August, eastern deciduous forests are often too green or wet to burn. In fact, eastern deciduous forests will readily burn only when the trees are leafless and the understory is dry—conditions that occur late in the fall, during winter, or early in the spring; all times when there are virtually no lightning strikes and hence no lightning-caused fires.

Thus, the only way for eastern forests to have displayed the open stand characteristics and species composition that were common at European settlement is if those communities had regularly been burned by native people as part of aboriginal land management activities (Kay 2000, Mann 2005). Without humans actively managing these systems, the forests would be entirely different. It is also likely that aboriginal burning created the many eastern prairies and ''barrens'' reported by early Europeans (Campbell et al. 1991, Belue 1996, Barden 1997, Bonnicksen 2000, Mann 2005). Canebrakes (*Arundinaria gigantea*), too, likely owed their existence to native burning and other aboriginal land management practices (Platt and Brantley 1997).

Southern Canadian Rockies

Fire-history studies and repeat photographs both indicate that Banff and Jasper national parks once experienced a high frequency of low-intensity fires. Since the parks were established, however, lightning-caused fires have been exceedingly rare. In some vegetation types, fire return intervals are now 100 times greater than they were in the past (Wierzchowski et al. 2002). Lower montane valleys that once burned every 5 y or less now do not burn at all. Based on this and other evidence, Parks Canada has concluded that native burning, not lightning-caused fires, was critical in maintaining what heretofore was believed to be the ''natural'' vegetation mosaic of the southern Canadian Rockies (Kay et al. 1999). That is to say, there simply are not enough lightning-caused fires to account for historical burn and vegetation patterns (Wierzchowski et al. 2002).

Yellowstone National Park

Prior to park establishment, Yellowstone's northern grasslands had a fire return interval of once every 25 y (Houston 1973). Yellowstone has had a ''let burn'' policy for over 30 y now, 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 by lightning. Besides, the 1988 fires are thought to be a 100- to 300-y event, so similar fires could not have caused the original 25-y fire frequency (Kay 2000). Lightning strikes occur frequently on the northern range, but when they do during June, July, and August, the herbaceous vegetation is usually too green to carry a fire (Kay 1990). Thus, it is likely that the park's original 25-y fire frequency was entirely the product of aboriginal burning.

Aspen Ecology

Repeat photographs and fire-history studies indicate that western aspen (*Populus tremuloides*) communities burned frequently in the past, yet experience has 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). At current rates of burning, ''it would require about 12,000 years to burn the entire aspen type in the West'' (DeByle et al. 1987:73). Something is clearly different today from what it was in the past.

Research has shown that aspen communities will readily burn only when the trees are leafless and understory plants are dry, conditions that occur only during early spring and late in the fall (Brown and Simmerman 1986). Prior to 15 May and after 1 October, though, there are few lightning strikes and virtually no lightning fires in the northern or southern Rocky Mountains (Kay 1997, 2000, 2003). 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.

San Juan Mountains

Researchers in the southern Rockies contend that fire-history data obtained from fire-scarred conifers do not support the idea that aboriginal burning had any significant influence on ''natural'' fire regimes (Allen 2002, Vale 2002). Grissino-Mayer et al. (2004:1708), for instance, reported that they could find ''no compelling evidence that Native Americans influenced fire regimes'' in Colorado's San Juan Mountains. Lightning-fire data, though, do not support that conclusion. According to Grissino-Mayer et al. (2004:1716), ''57% of all fires prior to 1880 occurred during the spring dormant season'' based on microscopic analysis of when fire scars were actually formed. Yet lightning-fire occurrence data provided by the National Interagency Fire Center show that only 11% of lightning fires occur during that period, and they account for only 3% of the area burned (Figure 3). This would suggest that something other than lightning was responsible for the earlier fires (Kay 2000:20–21).

Northern Great Plains

Baker (2002:51–66) questioned the validity of using early historical accounts to support the idea that native people routinely used fire to manage their environment. According to Baker, few Europeans actually observed Native Americans setting the fires that early explorers attributed to native people and early explorers were also ignorant of the role lightning played in starting fires, when they attributed fire after fire to aboriginal ignitions. In addition, Baker (2002:52) claimed that Europeans were biased in attributing fires to natives because whites wanted ''to paint . . . Indians as reckless savages and poor land stewards who did not deserve to keep their land.'' That is to say, because Europeans thought fires were ''bad,'' attributing landscape burning to native people would put aboriginal inhabitants in an unfavorable light. While there is some truth in this argument (Decker 2004), alternatively, early explorers could have attributed most fires to native people because native people started most fires (Pyne 2003).

One way to answer the questions raised by Baker is to look at the current distribution of lightning-caused fires and to compare those data with observations from the early 1800s. Higgins (1984) reported that the majority of lightning fires on the northern Great Plains occur during June, July, and August (Figure 4a). Currently, there are few lightning-caused fires early in the spring or late in the fall because there are few lightning strikes outside of June, July, and August. Alexander Henry the Younger (Gough 1988) manned a trading post on the northern Great Plains from 1800 to 1807, and in his daily journal he recorded when the surrounding prairies were on fire. Henry observed prairie fires early in the spring and late in the fall but failed to report a single fire during June, July, or August (Figure 4b).

Vegetation on the northern Great Plains is often too green to burn during the June, July, and August growing season, but during droughts, lightning can set the prairies on fire during those months—these are the fires we see today. In the past, though, fire commonly swept the northern plains during early spring and late fall when the grasses are normally cured-out. Because there are virtually no lightning strikes early in the spring or late in the fall, all the fires reported by Alexander Henry the Younger likely were set by native people, whether Henry actually saw natives set those fires or not.

Then, too, there is Peter Fidler's journal (Haig 1992), a source not cited by Baker (2002). During the winter of 1792–1793, Peter Fidler traveled with a band of Piegan natives from Buckingham House east of present-day Edmonton, Alberta, to the Oldman River just north of the U.S. border. Fidler entered the southern Canadian Rockies and his journal is the earliest, first-hand, European description of the Rocky Mountains. Fidler repeatedly described how native people, both inadvertently and purposefully, set the plains on fire. And, most amazingly, during winter, well outside what is today the ''normal'' burning season. As there are no lightning strikes on the northern Great Plains during winter, every fire reported by Fidler must have been set by native people.

In addition, Fidler reported that the plains were commonly afire during spring and fall, but he made a mistake by attributing the spring and fall fires, which he did not personally observe, to lightning, and not to natives (Haig 1992:36). As there are no lightning fires on the northern Great Plains during spring or fall (Higgins 1984, Wierzchowski et al. 2002), all the burning reported by Fidler can be attributed to native people. In the spring of 1793, Fidler left the southern Alberta prairies and returned to Buckingham House, a journey of approximately 480 km. Over that distance, Fidler reported that they could find virtually no unburned ground on which to pasture their horses, such was the extent of aboriginal burning:

> 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 Cotton

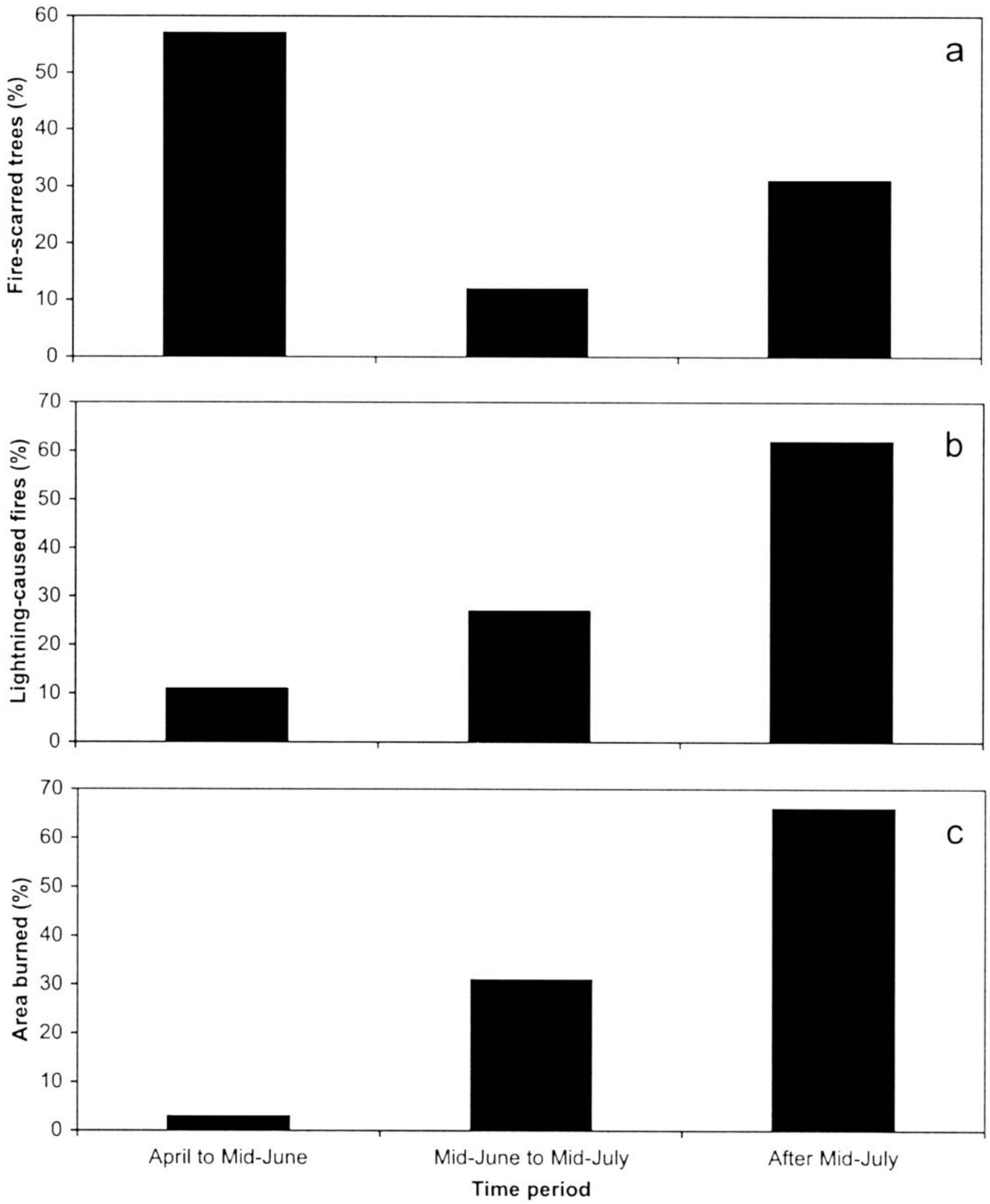

Fig. 3. Fire history of Colorado's San Juan Mountains. (a) The proportion of trees scarred by fire during different time periods prior to 1880, as reported by Grissino-Mayer et al. (2004). (b) The distribution of lightning-caused fires reported on the San Juan National Forest from 1970 to 2002. Data provided by the National Interagency Fire Center, Boise, ID. (c) The distribution of the area burned by lightning-started fires on the San Juan National Forest from 1970 to 2002. Data provided by the National Interagency Fire Center, Boise, ID.

> 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, & it drives along with amazing swiftness [Haig 1992:36].

West Coast Forests

Frequent fires once shaped many coastal forests in northern California, Oregon, and Washington. Coastal redwoods (*Sequoia sempervirens*), for instance, historically were visited by fire every 10–20 y or less (Brown and Baxter 2003, Stephens and Fry 2005). Frequent fire also once maintained a multitude of prairies, balds, and open areas within the forest mosaic (Zybach 2003). Lightning fires in these forests, however, are virtually nonexistent and these areas have some of the lowest lightning-fire ignition rates in the West (Table 1). Thus, many ecologists and anthropologists attribute the earlier burning to native people, who used fire to improve the productivity of various plant communities (Norton 1979, Boyd 1986, Lewis 1990, Liberman 1990, Brown and Baxter 2003, Wray and Anderson 2003, Zybach 2003, Anderson 2005, Carloni 2005, Keeley 2005, Stephens and Fry 2005). In the absence of regular native burning, prairies and

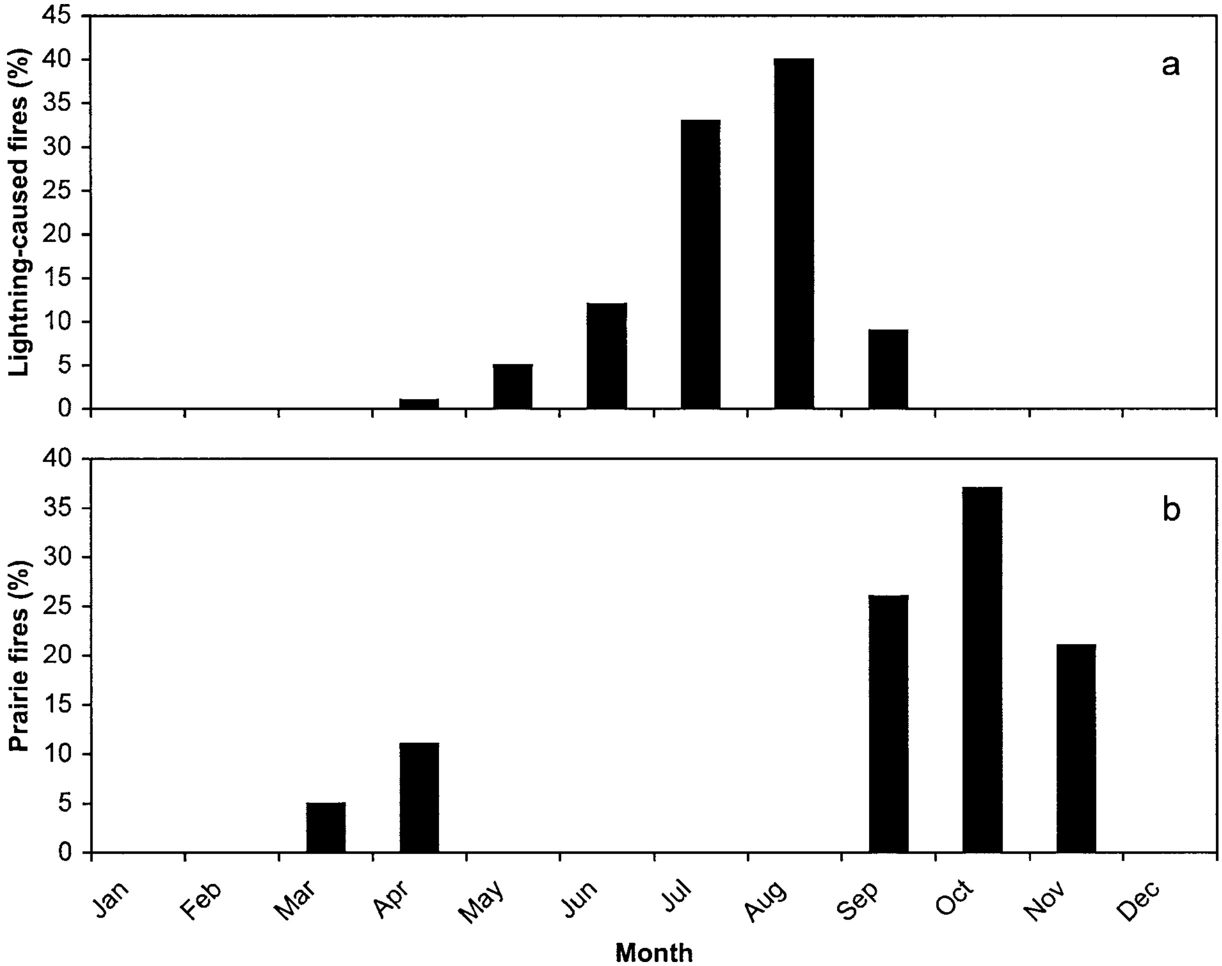

Fig. 4. The distribution of fires on the northern Great Plains. (a) The distribution of lightning fires that occurred from 1940 to 1981, as reported by Higgins (1984). There are few lightning fires during spring or fall because there are very few lightning strikes during those periods. (b) The distribution of prairie fires as reported by Alexander Henry the Younger from 1800 to 1807 when the northern Great Plains were under aboriginal control (Gough 1988).

balds are now overrun by encroaching conifers. The entire Willamette Valley, for instance, which was largely a grassland at European contact, reverts to forest in the absence of regular burning (Habeck 1961, Boyd 1986, Zybach 2003).

Whitlock and Knox (2002), though, contend that declining fire frequencies are due to climatic change and that, historically, aboriginal burning was unimportant. Whitlock and Knox, however, failed to explain how global climatic circulation patterns could change to such an extent that lightning-strike densities would increase in coastal areas. Moreover, even if known lightning-fire ignition rates were 100 times higher in the past, they would still have been overshadowed by human ignition rates, as coastal areas of northern California, Oregon, and Washington were densely populated by a vast array of aboriginal people due to abundant stocks of salmon (*Oncorhynchus* spp.), vegetal foods, and marine resources (Zybach 2003). Whatever climatic changes may have occurred were inconsequential given the level of aboriginal burning that existed.

First Contact

A similar debate has been going on for many years over what caused Pleistocene megafaunal extinctions as modern humans spread out of Africa (Kay and Simmons 2002). One school holds that climatic change drove the extinctions, while the other contends that humans killed-out the megafauna in the Americas and around the world—see Kay (2002) for a detailed discussion of this debate.

To separate between these competing hypotheses, Miller et al. (2005) looked at carbon isotopes in emu (*Dromaius novaehollandiae*) eggshells and wombat (*Vombatus* spp.) teeth—records that span 150,000 y in Australia. Miller et al. (2005) reported an abrupt change in feeding habitats 45,000–50,000 y ago when humans first colonized Australia. As noted by Johnson (2005:256), ‘‘The fact that the distributions and feeding habits of both species changed so little in response to climate extremes, but so much when people arrived, tells us that the impact of human arrival far exceeded the effects of any of the climate changes of the past 140,000 years.’’ Miller et al. (2005:290) suggested, "that systematic burning practiced by the earliest human colonizers may have converted a drought-adapted mosaic of trees and shrubs intermixed with palatable nutrient-rich grasslands to the modern fire-adapted grasslands and chenopod/desert scrub." Similarly, Robinson et al. (2005:295) reported a sharp rise in charcoal recovered from sediment cores at the time humans initially colonized eastern North America and suggested that this represented anthropogenically driven "landscape transformation" on a grand scale. As humans drove the megafauna to extinction by hunting, escaped campfires and purposeful burning completely reconstituted vegetation communities.

CONCLUSIONS

According to Parker (2002:260), who discounted the ecological impact of aboriginal burning, "nostalgia and political agendas are no substitute for valid evidence," and I concur, as do others (LaLande 2003, Pyne 2003). The evidence suggests that lightning-caused fires were never more frequent than native-set fires—either escaped campfires or purposefully started fires at even the lowest aboriginal population estimates. Various ecological examples also suggest that native burning was a much more important ecological factor than lightning-caused fires. There is also the problem that reported fire return intervals do not present a true measure of how often areas once burned. It has been known for some time that low-intensity surface fires, which were the norm in many ecosystems prior to European settlement, do not scar each tree they burn, even if that tree had been previously scarred.

The only experimental data that I have been able to locate are for oaks in eastern forests where researchers repeatedly prescribed-burned stands at 1-, 2-, or 3-y intervals and then cut down the trees to count fire scars (Smith and Sutherland 1999, Sutherland and Smith 2000). On average, only one-third of burned trees were actually scarred by fire (Elaine Sutherland, U.S. Forest Service, personal communication). Similarly, Skinner and Taylor (2006) noted that 86% of Douglas-fir (*Pseudotsuga menziesii*) stumps with internal fire scars had no external evidence of the trees having been burned. When those hidden fire scars were taken into account, the estimated fire return interval declined by nearly 50% (Skinner and Taylor 2006:204–206), while Shirakura (2006) observed that only one in seven fires were recorded by oaks in east-central Oklahoma. This would suggest that published fire-history studies tend to underestimate the true frequency of burning.

How often did areas burn in the past? As often as native people wanted them to burn. There is little doubt that Native Americans fully understood the benefits they could receive by firing their environment (Anderson 2005). To suggest otherwise is to assume aboriginal people were ecologically incompetent (Andersen 2005), a supposition that is not supported by any reading of the historical or ethnographic record (Mann 2005). Thus, the idea that the Americas were a pristine wilderness, untouched by the hand of man (Vale 2002) is a statement of belief, not a fact supported by science (Kay 2002, Pyne 2003).

Finally, this paper is a first attempt at estimating how many fires native people may have started and, as such, I did not consider cultural differences or how aboriginal burning may have varied over time, under different subsistence strategies, or by area. I also assumed that native people were systematically distributed across the landscape, which was surely not the case with more settled societies. Nevertheless, even with the simplifying assumptions that were employed, aboriginal use of fire most likely overwhelmed lightning ignitions as Stewart (1956, 1963, 2002), Anderson (2005), and others contend.

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How does lightning form? Lightning is an electric current. To make this electric current, first you need a cloud. When the ground is hot, it heats the air above it. This warm air rises. As the air rises, water vapour cools and forms a cloud. When air continues to rise, the cloud gets bigger and bigger. In the tops of the clouds, temperature is below freezing and the water vapour turns into ice. Now, the cloud becomes a thundercloud. Lots of small bits of ice bump into each other as they move around. All these collisions cause a build up of electrical charge. Eventually, the whole cloud fills u In 2020, the Western United States experienced a series of major wildfires. Severe August thunderstorms ignited numerous wildfires across California, Oregon, and Washington, followed in early September by additional ignitions across the West Coast. Fanned by strong, gusty winds and fueled by hot, dry terrains, many of the fires exploded and coalesced into record-breaking megafires, burning more than 8.2 million acres (33,000 square kilometres) of land, mobilizing tens of thousands of firefighters A COMPARISON OF ABORIGINAL AND LIGHTNING IGNITION RATES IN THE UNITED STATES Charles E. Kayâ€™ Utah State University, Department of Political Science, Logan, UT 84322-0725, USA ABSTRACT It is now widely acknowledged that frequent, low-intensity ï¬res once structured many plant communities. Despite an abundance of ethnographic evidence, however, as well as a growing body of ecological data, many professionals still tend to minimize the importance of aboriginal burning compared to that of lightning-caused ï¬res.Â Are lightning ï¬res unnatural? A comparison of aboriginal and lightning ignition rates in the United States. Pages l6Â»28 in R. E. Masters and K. E.M. Galley (eds.). The lightning protection industry began in the United States when Benjamin Franklin postulated that lightning was electricity, and a metal rod could be used to carry the lightning away from a building. Lightning is the direct cause of over 50 deaths and 400 injuries each year, and it is difficult to protect individuals in exposed outdoor areas. Direct lightning strikes cause fire damage in excess of $200 million per year, and insurance companies pay claims in the billions of dollars associated with lightning either directly or indirectly.Â General System Information. The Standards in the United States for complete lightning protection systems include NFPA 780, UL 96 & 96A, and LPI 175. Most lightning occurs within the clouds. "Sheet lightning" describes a distant bolt that lights up an entire cloud base. Other visible bolts may appear as bead, ribbon, or rocket lightning. During a storm, colliding particles of rain, ice, or snow inside storm clouds increase the imbalance between storm clouds and the ground, and often negatively charge the lower reaches of storm clouds.Â About one to 20 cloud-to-ground lightning bolts is "positive lightning," a type that originates in the positively charged tops of stormclouds. These strikes reverse the charge flow of typical lightning bolts and are far stronger and more destructive. Positive lightning can stretch across the sky and strike "out of the blue" more than 10 miles from the storm cloud where it was born.