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Elk Response to the La Mesa Fire and Current Status in the Jemez Mountains

Craig D. Allen[1]

Abstract.—Faunal remains in local archeological sites and historic information suggest that elk populations in the Jemez Mountains were low from ca. 1200 A.D. through ca. 1900 A.D., when they were extirpated from this region. Elk were reintroduced to the Jemez country in 1948 and 1964–1965, and their population apparently grew exponentially, reaching 1000 animals in the 1970's and about 7000 by 1991.

Elk populations in Bandelier National Monument and adjoining areas increased rapidly after the 1977 La Mesa Fire. Winter use by elk in the La Mesa Fire area, centered on Bandelier, grew from about 100 animals in 1978 to around 1500 elk by 1992. The dramatic increase in the Bandelier elk herd (an annual growth rate of 21.3% and a 3.6 year population doubling time) was due in part to the creation of about 6000 hectares of grassy winter range in and around the park by the La Mesa Fire. Some of this local population increase reflects concentration of elk into this favorable wintering habitat from surrounding portions of the Jemez Mountains.

Existing data are inadequate to determine whether elk populations are still growing rapidly in the Jemez Mountains. While annual aerial surveys since 1990 in Bandelier reveal no clear population trend, a variety of observations demonstrate increasing elk use of lower elevation areas. Negative resource impacts from today's high elk populations are beginning to be widely noted across the Jemez Mountains, especially in high-use portions of the Bandelier National Monument area. Affected resources range from plant communities to soils and even archeological sites. Given the large uncertainties associated with the current data on elk populations, care should be taken to avoid further population increases until the resource impacts of this new phenomenon (large numbers of elk) can be identified, desirable population levels identified (based to a significant degree upon ecological information and resource carrying capacities, as well as social considerations), and appropriate cooperative management strategies implemented.

INTRODUCTION

The habitat changes associated with the La Mesa Fire have benefited some species, prominently including elk. This paper reviews elk response to the La Mesa Fire, and provides an overview of the past and current status of this species in the southeastern Jemez Mountains.

Prehistoric Elk Abundance

Rocky Mountain elk (*Cervus elaphus nelsoni*) are considered native to the Jemez Mountains (Bailey 1931). Figure 1 shows a prehistoric elk petroglyph,

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Figure 1.—Prehistoric elk petroglyph, White Rock Canyon near Bandelier National Monument. Horizontal scale is 10 cm long with 1 cm subdivisions, while the vertical rod is divided into 25 cm sections. Photograph by Betty Lilienthal, ARMS Site Files collection, Laboratory of Anthropology, Santa Fe, New Mexico.

etched into a basalt boulder in White Rock Canyon near Bandelier National Monument. Elk were present here into the late 19th Century, but by 1906 they had probably been eliminated from the Jemez country (Bailey 1931:40).

There is no evidence that elk were ever abundant during prehistoric or historic times in the Bandelier area. Table 1 displays a compilation of ungulate faunal remains recovered from 45 local archeological sites (Allen—in review), almost all dating to before 1500 A.D. Out of a total of 218 ungulate individuals which were determined to species (based upon a total of 646 identified bones), only three individual elk were determined (based upon nine identified elk bones); eight of these elk bones date from the late 1800's, while the ninth was a 15th Century bone tool which might easily have been imported. While deer remains dominate local archeological faunal assemblages, bighorn sheep, pronghorn, and even bison remains exceed those of elk. (Since bison were absent from the local fauna their remains were presumably traded into the Bandelier area from the Great Plains to the east.) Kay (1990) reviews various factors that could bias the relative proportions of faunal remains excavated from archeological sites (e.g., differential preservation or field disposal of bone from larger ungulates by butchering at the kill site), concluding that these processes would not unduly discriminate against the presence of elk materials. If true, the paucity of local elk remains suggests low elk populations in and around today's Bandelier National Monument during the main period of prehistoric occupation (roughly 1200–1500 A.D.).

The large sample of excavated faunal remains (at least 226 ungulate individuals) from nearby Arroyo Hondo (Lang and Harris 1984), outside Santa Fe, similarly shows few elk remains (Table 1). The absence of any elk remains during the period of peak human population suggests that ancestral Puebloan peoples may have eliminated local elk populations (Lang and Harris 1984:49).

Indeed, a strong case has recently been made for prehistoric aboriginal control of elk numbers across

Table 1.—Ungulate remains recovered from archeological sites in and around the Jemez Mountains.

	Minimum Number of Individuals					
	Deer	Elk	Bighorn	Antelope	Bison	Ungulate
Jemez Mts. (45 sites)	154	3	30	24	7	58
Arroyo Hondo (Santa Fe)	157	6	—	56	7	213
Total	311	9	30	80	14	271

	Number of Identified Specimens (Minimum Estimate)					
	Deer	Elk	Bighorn	Antelope	Bison	Ungulate
Jemez Mts. (45 sites)	515	9	32	24	66	1,126
Arroyo Hondo (Santa Fe)	300	9	—	77	11	568
Total	815	18	32	101	77	1,694

widespread portions of the western U.S. and Canada (Kay 1990 and 1994, Martin and Szuter—in review). Kay (1994) bases his "aboriginal overkill" hypothesis of elk population control on various factors which also would have applied to Southwestern Pre-Columbian peoples, including: 1) the efficiency of Native American predation, which included cooperative hunting, use of dogs, food storage, ability to switch to non-ungulate foods, and various effective hunting techniques (such as running down elk in deep snow); 2) optimal-foraging studies which suggest that elk would have been a preferred prey species; 3) low elk numbers in the ungulate species remains found in archaeological contexts compared with the ratios of present ungulate communities; 4) the high numbers of Native Americans which were present in many areas before Old World diseases drastically reduced the aboriginal populations; 5) a presumed lack of effective Native American conservation practices; and 6) synergism between human and carnivore predation in suppressing prey populations.

Focussed more specifically on the Southwest, Osborn (1993) reviews rationales for high levels of ungulate utilization by prehistoric Native Americans, suggesting that the stereotype of the Anasazi-Hohokam-Mogollon peoples as farmers understates the importance of big game food resources, and thus hunting, in their subsistence patterns. Certainly crossing the mesas of the Bandelier area during Anasazi times would have required running a gauntlet of protein-hungry, crop-defending humans. Overall, it is plausible to envision that elk numbers in the Jemez Mountains area were suppressed by the large numbers of ancestral Puebloans who inhabited this region after circa 1200 A.D.

Historic Elk Abundance

Historic documents further suggest low elk populations in the Jemez Mountains area since Anglo-American contact. In the 1880's Adolph Bandelier attributed the local scarcity of game, including elk, to Native American hunting (Bandelier 1892:141). Henderson and Harrington (1914:3) state that for the overall American Southwest: "A study of the literature of early exploration does not indicate general distribution of vast herds of antelope, elk, and deer—and especially this is true of elk". More particularly, by the latter half of the 1800's elk were certainly scarce in the Jemez Mountains area (Henderson and Harrington 1914:2–3), becoming extinct around the turn of the century. It is curious that the grassy, fire-maintained, open forests which characterized much of the Jemez landscape in earlier centuries apparently supported so few elk. Perhaps the pre–1880 recurrence of landscape-wide fires across the Jemez Mountains every 20 or so years (Allen et al. 1995, Touchan et al., This Volume) contributed to the effects of human and wild carnivore predation to constrain elk populations by occasionally imposing limited forage availability across broad portions of their mountain refuges, forcing more elk down into areas where human hunting pressures were greater. In any event, by the time of Vernon Bailey's biological surveys of the Jemez area in 1904 and 1906 elk were apparently extirpated. As he stated (Bailey 1931:40):

In 1906, the writer saw a fair-sized elk horn in a good state of preservation on the fence at a Mexi-

can ranch near Jemez Hot Springs, and was told that it was picked up on Cebolla Creek in the central part of the Jemez Mountains. He could get no records of elk in the Jemez Mountains in recent years, but has no doubt that they once covered these mountains, which are in close connection with the San Juan Range.

Overall, the available evidence suggests that since the La Mesa Fire the Jemez Mountains population of reintroduced elk has grown to levels far greater than anything known since at least A.D. 1200.

ELK POPULATION TRENDS IN THE JEMEZ MOUNTAINS

Reintroduction and Population Growth

In 1948 the New Mexico Game and Fish (NMGF) Department released 21 cows/calves and 7 bulls of *Cervus elaphus nelsoni*, from Yellowstone National Park, into the Jemez Mountains in "the Clear Creek area" on the south side of the San Pedro parks (letter of 19 Dec., 1961, from NMGF Director Fred Thompson to Bandelier National Monument). Bandelier's 1948 "Annual Wildlife Report" estimates a population of 5 elk in the park, noting:

> This is the first report of elk on the Bandelier area. In early May of this year 28 elk were introduced to the higher Jemez (m)ountains to the north and east (sic—should be west) of the monument by the State Fish and Game Department. On July 9 the tracks of a bull and cow elk were observed on trails in the upper portions of Bandelier (*author's note:* likely on the mesa south of Upper Crossing at about 2200 m elevation, given the different park boundary of that time). On September 15 four bulls were seen in the lower end of Alamo Canyon near our southern boundary. We shall watch with keen interest the activities of these newcomers during the winter months (S. Keefe, 25 Sept., 1948, report on file at Bandelier National Monument).

By 1961 NMGF estimated a population of at least 200 elk in the Jemez Mountains, all descendants of the 28 founders (letter of 19 Dec., 1961, from NMGF on file at Bandelier). Yet from 1948–1965 elk were rarely seen in Bandelier, with park population estimates ranging from 0 to 6 individuals (incomplete set of annual wildlife reports on file at Bandelier). The park apparently did not provide particularly good elk habitat at that time, despite the increased protection that it offered from poaching and other human disturbances. In 1964–1965 another 58 elk from the Jackson Hole area were released into the mountains of Los Alamos County adjacent to Bandelier (White 1981).

The elk population in the Jemez Mountains (delineated as Unit 6 by NMGF) has apparently exhibited exponential population growth over at least portions of the past 47 years (Figure 2). If the population grew from 28 elk in 1948 to 200 animals in 1961, this represents a 16.3% annual increase and a 4.6 year doubling time. By 1989 the Unit 6 elk herd had grown to an estimated level of roughly 6000–8000 individuals, with about 3500 elk summering on the Baca Location (R. Isler, NMGF—1989 personal communication); this remains the range of "official" NMGF population estimates (L. Fisher—1995 personal communication). However, note that a long-time Unit 6 wildlife officer has consistently estimated only 3500–5000 elk in the Jemez area for the period 1990–1995 (P. Cassidy—1995 personal communication). For the time period 1948–1992, given the increase from the original 28 planted elk to an estimated 7000 elk, the calculated annual growth rate for the Jemez elk herd is 13.4%, with a doubling time of 5.5 years. If the elk population is assumed to have grown from 200 animals in 1961 to the median NMGF estimate of 7000 animals in 1992, this indicates a 12.2% annual population growth, with a doubling time of 6.0 years. This large population growth occurred despite significant increases in permitted elk hunting in Unit 6 since 1980 (Table 3).

Rapid growth of elk populations has also occurred in the state as a whole. By 1910 all elk populations in New Mexico were considered extirpated (Bailey 1931:40–44, Findley 1987:141–142), probably due to uncontrolled hunting and competition for herbaceous forage with domestic livestock. Rocky Mountain elk reintroductions into New Mexico began in 1911 (Bailey 1931:41). Elk populations grew to estimated statewide population levels of 32 in 1911 (Bailey 1931:41), "about 60" in 1912 (Findley 1987:142), 126 in 1914 (compiled from Bailey 1931:41), 750 in 1923 (Findley 1987), 680 in 1926 (Ligon 1927:71), between 3500 (Bryant and Maser 1982) and "perhaps 4000" (Findley 1987) in 1934, "almost 11,000" in 1967 (Findley 1987), and 10–12,000 elk by 1976 (Bryant and Maser 1982). The 1992 population was estimated to be 40,000 elk (D. Weybright, NMGF—1992 personal communication). If there were 10,800 elk in 1967 and 40,000 in 1992, this would indicate a 5.4% annual growth rate and a 13.2 year doubling time over this period.

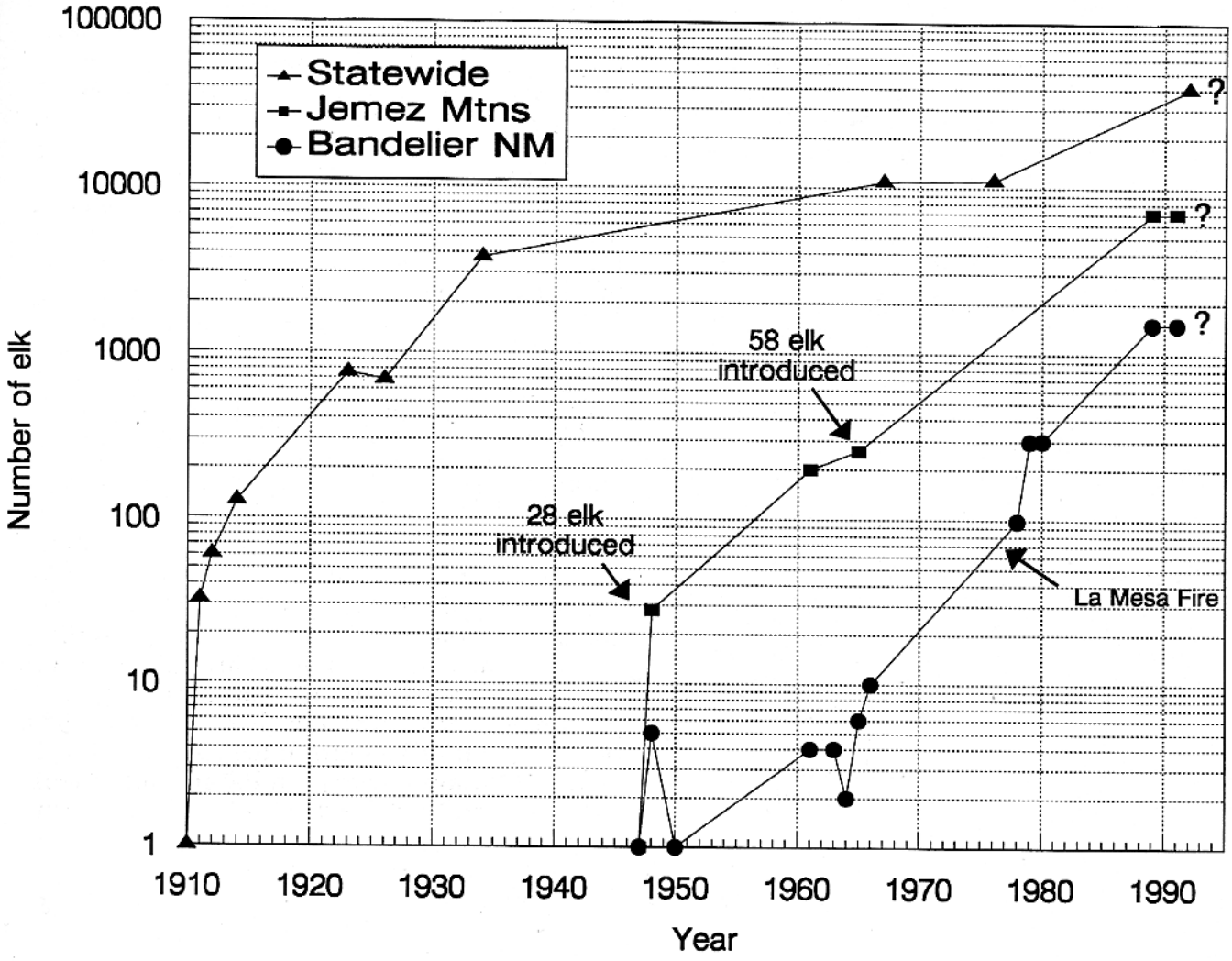

Figure 2.—Estimated changes in elk populations in New Mexico ("Statewide"), the Jemez Mountains, and Bandelier National Monument. Note the logarithmic scale on the y-axis.

Alternatively, if we assume 11,000 elk in 1976 and still 40,000 in 1992, this translates into a 8.4% annual growth rate and a 8.6 year doubling time for the period 1976–1992. It is thought by NMGF that the total number of elk in New Mexico has increased little, if at all, since 1992 because of high harvest levels (L. Fisher—1995 personal communication). Statewide, the annual (legal) elk harvest has increased from about 2800 in 1985 to 11,000 in 1993, with a concurrent increase in cow elk taken from 800 to 5,000 (L. Fisher—1995 personal communication).

Uncertainties in Elk Population Data

It is difficult to accurately determine elk population parameters in forested, montane wildlands like the Jemez Mountains. While aerial surveys are widely used, results are biased by numerous factors including speed and height of flight, transect width, terrain, variation in observers and pilots, time of day, snow conditions, and low elk sightability in many forested habitats (Caughley 1974, Davis and Winstead 1980, Samuel et al. 1987, Kie 1988). The probability of sighting elk in the Rocky Mountains is quite variable and usually less than 50% (Bear et al. 1989). During winter surveys bulls are typically alone or in small bachelor groups which are relatively hard to spot from the air compared to the larger cow/calf bands, introducing another bias. Thus NMGF estimates of elk populations in particular areas (like Unit 6) are rather imprecise, inasmuch as they are largely based upon limited, non-systematic, aerial surveys and the field impressions of local wildlife officers.

These same sampling biases also affect recent aerial surveys at Bandelier (Table 2, Figure 3), despite efforts to minimize these effects through relatively intensive and spatially systematic flights with experienced NMGF observers. Bandelier's annual survey counts have averaged 70% of the total elk surveyed by NMGF in Unit 6 since 1990 (range = 46% to 98%, Table 2), reflecting the relative intensity of the park's surveys (as well as the easily visible concentrations of elk in the open burn areas). These annual park flights have also maintained relatively consistent spatial coverage between years across the La Mesa Fire area. However, significant portions of the park have remained unsurveyed in these efforts, including the Sandoval County portions of the upper Frijoles watershed and the deep and extensive canyon systems. Also, even in the surveyed areas the flight pattern intensity is inadequate to fully cover the complicated terrain—about 1/3 of the surface area of these "surveyed" uplands is likely missed in any given year.

Note that the "percent of total elk counted which were not classified" (into gender or age classes) is over 50% for most of the recent Bandelier surveys (Table 2). This is because large herds of 100–200+ individuals are typically encountered in the La Mesa Fire area (Figure 3), and it is hard to accurately classify such big groups. Since these large unclassified groups are usually cow/calf herds, the true ratio of bulls to cows in Bandelier is likely lower than presented in Table 2, while the true ratio of calves to cows is uncertain.

Table 2.—Winter aerial count data, elk, Bandelier National Monument.

Year	# ELK	% ?	% #6	Bull: COW	♂	♀	:JUV	JUV: ADUL	# MIN	E/M
1984	345	0	—	.03	19	100	50	.42	52	6.6
1985	281	0	66	.21	52	100	67	.44	?60	?4.7
——										
1987	395	0	66	.25	38	100	63	.46	87	4.5
——										
——										
1990	504	.80	83	.80	93	100	29	.15	93	5.4
1991	907	.42	98	.26	41	100	38	.27	138	6.6
1992a	777	.63	—	.43	59	100	38	.24	79	9.8
1992b	867	.65	82	.45	62	100	38	.24	155	5.6
1993	499	0	47	.15	25	100	29	.23	214	2.3
1994	939	.71	66	.31	40	100	45	.32	200	4.7
1995	548	.62	46	.20	43	100	66	.46	115	4.8

Explanation of Headings (from left to right):

YEAR = year of helicopter survey (precise dates listed below)
- 1984 = 2/2/84
- 1985 = 1/7/85
- 1987 = 1/23/87
- 1990 = 1/31/90
- 1991 = 1/28/91
- 1992a = 2/11/92 (first 79 minutes)
- 1992b = 2/11/92 (all 155 minutes, last 76 minutes spent in low-elevation, piñon-juniper woodlands)
- 1993 = 2/1/93 (note that much of this flight time was spent over low-elevation, barren, piñon-juniper woodlands where few ungulates were observed)
- 1994 = 2/17/94 (little snow cover)
- 1995 = 2/7/95 (little snow cover)

ELK = total # elk counted
% ? = percent of the total elk counted which were not classified
% 6 = percent of the total elk surveyed by NMGF in Unit 6
BULL:COW = ratio of adult male to non-juvenile female (cow) elk
♂ = number of adult and yearling males per 100 cows
♀ = number of cow elk, standardized at 100
:JUV = number of calves per 100 cows
JUV:ADUL = ratio of juveniles to adult elk
MIN = number of flight minutes spent counting ungulates
E/M = number of elk counted per minute of flight counting time

Elk Mortality

Estimates of elk mortality by NMGF are also beset with large uncertainties, since they are primarily derived from voluntary mail-return surveys of hunter success. Uncertain biases and low return rates plague such surveys; e.g., statewide survey return rates since the mid–1980's range from 25–33% (L. Fisher—1995 personal communication). A possible, cost-effective, remedy is to utilize telephone surveys, which can provide more comprehensive and accurate results (Steinert et al. 1994).

Results from mail-in surveys since 1988 in Unit 6 suggest that the success rates of bow hunters have hovered around 20%, rifle success rates around 30%, and private land hunter success rates between 65% and 80%. The surveys indicate that about 1000 elk are killed by state-regulated hunters each year in Unit 6 (Table 3). Poaching and roadkills are estimated to annually kill an additional 200 and 100 elk, respectively, in Unit 6 (P. Cassidy—1993 personal communication), but substantive corroborating data are lacking. Mortality rates from other causes (e.g., natural predation, disease) are unknown. Take of elk on Native American lands (e.g., the local pueblos of Santa Clara, San Ildefonso, Cochiti, Zia, and Jemez) is unregulated by the State of New Mexico and currently unassessed by NMGF. Overall, the data currently available to NMGF do not allow precise determination of ongoing elk population status or trends at local or regional scales.

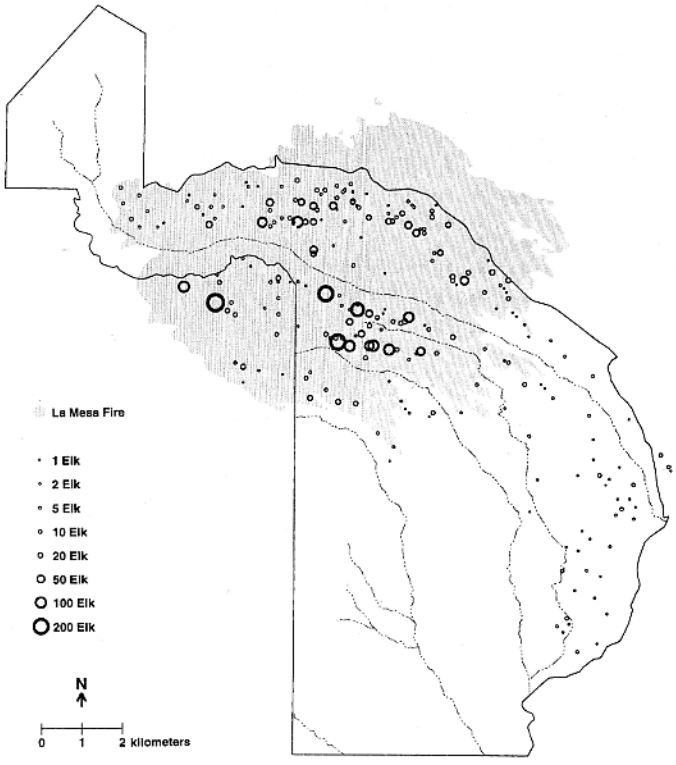

Figure 3.—Aerial survey observations of elk at Bandelier National Monument, 1990–1995, excluding 1993. Each point represents an observation in a particular year. The solid line represents the park boundary, dashed lines major canyon drainages. Adjoining lands include the Santa Fe National Forest (west, southeast, and north), Los Alamos National Laboratory (northeast), the Baca Ranch (northwest), and Cañada de Cochiti (south). The northwestern and southwestern portions of the park were essentially not surveyed in these years.

Elk populations in the Bandelier area may have high survival rates, facilitating rapid population growth. White (1981) presented local survival data on 28 radio-collared elk for the period spanning early 1978 to May 1980. Sixteen elk were collared in early 1978 and 12 in early 1979. Twelve of 13 calves survived at least through the first year after being collared (in winter)—the one death was apparently caused by lightning. Twenty-three of 28 total elk lived through the first year of monitoring, while 13 of 16 survived at least 25 months. Of the 28 collared elk, 22 were still alive in May 1980. Causes of mortality were legal hunting (2), poaching (2), lightning (1), and malnutrition (1). One of the collared females has been seen repeatedly in Bandelier as late as the winter of 1993–94, demonstrating local survival in the wild for at least 15 and one-half years. Note that legal harvest of elk has increased markedly since the White study ended (Table 3).

Table 3.—Harvest history of elk in the Jemez Mountains (Unit 6). Data from New Mexico Department of Game and Fish, extrapolated from mail-in survey estimates of hunter success. Data for 1987 are not available. Explanation of headings: # HUNT = # of licensed hunters, TOTAL = Total # elk legally killed by hunters; ♂ = # male elk legally killed by hunters; ♀ = # female elk legally killed by hunters.

YEAR	# HUNT	TOTAL	♂	♀
1981	44	39	39	0
1982	1716	286	271	15
1983	1953	290	265	25
1984	2125	526	358	168
1985	2017	379	350	29
1986	2262	416	354	62
1987	—	—	—	—
1988	2635	728	515	213
1989	3053	855	540	315
1990	3172	1086	622	464
1991	3392	1029	640	389
1992	3178	1000	676	324
1993	2535	968	587	381
1994	3223	1458	771	688

White's biotelemetry study (1981) also showed that most of the collared elk were part of a population that was relatively immune to hunting mortality because of the geography of local land ownerships. These elk largely summered (and calved) in the high elevation forests and meadows of the Baca Ranch, moving to wintering areas on Bandelier and Los Alamos National Laboratory (LANL). Elk are protected from public hunting across this 65,000 ha expanse of connected lands, although several hundred elk permits are issued to the Baca Ranch each year. It is presumed that a large portion of the current, larger elk population in the Bandelier area continues to follow this seasonal migration pattern, which provides year-round access to the security, food and water supplies, and cover that elk need.

Differences between aerial survey data collected in February 1995 from Bandelier (Table 2) and the rest of Unit 6 (L. Fisher—1995 personal communication) hint at either the coarse resolution of these data, or perhaps mortality differences between subpopulations in this unit. While the Bandelier survey noted 548 elk (62% not classified), the surveys outside Bandelier counted 656 animals, with only 15% not classified (as there were no big groups of 100+ elk). The bull:cow:calf ratios differed markedly between Bandelier, at 43:100:66, and the rest of Unit 6 at 28:100:37. If these values accurately describe the sampled elk "populations", they suggest that bulls are more heavily harvested and reproductive success is lower outside the relative protection offered to the Bandelier/Los Alamos/Baca Ranch population. Alternatively, differences in these values between populations might simply reflect sampling problems.

The most important natural predator of elk in the Jemez Mountains, the gray wolf (*Canis lupus*), was eliminated from the area by the mid–20th Century (Brown 1988). People have also made attempts to reduce local populations of another elk predator, the mountain lion (*Felis concolor*) (Allen 1989:153), although Bandelier certainly harbors a number of lions today, as tracks and droppings are commonly found (S. Fettig—unpublished data). Without their primary natural predator (wolves), New Mexico elk populations must ultimately be limited by either human hunting or by starvation/disease types of mortality when habitat resource limits are exceeded.

There are practical limits to the number of elk that can be harvested from Santa Fe National Forest lands (the primary public hunting grounds in Unit 6). In areas of high road density, use of vehicles by road hunters scare the elk into less accessible portions of Forest Service land (where fewer hunters venture) or onto protected areas, such as Bandelier National Monument and LANL lands, and hunter success is limited. So, while reducing open road density improves the quality of elk habitat (and hunting success), it reduces the number of hunters who are willing to access the roadless areas, especially as horses, carts, or snowmobiles become nearly essential to pack kills out to the nearest road.

Overall, the existing data, as well as much anecdotal information, suggests that elk populations in the Jemez Mountains, as in much of New Mexico, are still expanding their distribution, and perhaps their numbers. The spread and exponential increase of New Mexico elk populations through *circa* 1990 (Figure 2) indicates that hunting harvests were conservative enough to allow elk populations to grow markedly, as intended by NMGF to restore elk to its native range in New Mexico. Population trends in the 1990's are not yet clear.

RESPONSE OF ELK TO THE LA MESA FIRE

The area around Bandelier and Los Alamos National Laboratory was the focus of much research on elk immediately after the 1977 La Mesa Fire. Studies conducted locally included radiotelemetry research on 30 collared elk (White 1981, White 1983), changes in utilization and migration patterns, including information from 70 permanent pellet transects (Conley et al. 1979), diets and physiologic response to differing diets (Rowland et al. 1983, Weber et al. 1984), and radionuclide concentrations in elk tissues (Meadows and Salazar 1982, Meadows and Hakonson 1982). These studies found that: 1) in the Jemez Mountains elk were primarily grazers, although they also used woody browse species (Rowland et al. 1983, Wolters, This Volume); 2) local elk use was concentrated on nonforest or early successional forest areas, prominently including about 50 ha affected by two wildfires in the early 1950's just above West Jemez Road (White 1981:3); and 3) in the Jemez Mountains most elk spent the majority of the year at upper elevations, especially on the Baca Ranch, with the bulk of the population seasonally migrating to lower elevation sites as needed to avoid deep winter snows.

Since the 1977 La Mesa Fire the population of the Bandelier area elk herd has increased dramatically (Figure 2), due to intrinsic population increase

combined with in-migration to about 6000 ha. of fire-created, grassy winter range. Conley et al. (1979) estimated that less than 100 elk wintered on Bandelier in 1977–78, and 296 in 1978–79. In 1979–80 an estimated 200–400 elk wintered in the La Mesa Fire area (Rowland et al. 1983). Wintering populations on Bandelier and adjacent LANL and Santa Fe National Forest lands were estimated in 1989 to be 1000–2000 individuals (R. Isler, New Mexico Dept. of Game and Fish—1989 personal communication). Annual helicopter counts in Bandelier since 1990 similarly suggest that on the order of 1500 elk now regularly winter on Bandelier and the adjoining portions of the La Mesa Fire area, since about 500 to over 900 animals were being counted in 1–3 hours of flight time (Table 2). If there were 100 elk wintering in the Bandelier area in 1978 and 1500 elk in 1992, this indicates an annual growth rate of 21.3%, and a 3.6 year doubling time!

Some of this rapid population increase undoubtedly reflects concentration of animals into this favorable wintering habitat. Recent aerial surveys clearly show that winter elk use is generally focused on the La Mesa Fire area (Figure 3). Protection from human disturbance and the availability of needed food resources are likely key factors behind these winter elk concentrations. The fire converted dense, monotypic ponderosa pine forests into a more productive and diverse mosaic of grassland, shrubland, and forests, resulting in a corresponding diversity of herbaceous and woody food available for elk to incorporate into their eclectic diets (see Rowland et al. 1983, Wolters—This Volume). Also, the moderate elevations of the La Mesa Fire area (between 2000 and 2600 m) apparently provide a locally optimum balance between vegetation that is sufficiently productive to be attractive and winter snow conditions which allow elk to access their potential food.

However, an exception to this pattern of concentrated elk use occurred during the winter of 1992–1993 (Figure 4). Interspersed snow and rain storms created dense, icy snowpack conditions which apparently restricted elk utilization of the grassy La Mesa Fire burn area that winter (cf. Lyon and Ward 1982:471). As a result, many fewer elk were observed in the burn area that winter (Figure 4, Table 2). Also, the large herds of 100+ animals which have been evident every other year (Figure 3) were absent during the 1993 survey, which allowed all surveyed animals to be classified that year. While total elk numbers were apparently depressed in Bandelier that winter as more elk dispersed to adjoining lands, elk use was observed to be particularly widespread and relatively abundant across lower elevation portions of the park (Figure 4).

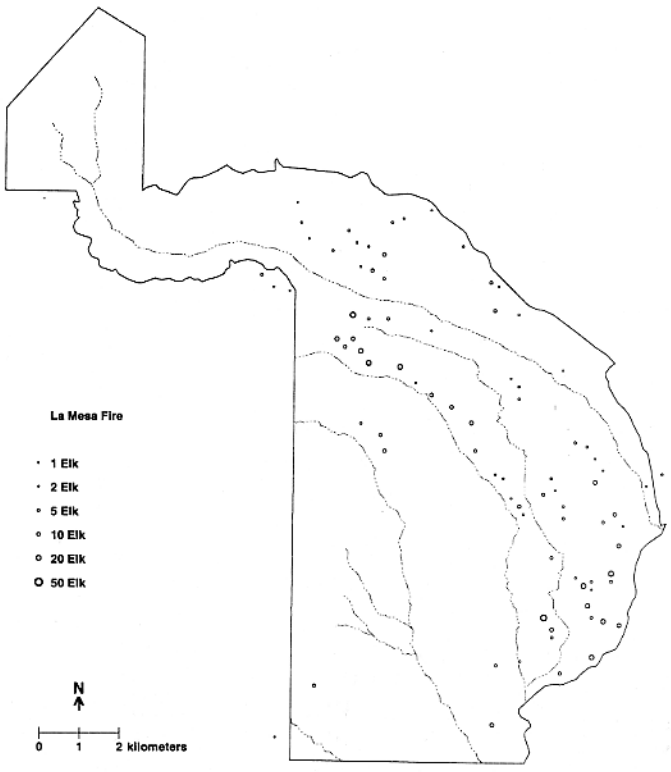

Figure 4.—Aerial survey observations of elk at Bandelier National Monument, 1993. The solid line represents the park boundary, dashed lines major canyon drainages. The linear-bounded, northwestern portion of the park was not surveyed.

At the time of the initial post-La Mesa Fire studies, elk populations on Bandelier were relatively small and only used the burn area in the winter, but the attractiveness of the burn for elk and the potential for rapid population growth were apparent. For example, White (1981) predicted that:

> The habitat created by the La Mesa fire and the use of this habitat by elk may cause a future overpopulation of elk. Problems related to overpopulation include damage to vegetation, which increases soil erosion, and an increase in accidents between elk and automobiles. Because neither Bandelier National Monument nor the Laboratory allows public hunting on their lands, elk populations will be difficult to control. The hunting pressure necessary to control elk herds often drives them to the refuges provided by Bandelier and the Laboratory.

The natural plant succession that will occur on the La Mesa burn also may lead to elk over-

population and to the subsequent problem of elk-damaged vegetation. Early successional stages are preferred by elk for wintering habitat, as demonstrated by the response of radio-collared animals to the fire habitat. A population increase probably will result. However, later successional stages (that is, as a ponderosa pine forest replaces the present grass cover) will not be beneficial to elk. Therefore, any population increase caused by the currently available food supply on the La Mesa burn may lead to an overpopulation at later stages when less food is available.

Unfortunately, but not surprisingly, these predictions are becoming reality in the Bandelier area.

RECENT ELK-RELATED OBSERVATIONS IN THE BANDELIER AREA

While there is no doubt that the local elk herd has grown rapidly during the last three decades, existing data are inadequate to accurately determine the current population trend. As described above, recent aerial surveys at Bandelier are beset by high levels of uncertainty. In particular, the large percentage of unclassified animals in most recent surveys (up to 80% unclassified—see Table 2) and the lack of any measures of variance reduces the reliability of any conclusions derived from these data. The large interannual variability in some observed survey parameters (e.g., the bull:cow ratio) further suggests cautious use of these values. Still, inasmuch as these are the best local data available, some survey results are worth reporting, along with a variety of other elk-related observations from this area.

In the period 1990–1995, winter juvenile:adult ratios in Bandelier elk averaged 0.28, with a range from 0.15 to 0.46 (Table 2). These values suggest that significant population growth may be continuing, unless adult mortality rates are greater than seems likely for this relatively well-protected (i.e. little-hunted) subherd. Indeed, true juvenile:adult ratios may be even higher, given that large cow:calf herds could not be classified in most years. There is also a trend of increasing juvenile:adult ratios since 1993 at Bandelier. However, the implication of these ratios for elk population growth is uncertain without better mortality data.

Deep or icy winter snowpacks, or unusually cold weather, can act as a check to elk populations by causing them to expend more energy to move and dig for food, and by forcing them to lower elevations where food may be less plentiful or they are more subject to human disturbance. However, the burgeoning of the local elk population has occurred despite greater than average snowpack conditions most winters since the La Mesa Fire, including the record snowfall winter of 1986–87 (Bowen 1990:150, unpublished data on file at Bandelier) and the icy snows of 1992–1993 (personal observation). This suggests that snow conditions in the Jemez Mountains will seldom serve to directly reduce current elk population levels. Indeed, most winters some elk are able to stay at relatively high elevations throughout the winter, e.g., elk typically use south-facing slopes winter-long in the Valle San Antonio area (P. Cassidy—personal communication).

All local observers agree that over the past several years more elk are wintering farther down the mesas of the Pajarito Plateau. Moreover, in recent years resident populations have developed at lower elevations. In Bandelier, the aerial surveys conducted each winter since 1990 typically find groups of elk all the way down to the Rio Grande (Figures 3 and 4). Indeed, the 2/1/93 aerial survey found the largest groups of elk at low elevations in piñon-juniper woodland, with groups as large as 18 animals observed along the Rio Grande (Figure 4). Elk have been year-round residents on Burnt Mesa since at least 1989, when cow and calf groups were repeatedly observed by archeologists working in that area. In early 1991, certainly for the first time in over 100 years, elk began to utilize the open headquarters area of Frijoles Canyon on winter evenings. Elk were first heard bugling in piñon-juniper areas near Juniper Campground in fall of 1991 (personal observation). Elk sign (tracks, droppings) are now seen year-round throughout the park, including low-elevation woodlands and canyons. Adjoining Bandelier's south boundary, cow and calf elk have been observed year-round in the Cañada de Cochiti area in and downstream of Dixon's orchards (elevation <1740 m) since summer of 1992.

Similarly, Santa Fe National Forest staff have observed signs of expanding range and increasing elk impact in the Jemez Mountains (personal communications with M. Orr, Española District biologist, and J. Elson, Forest Range/Wildlife staff officer), including: heavy browsing on New Mexico locust, aspen stems, and Gambel's and wavyleaf oak; barking of aspen stands; and intense grazing pressure on moist montane meadows throughout the Jemez Mountains (see Wolters, This Volume). Concentrated grazing by wintering elk certainly occurs on the USFS portions of the La Mesa Fire

burn adjoining Bandelier (Figure 3), although determination of elk grazing effects is confounded in many areas by the presence of cattle, especially in moist meadows and riparian settings. Greater year-round use of lower elevation areas is being observed throughout much of the Forest, and elk have recently colonized the Caja del Rio area, opposite the Rio Grande from Bandelier. For example, on 5/24/95 two cow elk were seen along the Rio Grande about 2 km south of the mouth of Frijoles Creek, across the river from Bandelier on Forest Service land (S. Fettig—personal communication). While definite elk effects are certainly observed in a number of particular areas, the extensiveness of negative impacts is unknown and available evidence does not show that elk populations are currently pushing against some sort of ecological carrying capacity all across the Jemez Mountains.

Los Alamos National Laboratory biologists have also observed recent increases in elk numbers and spread of elk-use areas within LANL (personal communications with T. Foxx and J. Biggs). There is ample evidence of elk in all Technical Areas, with year-round use seen throughout the Lab since the early 1990's. Elk with calves are now observed in summer at Mesa del Buey and in lower Pajarito Canyon (near White Rock). Elk tracks are observed all the way down to the Rio Grande in the TA–33 area. Overflight prohibitions have precluded aerial survey efforts to date, but it is apparent that large numbers of elk winter on LANL lands, which include a portion of the La Mesa Fire area immediately north of Bandelier. The western lands of San Ildefonso Pueblo, which adjoin LANL, White Rock, and the detached Tsankawi Unit of Bandelier, also receive considerable winter use by elk. Elk have been causing damage to yards in the White Rock townsite for a number of years (at least throughout the 1990's), causing conflict between people who like to feed the elk and those who dislike the harm to their property.

Contamination of elk by radioactive materials at LANL has received study, with conclusions to date indicating little cause for concern (Meadows and Salazar 1982, Meadows and Hakonson 1982, Fresquez et al. 1995-a). However, recent findings of high levels of strontium–90 (Fresquez et al. 1995-b) in a preferred browse species (rabbitbrush), and the small sample sizes of elk tissue sampled in the past, suggests the potential for unassessed elk (and deer) contamination problems.

Elk have become an important traffic hazard in Los Alamos County (Burns 1992), as night-time drivers commonly encounter elk along local highways. The Los Alamos Police Department recorded at least 51 car accidents involving elk, and 54 with deer, between January 1990 and February 1995 (Gonzales et al. 1995). At least 29 additional accidents were recorded during this time period as "animal", most of which likely involved elk or deer. These encounters account for about 6% of all accidents in Los Alamos County (Los Alamos Police Dept.—unpublished data). While two-thirds of elk-related accidents occurred in fall or winter, this hazard is now present year-round and affects roads through low-elevation woodlands. Regrowth of trees and shrubs near the road in the 1977 fire area is decreasing visibility and further increasing the hazard of collisions with animals.

Resource Impacts in the Bandelier Area

As large herbivores, elk can play a key role in structuring local ecosystems (Kay 1990, 1994). Thus the recent increases in elk numbers and range are having a number of effects on local resource values. For example, elk use of the La Mesa Fire area is so ubiquitous that it is difficult to find upland areas that have not been recently affected by elk-mediated transfers of nutrients, as evidenced by the fecal pellet groups of elk (see C. White, This Volume).

Many examples of elk impacts on Bandelier vegetation have become apparent. For example, the shattered rosettes of *Yucca baccata* found across local piñon-juniper woodlands each spring indicate one food preference of wintering elk. Intensive elk browsing has largely destroyed aspen (*Populus tremuloides*) reproduction from upland portions of the La Mesa Fire (e.g., Apache Mesa, Mesa del Rito) and the headwaters of the Frijoles watershed, while mature aspen trees are heavily barked in many areas (cf. Allen 1989:136–138). Photographs taken from permanent points in open grasslands on Cerro Grande reveal that clumps of the shrub *Holodiscus dumosa* were browsed back severely between October 1983 and October 1992. In the prime elk wintering areas of the La Mesa Fire, browsing effects are evident on a variety of shrubs, including New Mexico locust (*Robinia neomexicana*), various oak (*Quercus*) species, and especially the small buckbrush (*Ceanothus fendleri*), which in particular is severely browsed. The uniformly mowed tops of young locust sprouts indicates that elk browsing is currently a major factor slowing the still-rapid spread of locust clones across wide portions of the 1977 burn. Elk buckrubs are also somewhat slow-

ing tree re-establishment into the La Mesa Fire burn area (cf. Allen 1989:137).

Moist meadows in Bandelier are being kept in an early seral stage by excessive elk use (see Wolters, This Volume). Similar impacts are apparent in nearby portions of the Jemez Mountains, where elk and cattle combine to overgraze many meadows (personal observation). Portions of the grassy La Mesa Fire burn area are also being utilized heavily by elk (e.g., Escobas Mesa, see Wolters, This Volume). The initial post-fire flush of high plant productivity has passed, and vegetational succession has begun to return many La Mesa Fire areas back to pine forests again, which will support fewer elk. These observations imply increasing pressure through time on other elk-favored vegetation types in Bandelier if elk populations remain at or exceed current levels.

Severe erosion problems exist in Bandelier's piñon-juniper woodlands (Allen 1989:165–167), and park resource managers are concerned that increasing elk utilization of these areas may exacerbate these erosion problems by reducing already stressed herbaceous ground cover in the interspaces between the small trees. By their sheer numbers and large food intake requirements (on the order of 10 to 25 pounds of forage per day per adult elk [Nelson and Leege 1982:363]), elk grazing could easily have negative impacts on woodland conditions analogous to the well-documented effects of smaller feral burros in Bandelier from ca. 1930–1980 (Koehler 1974, Earth Environmental Consultants 1974, USDI National Park Service 1976, Potter and Berger 1977). Any similar increases in soil erosion from LANL lands might lead to increased runoff of radioactive materials, such as depleted uranium, which is a widespread surface soil contaminant in some woodland areas of LANL (Becker 1992).

Because local archeological sites are primarily found in woodland areas this erosion is also a major cultural resource problem at Bandelier, as about 70% of archeological sites within Bandelier are being damaged by soil erosion (Head 1992). Bandelier has been testing methods for increasing herbaceous ground cover in eroding woodland areas (Chong 1994; unpublished data on file at Bandelier), which are largely in remote portions of the Bandelier Wilderness that would be attractive wintering habitat for elk if adequate food existed. Thus concern exists that the potential for successful erosion control will be set back by the attraction of more elk to the treatment areas.

Elk are large animals—the mean weight of 5 local adult females was 233 kg (513 lb) (Meadows and Hakonson 1982), and adult males of Rocky Mountain elk typically weigh over 300 kg (Peek 1982). The concentrated hoof action of large numbers of these heavy animals is also starting to damage park resources. Ongoing revegetation research in piñon -juniper woodlands (Chong 1994, B. Jacobs—personal communication) reveals that by spring elk hoofprints can cover most of the bare ground surface between woodland trees. Similarly, recent surveys have found that numerous archeological sites within Bandelier are being damaged by trampling from large ungulates, mostly elk (Figure 6). New elk trails continue to emerge in various parts of the park, from mesatops to steep canyon walls.

Water sources, which are relatively scarce in higher elevation areas of the Jemez Mountains, are being degraded in portions of the park and nearby areas by heavy elk use. Some small ponds display elk-trampled margins, wallows, and highly turbid water (personal observation). These scarce waters are ecologically important for reasons which may be compromised by elk-induced changes in water quality, (such as the breeding of amphibians). I have observed various places where elk have turned small seeps into wallows, such as sites located west of Corral Hill, near the headwaters of Frijoles Creek, and at the base of the Cañada Bonito grassland.

Elk may compete with mule deer in various ways (Nelson 1982:425; Lyon and Ward 1982:464). While deer populations in many parts of New Mexico have been depressed in recent years, Bandelier has exhibited relatively high deer populations for several decades (Allen 1989:132–134, Table 4), probably because it offers a fairly secure refuge from poaching as well as legal hunting. Eberhardt and White (1979) demonstrated that LANL deer occupied consistent home ranges year-round, although this was prior to the recent buildup of elk numbers. Aerial surveys in Bandelier since 1990 provide indications that mule deer numbers may be in decline (Table 4), although cautious interpretation is required due to the large and unquantified uncertainties associated with these data. The spatial distributions of elk and deer revealed by the winter aerial surveys (compare Figures 3 and 5) suggest that deer are largely excluded from zones of high elk density in the La Mesa Fire area. Heavy elk use of the La Mesa Fire area may be reducing winter deer utilization of this relatively desirable grass and shrub-rich zone, forc-

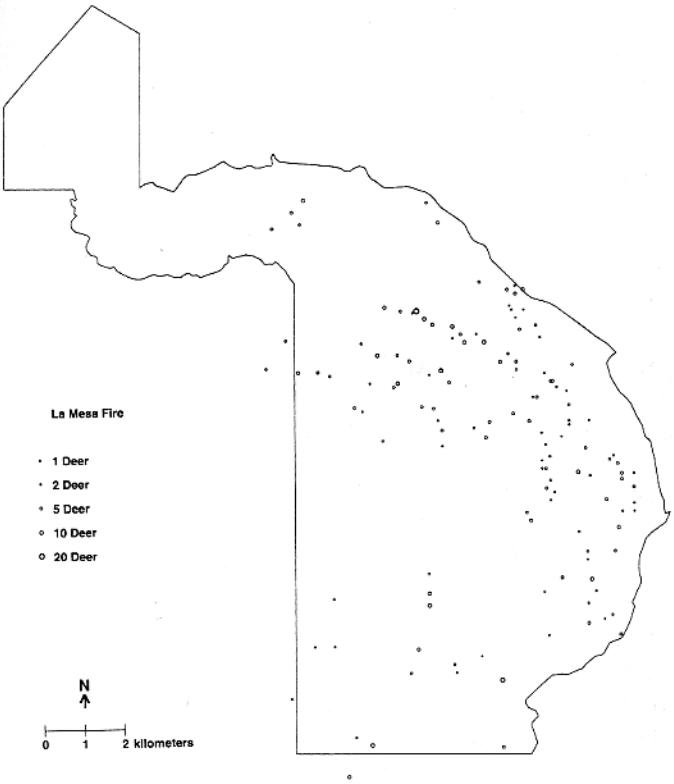

Figure 5.—Aerial survey observations of deer at Bandelier National Monument, 1990–1995. Each point represents an observation in a particular year. The solid line represents the park boundary, dashed lines major canyon drainages. The linear-bounded, northwestern portion of the park was not surveyed.

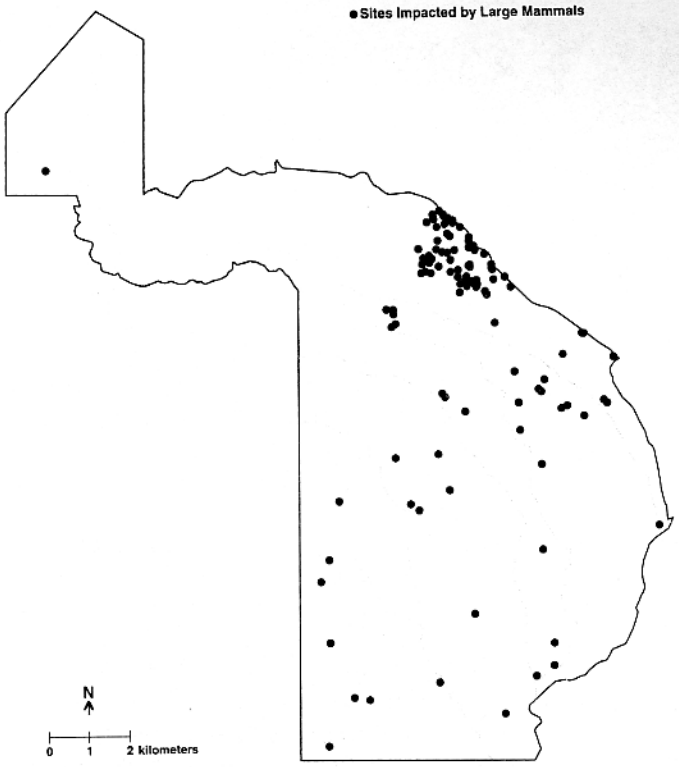

Figure 6.—Archeological sites impacted by elk or deer at Bandelier National Monument, based upon post–1986 surveys of about 44% of the park (unpublished data on file at Bandelier).

ing the deer to occupy less productive areas downslope in piñon-juniper woodlands and thereby diminishing their winter survival and subsequent reproductive success.

CONCLUDING THOUGHTS

Overall wintering conditions for elk will likely improve across the Jemez Mountains during the coming decade. Land management agencies will create more grassy winter ranges at moderate to low elevations through ongoing "ecosystem management" efforts to reduce forest and woodland densities with large-scale prescribed burns and understory thinning projects. As a result, there will continue to be potential for further elk population increases in Unit 6.

On the other hand, large portions of the La Mesa Fire burn area may become less desirable habitat for elk as vegetational succession proceeds. Many open grassland patches are rapidly turning into shrub thickets, and ponderosa pine regeneration is

Table 4.—Winter aerial count data, deer, Bandelier National Monument.

YEAR	# DEER	♂:	♀	:JUV	D/M
1984	24	19	100	50	0.46
1985	18	160	100	100	?0.3
——					
1987	121	46	100	70	1.4
——					
——					
1990	156	25	100	55	1.68
1991	161	26	100	68	1.16
1992a	53	32	100	57	0.67
1992b	78	26	100	56	0.50
1993	137	24	100	48	0.64
1994	79	7	100	77	0.40
1995	46	9	100	65	0.40

Explanation of Headings (from left to right):

YEAR = year of helicopter survey (precise dates in Table 2)
# DEER = total # deer counted
♂: = number of adult and yearling males per 100 non-juvenile female deer
♀ = non-juvenile female deer, standardized at 100
:JUV = number of juveniles per 100 non-juvenile female deer
D/M = number of deer counted per minute of flight counting time

well established across extensive areas. While elk herbivory is modulating the successional pathway of much of the burn area, it will not prevent open grasslands from returning to forests which will support fewer elk. Still, park prescribed burning programs (Lissoway 1995) and other vegetation management efforts (Sydoriak 1995) are expected to maintain or develop herbaceous understories throughout the park, so ample elk wintering habitat should continue to be available in the park.

There are multiple indications that excessive conservatism should be avoided in managing the overall population of elk in Unit 6. Current elk populations are apparently larger than anything known for at least the past 800 years. Various signs of elk-induced resource stress are becoming apparent, and the potential for elk-related conflicts between land managers has been increasing. With the probability of further improvements in winter ranges and the demonstrated high reproductive potential of cow-dominated elk populations, elk numbers could rise even further. Major data uncertainties preclude precise knowledge of elk population dynamics, including responses to management actions such as hunting. Recent growth in elk numbers has coincided with the anomalously wet period of the past 18 years (Grissino-Mayer 1995, Allen—in review). Current concerns over elk effects on other resources will become more urgent when the next extended dry spell hits New Mexico, as drought will highlight elk impacts on vegetation and competition with livestock on public and private lands. Overall, prudence suggests limiting further growth in Unit 6 elk populations until some of these issues are resolved. In this light, the higher harvest levels estimated for Unit 6 in 1994 (Table 3) are encouraging.

The New Mexico Game and Fish Department has recently been soliciting comments from the public and various interest groups in an effort to develop a formal "Long Range Plan for the Management of New Mexico's Elk". The October 1995 draft of this document (NMGF 1995) opens with the stated goal "(T)hat hunters and interested individuals enjoy high levels of elk recreational opportunities and experiences". These social considerations are certainly important. However, the single-species focus on recreational considerations presented by this document, to the near-exclusion of ecological information or wider resource management issues, is worrisome. Elk management needs to be considered within broader contexts of **both** societal and ecological issues, otherwise unnecessary conflicts could develop with various land managers in New Mexico who have overriding management objectives which may be inconsistent with high elk numbers.

The NMGF draft management plan seems cautious in its formulation of elk-related issues (NMGF 1995). It states that the main problems specific to Unit 6 are (sic):

1) "Poor quality winter ranges cause elk to concentrate on National Park, National Laboratory, Tribal, and private lands creating difficulty in attaining hunt objectives and trespass problems"; and 2) "Divergent management objectives of New Mexico, Los Alamos National Labs and Bandelier National Monument, and the Baca Location hampers effective elk management".

The draft plan suggests that the primary strategies to resolve these problems are to:

1) "Develop cooperative agreements with public land agencies and affected agencies and individuals to enhance winter habitat on public lands"; and 2) "Develop cooperative management agreements with the Baca Location, Los Alamos National Labs and Bandelier National Monument to meet joint objectives".

These are important issues and strategies to pursue, especially the emphasis on cooperative interactions among local land managers. In addition, at least two key questions must be thoroughly addressed if the proposed cooperative agreements are to be successful: 1) What ecological considerations (and tradeoffs) should be included in determining elk-related management goals? 2) Given overall social and ecological considerations and trade-offs, what are appropriate target numbers of elk, both overall and for particular portions of Unit 6?

Bandelier is just beginning to quantitatively document the impacts of elk grazing to park resources and review the options which may be available for controlling excessively large in-park populations. A number of research needs have been identified to address elk-related issues at Bandelier (Sydoriak 1995), including needs for better data on population dynamics, seasonal use of habitats across landscape gradients, "migration" corridors, effects of elk use on herbaceous vegetation and soil surface conditions, and possible development of carrying capacity indicators. However, it is already apparent that novel management actions may be required **within** Bandelier to prevent excessive elk impacts to various park resources unless adequate control is also applied to overall elk population numbers in the Jemez Mountains.

How will local elk populations be limited? Perhaps some combination of public and private hunting similar to the current mix will be adequate to control elk numbers, although the geography of Bandelier-area land ownerships certainly increases the difficulties in managing local elk populations. To date the Baca Ranch has supported high elk numbers for reasons ranging from aesthetic appreciation of free-ranging herds of these magnificent animals to the favorable economics of their trophy elk hunting business (where more elk means a larger pool from which to select high-value bulls). While the current seasonal migration patterns of local elk have yet to be fully determined, it is clear that many elk move directly from the Baca to the security of Bandelier and LANL in the fall, avoiding any exposure to public hunting pressure. This obviously creates population control challenges, as hunting on Bandelier is expressly prohibited by Code of Federal Regulations (CFR), Title 36, Part 2, Section 2.1 (preservation of natural resources), Section 2.2 (wildlife protection), and Section 2.4 (weapons, traps, etc.). Opening the park to public hunting would require an act of Congress, and direct reductions by park or NMGF staff for management purposes would be controversial and require substantial NEPA documentation and public review. However, there may be other ways to reduce the sense of security elk currently experience in Bandelier that could decrease the attractiveness of the park as wintering habitat.

In conclusion, the habitat changes initiated by the La Mesa Fire have supported the recent development of a large elk population in the Bandelier area. Such high elk numbers are apparently an ecologically novel situation, and many signs of elk-related resource stress are becoming apparent. The Bandelier area elk population is inextricably linked to the overall status of elk in the Jemez Mountains. Large uncertainties and data gaps cloud our understanding of current elk population dynamics in Unit 6. Care should be taken to avoid further increases in Jemez Mountains elk numbers until the resource impacts of this historically unprecedented phenomenon (high elk numbers) can be identified, desirable population levels agreed upon (based to a significant degree upon ecological information and resource carrying capacities, as well as social considerations), and appropriate cooperative management strategies determined and implemented.

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