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Potential Ungulate Prey for Gray Wolves

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Abstract. Data were gathered for six ungulate species that reside in or near Yellowstone National Park. If gray wolves (*Canis lupus*) are reintroduced into the Yellowstone area, their avoidance of human activities or their management by humans may determine their range. Therefore, the area of wolf occupation cannot be predicted now. We restricted our analysis to Yellowstone National Park and to the adjacent national forest wilderness areas. We included mostly ungulate herds that summer inside or adjacent to the park and that would probably be affected by wolves. Our wolf study area includes Yellowstone National Park and adjacent wilderness areas most likely to be occupied by wolves. We reviewed publications, park records, survey reports, and state fish and game surveys and reports for statistics on ungulate populations. These data provide an overview of ungulate populations and harvests. Each ungulate herd is described in detail. We restricted our analysis to 1980–89, because population surveys were more complete during that period and because population estimates of most ungulate populations had increased by the 1980's. We feel the higher estimates of the 1980's reflect more up-to-date techniques and are most representative of the situation into which wolves would be reintroduced.

Ungulate Populations and Harvest

Elk

Seasonal Ranges and Distribution

Portions of eight elk (*Cervus elaphus*) herds from our wolf study area spend summers in Yellowstone National Park (Figs. 1 and 2). Estimates from the eight elk herds summering within Yellowstone National Park ranged from 25,000 to 31,000 annually (Table 1). This estimate is based on the proportion of radio-collared elk (n = 386) in eight herds that migrate into the park each summer (see details in the Appendix). Roughly

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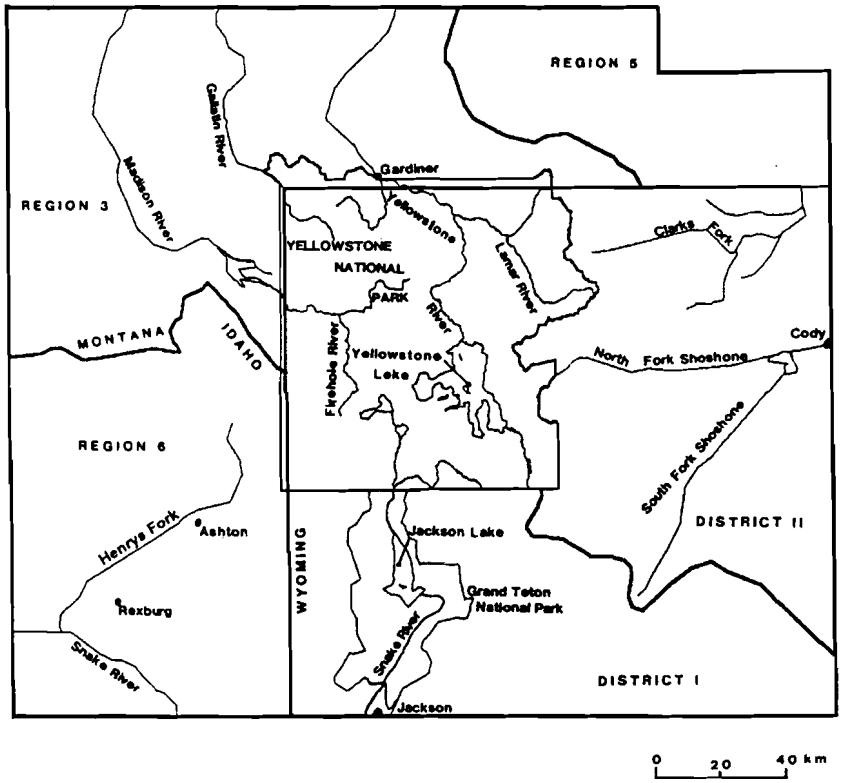

Fig. 1. Yellowstone National Park and wolf study area, including five state game management units in the three states surrounding the park.

58–63% of the elk in the eight herds summer within the boundaries of the park, while 37–42% occupy summer ranges within 40 km of the park boundary.

Elk occupy summer ranges within Yellowstone National Park from 138 to 160 days a year (38 to 44% of the time), when they would be most available to wolves. Fall migrations last from 19 days for the Jackson herd (Smith and Robbins, in preparation) to 27 days for the Sand Creek herd (Brown 1985). Spring migrations last 46 days for the Sand Creek herd (Brown 1985), and some calves are born en route to Yellowstone (Brown 1985; Smith and Robbins, in preparation). Calves born to these migrating cows probably will encounter fewer wolves than calves born in Yellowstone or immediately adjacent wilderness areas.

Elk outside the Yellowstone area may be less accessible to wolves during winter. Three elk herds spend the winters distant from the park and close to human population centers, such as the towns of Ashton or Idaho

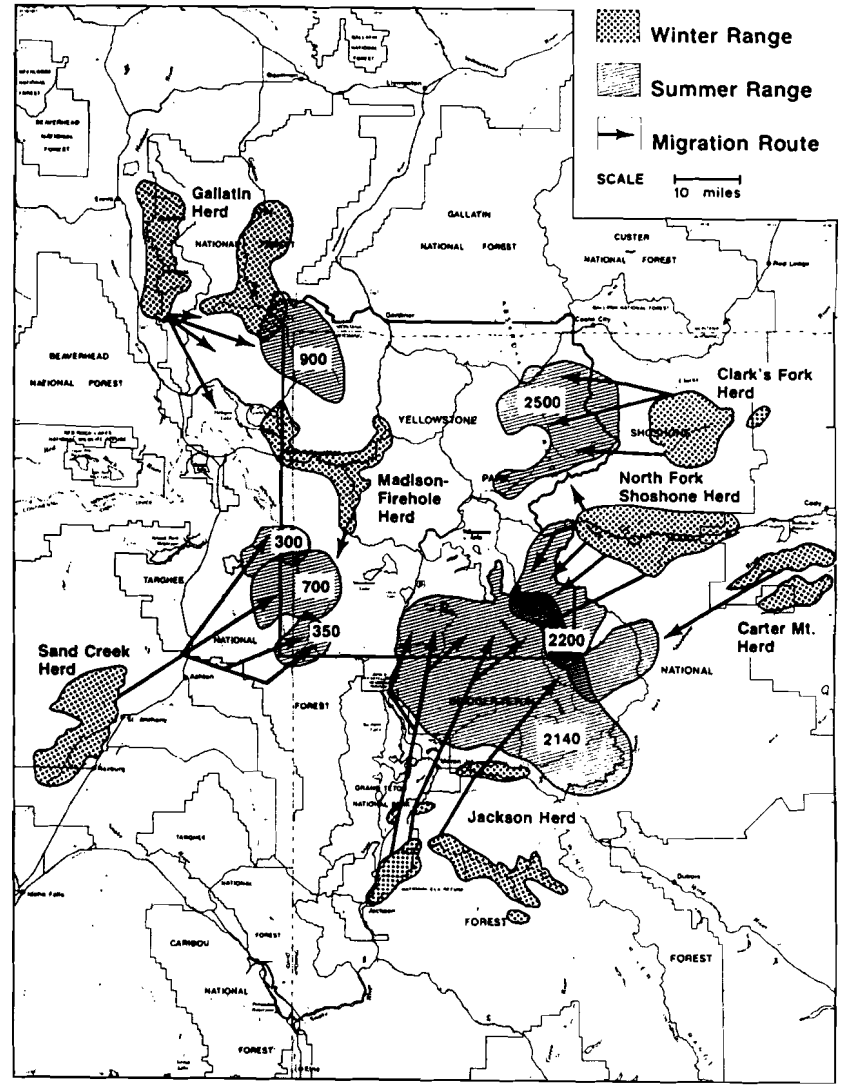

Fig. 2. The approximate winter range and those portions of summering areas in Yellowstone National Park for seven elk herds other than the northern herd. The numbers indicate the approximate numbers of elk from each herd that summer within the park.

Falls, Idaho; Jackson, Wyoming; or towns of the Bighorn Basin, Wyoming. The Carter Mountain, Jackson, and Sand Creek elk herds spend winters 48–64 km from the park boundary. Wolf activity is less likely on winter ranges near human population centers.

Table 1. Estimates of eight major elk (*Cervus elaphus*) herds summering in Yellowstone National Park, 1984–1988 (Cada 1970–75; Craighead et al. 1973; Taylor 1978–86; Rudd 1982; Brown 1985; Davidson et al. 1985, 1986; Yorgason et al. 1986; Boyce 1989; Lockman et al. 1989; Vore 1990; B. Smith, in preparation; D. Vales, unpublished report).

Herd	Herd size	Proportion of radio-collared[d] elk summering in Yellowstone	Sample size of collared elk	Estimated number of elk summering in Yellowstone	Mean number of elk wintering in Yellowstone	Years of radiolocation data	Days spent on summer range	Summer locations
Gallatin	1,850[a,c]	48	72	900	580[a]	1969–86	150	Gallatin Range, Specimen Creek
Sand Creek	4,900[b]	0.21	84	1,056[b]	0	1981–87	138	Bechler Meadows, Madison Plateau, Chick Creek
Jackson	16,000[b]	0.28	85	4,480	0	1978–82	150	Thorofare, Two Ocean Plateau, Big Game Ridge, and Chicken Ridge
Carter Mountain	2,550[b]	tr	0[d]	100+	0	1986–88	—	South Fork Shoshone
North Fork Shoshone	2,600[b]	78	18	2,020	0–500	1979–80	160	Signal Hills, Thorofare

Table 1. *Continued.*

Herd	Herd size	Proportion of radio-collared[d] elk summering in Yellowstone	Sample size of collared elk	Estimated number of elk summering in Yellowstone	Mean number of elk wintering in Yellowstone	Years of radiolocation data	Days spent on summer range	Summer locations
Clarks Fork	3,180[b]	0.83	18	2,600	0	1979–80	160	Upper Lamar, Pelican Valley, Mist Creek
Northern	21,000[b]	0.98	68	20,580	17,457	1985–88	140	All of Yellowstone Park
Madison–Firehole	800[a]	1.00	6	800	800	1965–66	—	Madison drainage, Madison Plateau
Total	—	—	—	32,536	16,837 19,337	—	—	—

[a] Count.
[b] Estimate.
[c] Vales and Peek (1993) concluded this number underestimates the herd size.
[d] No radiotelemetry studies were conducted on the Carter Mountain herd. Such a study is scheduled for 1990 (L. Roop, personal communication).

The Clarks Fork and North Fork Shoshone elk herds winter within 30 km of Yellowstone in remote areas where wolf activity is likely. Portions of four elk herds winter within the boundaries of the park. About 80% of the northern Yellowstone herd, nearly 100% of the Madison–Firehole herd, 31% of the Gallatin herd, and about 15% of the North Fork Shoshone herd winter in the park (Table 2). In the 1980's, 13,480–20,880 elk wintered in the park each year in these 4 herds.

Population Trends

During the past 20 years, population estimates for the 8 elk herds that summer in or near Yellowstone increased dramatically from about 30,000 elk to about 46,700 elk (Houston 1982; Brown 1985; Hurley et al. 1988; Boyce 1989; Lockman et al. 1989; Vales and Peek 1993; Appendix). Population estimates for the Sand Creek and the northern Yellowstone elk herds increased about fourfold during this period. The Jackson and Gallatin herds have remained relatively stable over these 20 years; both declined but then recently increased (Taylor 1986; Boyce 1989; Vales and Peek 1993). Only the Madison–Firehole herd may have declined over this period; recent counts showed 500 to 600 elk (Table 2), but 1970's counts showed 800–1,000 elk (Cole 1983).

Nine elk herds that summer in or near Yellowstone increased dramatically during the 1980's, including the small Targhee herd. Three herds had significantly increasing population rates of change (λ values ranged from 1.12 to 1.21)—the Targhee, North Fork Shoshone, and the Carter Mountain herds. The Jackson, northern Yellowstone, Clarks Fork, and Gallatin herds grew more slowly (1.02 to 1.07); the Sand Creek and Madison–Firehole herds did not grow appreciably during this period. Estimates for the minor Targhee herd increased dramatically, but a change in the estimation technique may have accounted for much of the recent increase (Lockman et al. 1989). At peak population levels in 1988, an estimated 51,327 elk comprised these 9 herds. Improved census techniques and counting effort may have contributed to some of the reported increases.

Harvests

Human harvests include ungulates legally taken for purposes of sport hunting in our wolf study area. Annual elk harvests for the herds residing in the wolf study area averaged 7,650 elk/year (Table 3). The effects of the harvest on population growth is greater when more adult cows are included in the harvest. Percent harvest of the various groups of elk are not entirely comparable because the extent of adult cow harvest varied from 24 to 45% of each herd's total harvest. Elk harvests ranged from 6 to 36% of the minimum population counts, but the elk herds are probably 20 to 40% larger than the reported herd sizes. Visibility corrections and population models suggest that 20 to 40% of the elk are missed during aerial counts (Samuel et al. 1988; Lockman et al. 1989; Mack and Singer 1993; Vales and Peek 1993). Population models or visibility corrections

Table 2. Estimated early winter elk (*Cervus elaphus*) populations for eight elk herds and one group of elk inhabiting the Yellowstone National Park area, 1980–1989.[a] Annual variations in counting conditions and effort may explain some of the variations in counts.

Year	Northern Yellowstone	Clarks Fork	North Fork Shoshone	Carter Mountain	Jackson	Sand Creek	Madison–Firehole	Gallatin	Targhee
1980–81	16,684	2,500	—	—	—	2,310	—	1,719	170
1981–82	18,075	2,600	1,800	2,000	15,533	2,327	—	1,682	170
1982–83	19,184	2,600	1,700	2,225	13,980	2,959	—	1,880	200
1983–84	19,930	2,550	1,700	2,400	13,293	2,287	—	2,068	215
1984–85	21,056	3,000	2,400	2,400	13,504	2,553	—	1,525	205
1985–86	18,982	3,000	2,400	2,050	14,431	2,269	588	2,297	215
1986–87	21,491	2,900	2,000	2,100	15,478	—	—	—	205
1987–88	18,267	3,334	3,131	3,047	16,509	2,815	560	—	440[b]
1988–89	18,919	3,666	2,945	3,101	16,093	2,441	476	—	490[b]
Average	1.02	2,905	2,259	2,202	14,852	2,495	541	1,862	256
λ[f]	0.02	1.04	1.21	1.12	1.02	1.008	[c]	1.07	1.13
r[g]	0.81[d,e]	0.04	0.08	0.05	0.02	0.008	—	0.03	0.12
Aerial counts as a probable proportion of actual population	—	—	—	—	0.80[e]	0.60[e]	—	0.80[e]	—
Distance (km) of winter range from park boundary	inclusive	32	8–13	48	48	20	48	inclusive	inclusive

[a] Adapted from Brown 1985; Rudd et al. 1988; Lockman et al. 1989; Mack and Singer 1993; Vales and Peek 1993; and aerial counts by the senior author.
[b] Change in technique for estimated elk likely explained large increases.
[c] Insufficient or questionable data to calculate λ.
[d] Probable percent of actual population calculated from aerial sightability (Lockman et al. 1989; Mack and Singer 1993; Vales and Peek 1993).
[e] Probable percent of actual population calculated from population models (Lockman et al. 1989; Mack and Singer 1993; Vales and Peek 1993).
[f] Finite rate of change.
[g] Rate of increase, slope of regression line of the log population counts.

Table 3. Estimated elk (*Cervus elaphus*) harvest for eight herds[a] inhabiting the Yellowstone National Park area, 1980–1989 (Brown 1985; Rudd et al. 1988; Lockman et al. 1989; Mack and Singer 1993; Vales and Peek 1993; and aerial counts by the senior author).

Year	Northern Yellowstone	Clarks Fork	North Fork Shoshone	Carter Mountain	Jackson	Targhee	Sand Creek	Gallatin
1980–81	247	532	257	—	3,748	70	962	284
1981–82	1,234	590	470	588	4,298	69	1,226	370
1982–83	1,804	859	610	477	3,548	57	1,036	284
1983–84	1,955	709	567	702	2,355	46	893	586
1984–85	1,419	646	666	866	1,561	46	685	346
1985–86	1,371	750	633	794	1,368	34	994	451
1986–87	1,595	600	376	455	1,254	30	1,531	—
1987–88	215	379	206	383	1,657	65	892	—
1988–89	2,773	884	546	424	2,756	74	1,236	—
Average harvest	1,401	661	481	586	2,505	54	1,050	912
Cows in harvest (%)	45	44	32	39	36	—	37	24
Estimated herd harvested (%)[b]	6	—	—	—	16	—	25	36

[a] Harvest figures for the Madison–Firehole herd are estimated at <1% annually and are not presented.
[b] Estimated herd sizes are from modeling efforts (Lockman 1989; Vales and Peek 1993; Mack and Singer 1993), which correct herd sizes upwards.

for the remaining elk herds were not attempted or were not yet complete (Hurley et al. 1989) at the time of this analysis. Therefore, for these four elk herds, we were unable to estimate the percentage of the elk herd that was harvested annually.

For elk herds with a high total rate of harvest and a high proportion of cows harvested—that is, the Sand Creek and Gallatin herds—Vales and Peek (1993) concluded that "...the presence of wolves means that hunter harvest will likely be confined to males most of the time." In situations where cow harvests or total harvests are less, the effects of wolves on hunter harvest are predicted to be much less (Boyce 1989). Following wolf recovery, both bull and cow harvests are predicted to be unchanged in the northern Yellowstone elk herd (Boyce 1993), although reducing the cow harvests by one-third in the northern herd was suggested to prevent elk declines following wolf restoration (Mack and Singer 1993). The proximity of an elk herd to its vegetation–ungulate ceiling (or ecological carrying capacity) will also influence the effect of human harvests or wolf predation (Theberge 1990), but the carrying capacity for the various elk herds is not well understood (Merrill and Boyce 1991).

Mule Deer

Seasonal Ranges and Distribution

Seven mule deer (*Odocoileus hemionus*) herds occur in our wolf study area. These deer populations would likely be preyed on at least in summer by wolves that live in the park and adjacent wilderness areas. Mule deer are known to migrate into Yellowstone each summer (Hurley et al. 1989; Kuck et al. 1989; Lockman et al. 1989; Singer 1991b; Appendix; T. Puchlerz, unpublished data); however, the mule deer winter ranges (Fig. 3) lie farther from the park boundaries and at lower elevations than the elk winter ranges (Table 4). From the park's boundaries, elk winter ranges lie an average of 22 km and deer winter ranges lie an average of 35 km. Several of the deer winter ranges are close to major towns such as Jackson, Cody, and Ashton. Wolves are much less likely to prey on mule deer than elk in winter because most deer ranges are close to human habitation. The Gallatin and northern Yellowstone mule deer winter ranges lie within or close to the park, and wolves are predicted to prey on those herds, especially in winter.

Population Trends

Approximately 15,531 mule deer occur in the 8 herds in our wolf study area. Populations increased significantly during the 1980's for the Targhee, Jackson, North Fork Shoshone, Clarks Fork, and Junipers–Sand Creek herds (λ = 1.11 to 1.37; Table 4). The South Fork herd grew more slowly (λ = 1.02), and the northern Yellowstone herd was stable. The total population estimates for the 8 herds increased by nearly 2,300 during

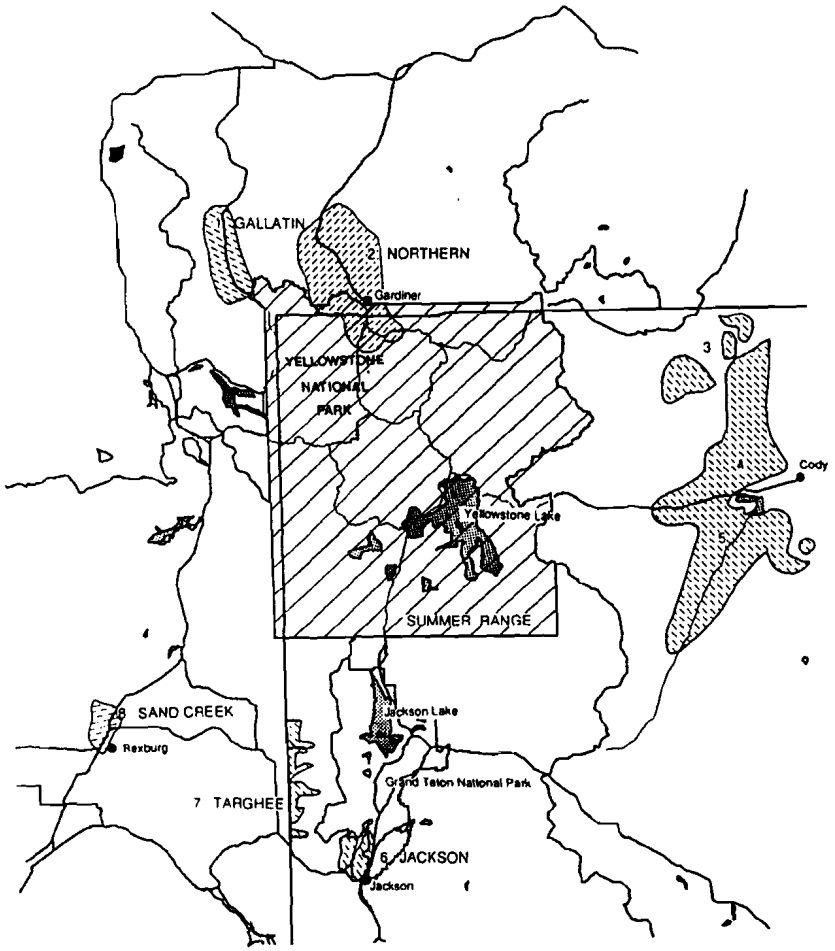

Fig. 3. Winter ranges for eight mule deer herds that summer in the Yellowstone area: *1* = Northern Yellowstone; *2* = Gallatin; *3* = Clarks Fork; *4* = North Fork Shoshone; *5* = South Fork Shoshone; *6* = Jackson; *7* = Targhee; *8* = Sand Creek.

the 1980's. Some of the most recent increases in estimates, like the Jackson and Clarks Fork herds, are largely the result of refined population harvest models (Hurley et al. 1989; Lockman et al. 1989). Recent population increases in mule deer in the Yellowstone National Park region are probably due to the milder winters of the 1980's (Singer 1991b). Ackerman (1989) and Mack and Singer (1991) concluded that about 35–40% of mule deer were missed on helicopter counts in the study area and that visibility of deer varied widely between counts. Therefore, mule deer numbers in Table 4 may be greatly underestimated.

Table 4. Annual trends in mule deer (*Odocoileus hemionus*) population size, 1980–1989, for seven deer herds that inhabit the Yellowstone National Park area (Foss 1987; Hurley et al. 1989; Kuck et al. 1989; Lockman et al. 1989; Mack and Singer 1993).

Year	Northern Yellowstone	Clarks Fork	North Fork Shoshone	South Fork Shoshone	Jackson	Targhee	Junipers–Sand Creek[a]
1980–81	2,944	3,000	950	4,125	—	550	—
1981–82	3,013	1,900	1,200	3,600	200	500	—
1982–83	3,274	5,000	2,675	6,150	230	550	1,443
1983–84	2,853	3,000	1,200	3,600	270	485	1,337
1984–85	2,835	4,000	1,400	4,800	275	510	1,983
1985–86	2,942	3,200	1,500	3,800	300	675	1,547
1986–87	3,057	3,900	1,600	4,300	325	770	—
1987–88	3,284	4,000	2,500	4,312	340	880	—
1988–89	2,617	6,699	2,500	4,800	700	1,000	1,684
Average	2,979	3,855	1,725	4,387	330	657	1,598
λ	0.99	1.21	1.22	1.02	1.37	1.22	1.11
r	—	0.08	0.09	0.01	0.13	0.08	0.05
Distance (km) of winter range from park boundary	0	32	48	27	48	24	16–48

[a] Partial counts only.

Harvests

Hunters kill an average of 3,406 mule deer each year from the 8 herds. Of these deer, an average of 22% of the total harvest (range 15–32%) are does, 77% (66–85%) are bucks, and 1% are fawns (Table 5). Mule deer harvests varied greatly between 1980 and 1989 in all the herds. A downward trend in harvests occurred in the Targhee and Jackson herds. We found no consistent long-term trends in the other herds.

Moose

Seasonal Ranges and Distribution

Moose live on 14 winter ranges in the Yellowstone area (Fig. 4, Table 6). Portions of each of the six wintering herds are known to summer within the park (Ritchie 1978; Trent et al. 1984; Alt and Foss 1987; Hurley et al. 1989; Lockman et al. 1989; Appendix; D. Tyers, Gallatin National Forest, Gardiner, Montana, unpublished data). The other eight moose herds may migrate near or into the park each summer, where they would potentially be killed by wolves. Six of the moose winter ranges are

Table 5. Annual trends in mule deer (*Odocoileus hemionus*) harvests, 1980–1989, for seven deer herds that inhabit the Yellowstone National Park area (Foss 1987; Hurley et al. 1989; Kuck et al. 1989; Lockman et al. 1989; Mack and Singer 1993).

						Junipers–Sand	
Year	Northern Yellowstone	Clarks Fork	North Fork Shoshone	South Fork Shoshone	Jackson	Targhee	Creek	Gallatin[a]
1980–81	346	574	202	794	76	85	1,239	90
1981–82	593	637	399	879	142	107	1,114	101
1982–83	618	564	289	781	3	125	1,293	88
1983–84	786	671	202	816	11	105	762	93
1984–85	622	550	232	882	15	56	238	71
1985–86	512	747	217	960	12	25	1,207	114
1986–87	536	498	255	778	7	33	728	61
1987–88	413	460	217	694	7	61	632	—
1988–89	561	383	166	548	5	63	2,075	—
Does in harvest (%)	—	19	15	21	32	17	30	—
Average harvest	554	564	242	792	31	73	1,020	68

[a] Includes only hunting district 310, that portion of the Gallatin Valley closest to the Yellowstone National Park boundary.

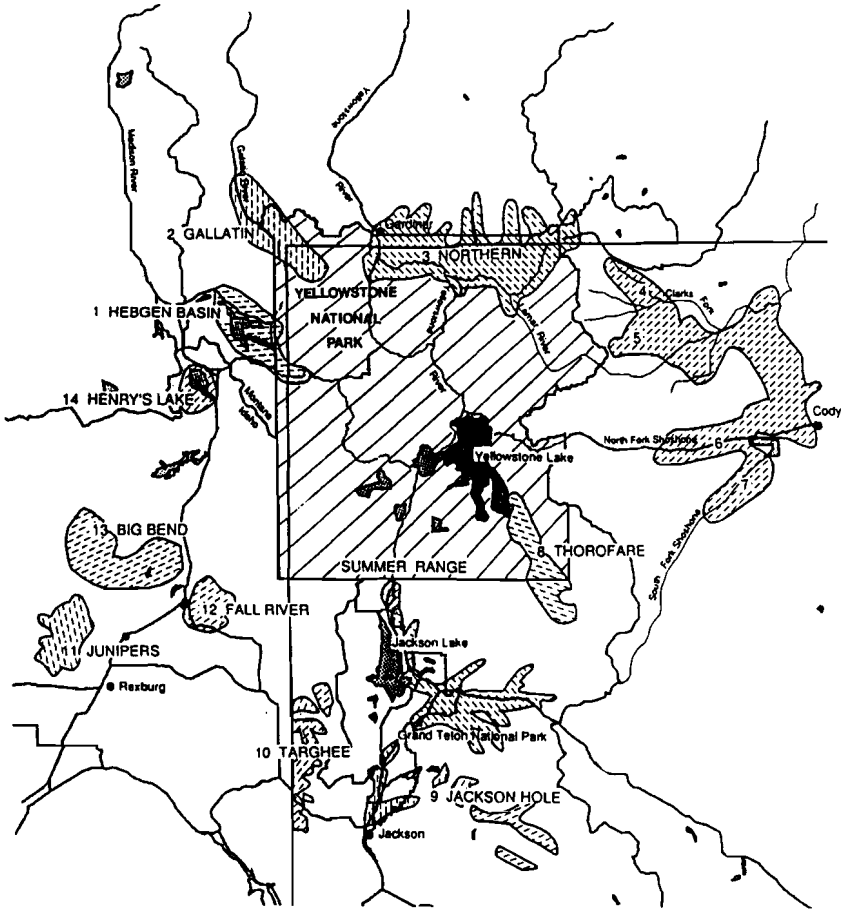

Fig. 4. Winter ranges for 14 moose herds in the Yellowstone area and moose summer range in Yellowstone National Park.

in or adjoin Yellowstone. Elk outnumber moose by a factor of 8 elk/1 moose in the Yellowstone study area, and moose are rated only 0.7 times as vulnerable to wolves as are elk (Singer 1991a). However, moose are ubiquitous in the study area, and on some of the higher elevations and deeper snow ranges (like Thorofare, upper Snake River, Targhee, upper Madison, and Buffalo River), elk outnumber moose by only 3–5:1. Moose will likely be significant prey for wolves on these deeper snow winter ranges. Therefore, we predict that moose will be a small component of the summer and winter diets of wolves, but moose may be an important factor to wolf occupation of the highest-elevation winter ranges.

Population Trends

Population estimates are available for only 6 of the 14 moose herds (Table 6). These 6 herds constitute about 4,000 moose. We conservatively

Table 6. Moose (*Alces alces*) population trends, 1980–1989, in and adjacent to Yellowstone National Park[a] (Ritchie 1978; Chu et al. 1988; Hurley et al. 1989; Lockman et al. 1989; Mack and Singer 1993).

Year	Northern	Jackson	Targhee	Fall River	Junipers–Big Bend	Henrys Lake
1980–81	396	2,200	130	151	172	65
1981–82	430	2,000	120	159	136	66
1982–83	405	1,800	125	138	353	61
1983–84	394	1,860	126	—	—	—
1984–85	392	1,830	126	—	—	—
1985–86	415	1,950	123	—	—	—
1986–87	400	2,030	145	—	—	—
1987–88	410	2,150	210	—	—	—
1988–89	446	2,300	300	217	372	224
Average	409	2,013	156	166	258	104

[a] No population estimates or counts were available for the Hebgen Basin, Gallatin, Sunlight Basin, North Fork Shoshone, South Fork Shoshone, or Thorofare herd units.

estimate that the remaining 8 herds total 1,500, and moose numbers in our wolf study area likely total 5,500. Most moose populations are apparently stable or increasing. Moose in the Yellowstone area use coniferous forests extensively, and aerial counts are probably underestimated. Through population models, Mack and Singer (1993) concluded that the northern Yellowstone moose herd was more than 2 times larger than previous estimates and more than 5 times larger than the highest aerial counts.

Harvests

Moose harvests in the 1980's averaged 545 moose annually in the study area (Table 7). Harvests in nine herds were bulls only, and harvests in the remaining five herd units were 75–86% bulls. Total legal harvests averaged less than 10% of the estimated moose populations. Since harvests are restricted predominately to bulls, we suspect that human harvests in most herds, with the possible exception of the northern Yellowstone, Gallatin, Jackson, and Targhee herds, are not significantly affecting moose populations. The effects of harvest on the four herds with cow harvests cannot be accurately determined until better population estimates exist (Mack and Singer 1993).

Bighorn Sheep

Seasonal Ranges and Distribution

Thirteen bighorn sheep (*Ovis canadensis*) herds winter in our wolf study area (Fig. 5). Many sheep migrate to mountain tops and high ridge lines in or near the park boundaries each summer (Houston 1982; Keating 1982; Hurley 1985; Irby et al. 1986; Hurley et al. 1989; Lockman et al.

Table 7. Moose (*Alces alces*) harvest trends,[a] 1980–1989, in and adjacent to Yellowstone National Park.

Year	Hebgen basin	Gallatin	Northern Yellowstone	Sunlight basin	North Fork Shoshone	South Fork Shoshone	Thorofare	Jackson	Targhee	Ashton, Idaho, moose[a] herds
1980–81	38	23	22	5	5	3	26	476	29	5
1981–82	43	29	28	5	4	5	25	450	22	7
1982–83	44	40	35	5	2	1	25	373	31	7
1983–84	42	34	32	5	3	4	23	317	29	42
1984–85	38	39	29	5	2	1	20	328	32	46
1985–86	42	34	29	5	4	5	20	214	40	57
1986–87	37	36	33	5	2	3	20	222	34	68
1987–88	—	—	32	5	5	4	24	229	43	68
1988–89	—	—	27	5	4	4	21	289	50	—
Average	40	33	29	5	3	3	22	322	34	35
Distance (km) of winter range from Yellowstone Park	adjoins	adjoins	adjoins	3	48	48	adjoins	adjoins	30	8–56[b]
Bull proportion of harvest	0.75	0.75	0.75	1.00	1.00	1.00	1.00	0.76	0.86	1.00

[a] Harvest statistics were not available separately for the Fall River, Junipers–Big Bend, Island Park, and Henrys Lake moose herd units in Idaho. The combined harvests for these four herds are presented.
[b] The Fall River moose winter range lies 8 km from Yellowstone National Park; Island Park winter range, 19 km; Big Bend winter range, 32 km; and the Junipers winter range, 56 km (Ritchie 1978).

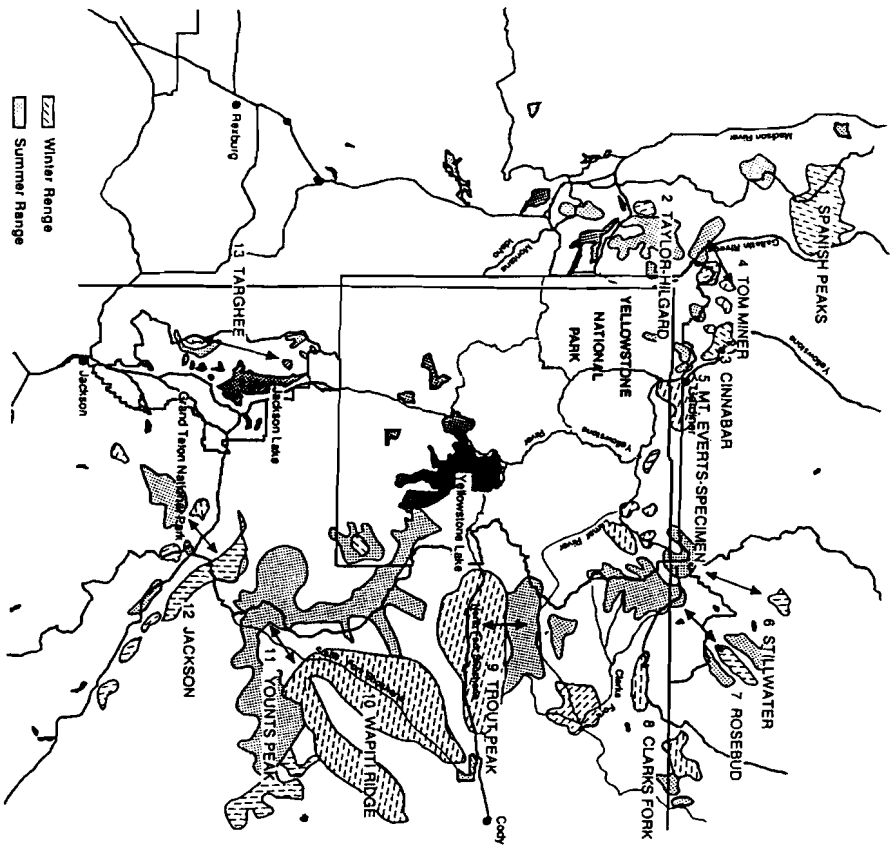

Fig. 5. Winter and summer ranges for 13 bighorn herds that occupy the Yellowstone National Park area.

1989; Appendix). Radiotelemetry studies of movements have been conducted on 5 of the 13 herd units.

Population Trends

Approximately 4,000 bighorn sheep reside in the Yellowstone area. Two larger populations east of the park in the study area—Trout Peak and Wapiti Ridge—increased during the 1980's, but most of the remaining herd units were stable or declined (Table 8). Bighorns are predicted to be only 0.3 times as vulnerable to wolves as elk and 0.15–0.23 times as vulnerable as mule deer (Singer 1991a). Bighorns will probably be a minor component of the wolf diet in places where elk or deer live.

Table 8. Bighorn (*Ovis canadensis*) population statistics in areas adjacent to Yellowstone National Park (NP) during the 1980's (Houston 1982; Keating 1982, 1985; Meagher 1982; Hurley 1985; Irby et al. 1986; Hurley et al. 1989; Lockman et al. 1989; M. Meagher, personal communication).

Herd	Estimated population size	Mean harvest[a] 1980's	Percent population change 1980's	Extent summer migration into Yellowstone NP	Distanct (km) of winter range from Yellowstone NP
North of Yellowstone[b]					
Spanish Peaks (301)[c]	—	4	—	none	32
Taylor–Hilgard (302)	—	3	—	none	16
Cinnabar Mountain (300)	80–130	8	stable	most herd	13
Tom Miner (300)	80–100	2	declined	most herd	5–8
Mount Evert–Specimen Ridge (303)	136[d]	3	declined[e]	most herd	includes Yellowstone
Stillwater (500)	40–50	2	declined	none	48
Rosebud (501)	70–100		stable	possible	32
East of Yellowstone					
Clarks Fork	500	13	stable	a few	5–8
Trout Peak	500	19	+14	a few	13
Wapiti Ridge	1,000	28	+14	includes Yellowstone	includes Yellowstone
Younts Peak	900	31	stable	a few	13–24
South of Yellowstone					
Jackson	500	15	stable or slight decline	none	56
Targhee	100	2	stable	a few	24
Total	3,906–4,016+	130	—	—	—

[a] Harvest consists of 3/4-curl-or-larger rams.
[b] West of Yellowstone there were no nearby populations.
[c] Montana hunting district numbers in parentheses.
[d] Actual count of sheep from Mount Everts along the Yellowstone River to the Specimen Ridge area.
[e] Population reduced by a pinkeye epidemic in 1982 (Meagher 1982).

Harvests

In the 1980's, an average of 130 rams was harvested annually from the 13 bighorn herds inhabiting the Yellowstone area (Table 8). All harvests were restricted to rams with three-fourths or larger curl. These harvests of only mature males likely have little influence on bighorn populations.

Mountain Goats

There are 800–830 mountain goats (*Oreamnos americanus*) in our wolf study area, but less than 100 occur in areas wolves might occupy (Fig. 6). Mountain goats are not native to Yellowstone. The nearest native population occurs 97 km to the west of the park near Monida Pass. Mountain goats occupying the park area originated from three releases: near Spanish Peaks, Montana, in 1947 and 1950 (Peck 1972); in the Absaroka Mountains of Montana between 1942 and 1948 (Guenzel 1980); and in the Palisades and Black Canyon area of Idaho in 1969–71 (Hayden 1984; also see review in Laundre 1990).

Current estimates for goat populations are 300 in the Spanish Peaks area, a few in the Gallatin Mountains, 100 in the Absaroka Mountains area (including 8 to 10 near Wolverine Peak), 150 to 180 in the Beartooth Mountains in Wyoming, and 250 in the Palisades Mountains in Idaho (Table 9; Swenson 1985a; Laundre 1990). Mountain goats could expand into suitable habitats in Yellowstone at some time in the future (Laundre 1990). Laundre (1990) estimated that the park could support 100 to 500 mountain goats following their invasion of the area.

Pronghorns

Seasonal Ranges and Distribution

Only one pronghorn (*Antilocapra americana*) herd—the northern Yellowstone herd—occupies the Yellowstone area year-round (Fig. 7). Pronghorns from the northern herd winter near the town of Gardiner, Montana, along the boundaries of the park and on adjoining private lands (Houston 1982; Singer 1991b). Some pronghorns remain to summer on the winter range. Others migrate 10–30 km to summer ranges on the higher sagebrush grasslands of Gardners Hole, Antelope Creek, Specimen Ridge, and the Lamar Valley (Fig. 7; Houston 1982). In summer, pronghorns from the northern range will be available to wolves, as will a small number of Idaho animals that summer in the Duck Creek and Cougar Creek area of Yellowstone. Northern range pronghorns will be largely unavailable to wolves in winter due to their proximity to Gardiner, Montana, a human population center most wolves will likely avoid.

Pronghorns summer in Henrys Lake, Idaho; Jackson, Wyoming; and Cody, Wyoming (Fig. 7). But pronghorns migrate each winter to lower elevations out of the study area (U.S. Department of Agriculture and U.S. Department of the Interior 1987; H. A. Harper, Grand Teton National Park, unpublished report).

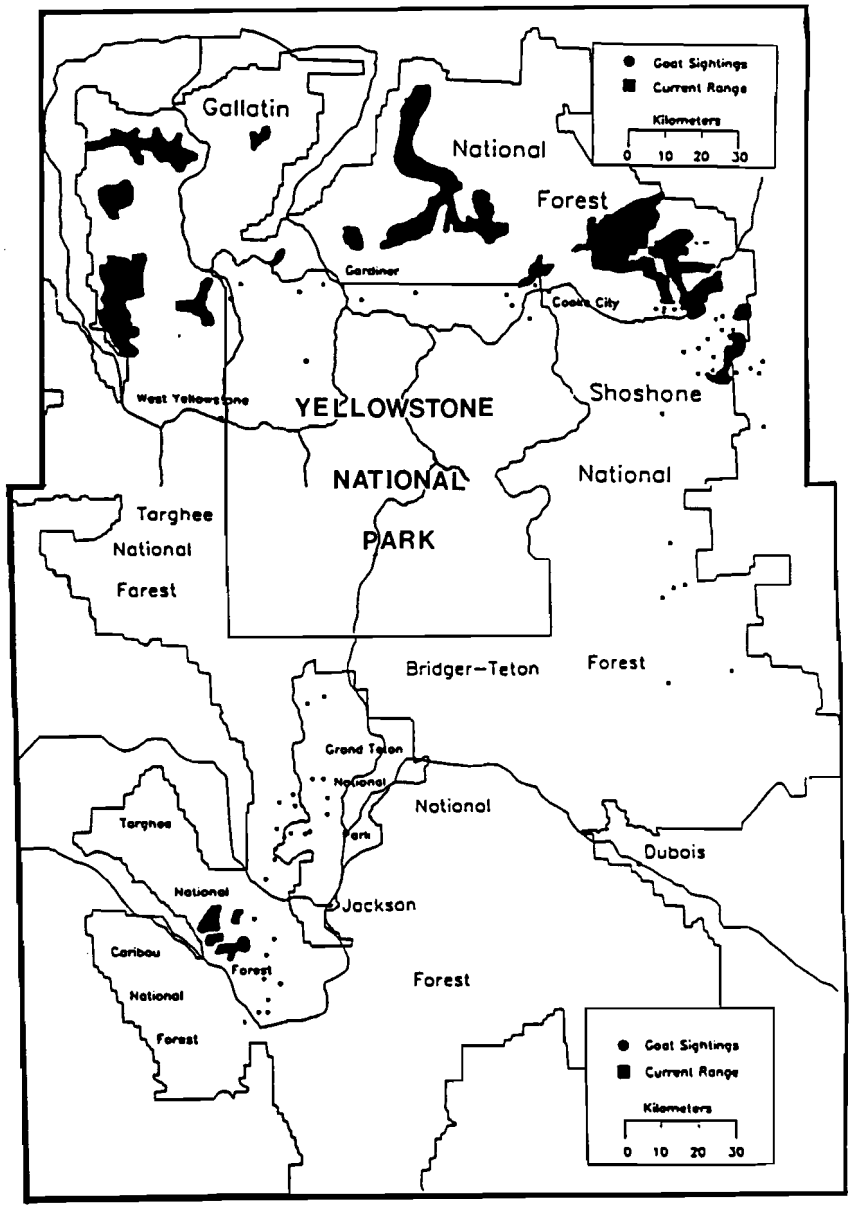

Fig. 6. Distribution and recent sightings of mountain goats on lands in and adjacent to Yellowstone National Park, 1987 (Laundre 1990).

Table 9. Non-native mountain goat (*Oreamnos americanus*) populations in areas adjacent to Yellowstone National Park (adapted from Laundre 1990).

Herd location	Estimated population	Distance (km) from Yellowstone National Park
North of Yellowstone		
Absaroka	100	0–24
Gallatin Range	(a few)	0–45
East of Yellowstone		
Beartooths	150–180	19
South of Yellowstone		
Palisades	250	80
West of Yellowstone		
Spanish Peaks–Hebgen Lake	300	10–24
Total	800–830	—

Population Trends and Harvests

Between 1930 and 1947, the number of pronghorns on the northern winter range varied between 500 and 800 (Houston 1982). Declining big sagebrush on the pronghorn winter range motivated park staff to artificially reduce pronghorn numbers during 1947–67 (Houston 1982). As a result of the reductions, counts declined to less than 200 during 1969–80 (Houston 1982; Scott 1987). Fawn ratios remained low at 38 ± 15 ($\bar{x}$ SD) fawns/100 does from 1967 to 1979 (Houston 1982). However, during the 1980's, pronghorns increased to nearly 500 animals. Fawn ratios after 1984 were higher than those for 1967–79. A total of 80 fawns/100 does was observed in November 1986, the highest recorded ratio since 1963 (Houston 1982). Pronghorn density on the 48-km^2 area of winter range increased from 3/km^2 in 1979 to 10/km^2 in 1988. Pronghorns declined about 27% following the drought of 1988 and the severe winter of 1988–89 (Singer et al. 1989).

Bison

Seasonal Ranges and Distribution

Four bison (*Bison bison*) herds occupy the study area. The Mary Mountain herd (1,500–1,800 animals), the Pelican Valley herd (300–500), and the northern range herd (300–700) inhabit the park. The Jackson Hole herd (80–150 animals) inhabits Grand Teton National Park and adjacent areas (Fig. 7; Meagher 1973, 1989; U.S. Department of Agriculture and U.S. Department of the Interior 1987). A handful of bison use the Bechler Meadows area of southwestern Yellowstone National Park.

All four bison herds migrate shorter distances (10–25 km) between seasonal ranges than the other ungulates. However, the northern herd ex-

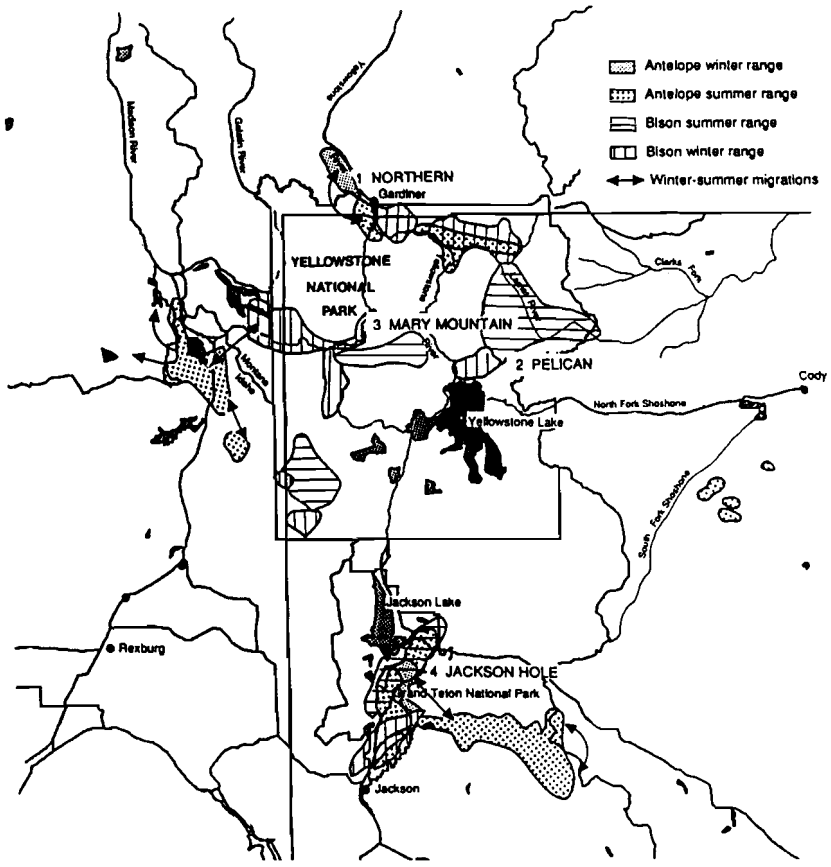

Fig. 7. Four winter–summer ranges used by bison in the Yellowstone National Park area: northern, Pelican, Mary Mountain, and Jackson. The northern antelope herd winters and summers in the Yellowstone National Park area; the other three antelope groups spend only summers in the park area.

tended its range and its migration during the 1980's (Meagher 1989) and has the potential for long annual migrations.

Population Trends and Harvests

Bison populations increased dramatically in the 1980's. The Mary Mountain herd increased about 33%—from 1,200 in 1980 to 1,600 in 1989 (Meagher 1989). The northern range herd increased 260% from an estimated 250 bison in 1980 to about 900 bison in December 1988. Immigration from the other park herds partially explained this increase (Meagher 1989). A hunt in Montana during 1988–89 reduced the northern range bison herd to about 300 by May 1989 (Meagher 1989), but recovery to 456 bison occurred by January 1991. The Jackson Hole bison herd grew

rapidly during the 1980's, but due to conflicts with agricultural activities and with elk on feed grounds, a U.S. Fish and Wildlife Service plan calls for reducing the herd to less than 150 animals.

Bison are predicted to be 0.7 times as vulnerable to wolves as elk; however, bison vulnerability was predicted to be more variable than other ungulates (Singer 1991a). Where bison numbers are well below the ungulate vegetation ceiling and where snows are shallow (like on the Jackson Hole and northern Yellowstone winter ranges), bison are predicted to be infrequently killed by wolves due to the defensive behaviors of bison. However, chest heights and foot loading (weight/hoof unit area) suggest that bison will be vulnerable to wolves in deep snows (Telfer and Kelsall 1984), and bison are the primary prey for wolves in several parts of northern Canada (Oosenbrug and Carbyn 1983). Singer (1991a) predicted that 74 bison would be killed by wolves for every 100 elk on the higher, interior Yellowstone National Park winter ranges (e.g., Mary Mountain, Pelican, Bechler Meadows). Any wolves frequenting Pelican Valley in winter must survive almost exclusively on bison as prey.

Availability of Ungulates to Wolves

During winter, 7 ungulate species (totaling 80,800 animals) inhabit our wolf study area (Table 10). About 30,100 (37%) of these ungulates occur within the boundaries of the park each winter and would be available to wolves. About 43,650 (54%) ungulates inhabit the combined Yellowstone area and immediately adjacent national forest wilderness areas where they would be largely available to wolves in winter. The remaining 46% of the ungulates inhabit areas closer to human habitation, where we predict less wolf activity.

Elk dominate the ungulate fauna more within the park than in adjacent areas. Elk outnumber all other ungulates combined in Yellowstone by a ratio of 100 elk/40 other ungulates. The ratio in the combined Yellowstone National Park–national forest wilderness areas is 100 elk/56 other ungulates, while the ratio is 100 elk/76 other ungulates when considering the entire wolf study area (Table 10). Relatively more moose, mule deer, and bighorns occur outside the park. Mule deer availability increased 50% when wilderness areas were included, and deer availability was 5 times higher in the entire study area than within the boundaries of Yellowstone National Park (Table 10).

Winter wolf diets are predicted to be 70% elk in Yellowstone, 68% elk in the combined Yellowstone National Park–national forest wilderness areas, and 56% elk in the entire study area (Table 10). The predicted mule deer portion of the wolf diet increased in direct proportion to the distance considered outside the park. Mule deer were predicted to make up 19% of winter wolf diets within the park and the contiguous northern range, 13% in Yellowstone and national forest wilderness areas, and 36% in the entire study area

Table 10. Numbers of ungulates and likely composition of wolf (*Canis lupus*) diet in three winter scenarios of wolf occupation of lands in the Yellowstone National Park area: park only—high probability of total occupation by wolves; park and contiguous national forest wilderness—moderate probability of total occupation; and park and all nearby adjoining lands—low probability of total occupation.

	Park only			Park and wilderness			Park and all nearby lands		
Species[a]	Number of ungulates	Percent availability	Predicted wolf diet (%)[b]	Number of ungulates	Percent availability	Predicted wolf diet (%)[b]	Number of ungulates	Percent availability	Predicted wolf diet (%)[b]
Elk	21,500	71	70	28,700	64	68	46,000	57	56
Mule deer	4,000	14	19	6,000	13	20	21,000	26	36
Bison	2,800	9	6	2,800	6	5	2,900	3	2
Bighorn	300	1	0.1	3,300	10	2	4,000	5	1
Moose	700	2	1	2,000	4	3	5,500	7	4
Pronghorn	600	2	3	600	1	2	600	0.5	0.5
Mountain goat	200	1	0	250	0.6	0	800	1	0
Total	30,100	100	99.1	43,650	98.6	100	80,800	99.5	99.5

[a] Elk = *Cervus elaphus*; mule deer = *Odocoileus hemionus*; bison = *Bison bison*; bighorn = *Ovis canadensis*; moose = *Alces alces*; pronghorn = *Antilocapra americana*; mountain goat = *Oreamnos americanus*.

[b] Mule deer were predicted to be selected by wolves 1.4 times as often as elk, bison 0.7, moose 0.7, bighorn 0.2, pronghorn 1.4, and mountain goat 0.2 (Cowan 1947; Carbyn 1982; Carbyn et al. 1987).

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Appendix. Distributions, Population Trends, and Harvests for Elk, Mule Deer, Moose, and Bighorn Sheep in the Yellowstone National Park Area.

Information Needs and Data Gaps

We rated essential population survey or information needs for each ungulate as follows: (1) annual aerial counts, (2) annual sex and age classification, (3) accurate sex and age information from the harvest, (4) visibility correction for animals not seen during the counts, (5) a current population harvest model, and (6) research studies or models of populations and their habitats. Elk received the highest information rating, 58%, followed by mule deer, 42%; bison, 29%; bighorn sheep, 28%; and moose, 18%. Mountain goats and white-tailed deer were not rated because they are unimportant to wolf recovery. Population data were adequate for modeling the predicted effects of wolf predation only for the Yellowstone elk populations (Boyce 1993; Vales and Peek 1993). A provisional model was constructed for the northern Yellowstone mule deer population (Mack and Singer 1992), but the moose population models were considered exploratory only (Boyce 1993; Mack and Singer 1993). Obtaining more extensive population data is recommended for mule deer and moose to better evaluate the effects of wolf recovery.

Elk

Seasonal Ranges and Distribution

East of Yellowstone

During spring, elk from the Clarks Fork, North Fork Shoshone, and Carter Mountain herds migrate west from winter ranges into Yellowstone (Fig. 1). Radiotelemetry studies (Yorgason et al. 1981; Rudd 1982; Rudd et al. 1983) show that about 80% of the Clarks Fork and North Fork Shoshone herds migrate into the park.

A small portion of the Carter Mountain herd apparently summers in the Thorofare and upper Yellowstone River area of Yellowstone National Park. Small groups have been tracked through fresh snow twice (from aircraft) from the Thorofare River to South Fork Shoshone winter ranges (in the Carter Mountain herd) after crossing the Absaroka Divide in the Thorofare Buttes area (F. J. Singer, Yellowstone National Park, unpublished data; G. Roby, Wyoming Game and Fish Department, personal communication).

South of Yellowstone

Elk occur in the Jackson and Targhee herds. The Jackson herd primarily winters in the Gros Ventre River Valley and on the National Elk Refuge. These winter ranges are 48 to 64 km south of Yellowstone and are distant from areas wolves would likely inhabit. Based on a sample of 97 radio-collared elk, approximately 40% of the Jackson elk herd summers in Yellowstone (28%) and the adjacent Teton Wilderness (12%).

For 1978–82, spring migration lasted an average of 21 days for elk migrating to Yellowstone. Many cows calved en route to summer ranges, and the mean stay on summer ranges in the park was 160 days (Smith and Robbins, in preparation). October snows precipitated earlier fall migrations but did not necessarily result in earlier arrivals at the National Elk Refuge. Mean fall migration lasted 19 days.

The Targhee herd summers south of Yellowstone in Wyoming. In winter, these elk migrate west onto ranges in Idaho or to southern exposures of several drainages within about 10 km of the Idaho–Wyoming state line (Lockman et al. 1989).

Southwest of Yellowstone

The Sand Creek elk herd occupies the area of Idaho adjacent to Yellowstone. Brown (1985) and Vales (1989) estimated that 76% of the Sand Creek herd occupied areas east of U.S. Highway 20 (including Yellowstone National Park) during summer. Twenty-four percent of the Sand Creek herd migrated into the park each summer (Brown 1985). Spring migrations to summer ranges lasted about 46 days (Brown 1985). Most calving occurred en route to Yellowstone summer ranges except when spring snows were shallow. Therefore, few newborn elk calves from this herd would be available for wolves during typical springs in Yellowstone. Brown (1985) also estimated that Yellowstone elk remained on summer ranges an average of 138 days, and that elk in Harriman State Park stayed on summer ranges 168 days. Naderman (Idaho Fish and Game Department, personal communication) estimated they stay 150 days on summer ranges. Fall migrations to the Sand Creek winter range lasted about 27 days (Brown 1985). The Sand Creek elk herd migrates through sagebrush flats to the Sand Creek winter range located west of the town of Rexburg and north of Idaho Falls. Additional elk from Yellowstone and areas southwest of the park winter on Conant Creek, upper Teton River Canyon, Bitch Creek, Badger Creek, and the Fall River (J. Naderman, Idaho Fish and Game Department, personal communication).

Population Trends

Southwest of Yellowstone

The Sand Creek elk herd increased dramatically during the 1980's following cessation of general either-sex seasons in the mid-1970's (Brown 1985). Elk numbered about 2,300 in 1981 and approximately 2,400 in 1989 (Brown 1985; Vales and Peek 1993). Trend counts averaged 2,435 elk during the 1980's (Parker et al. 1983; Chu et al. 1989). Population models, however, suggest that the herd numbers about 4,900 (Vales and Peek 1993). Management goals call for limiting the elk herd to less than 2,000 on the Sand Creek winter range to reduce potential conflicts with cattle grazing and reduce damage complaints on adjacent private lands (Chu et al. 1989). A number of elk winter in areas near the Sand Creek winter range, and not all elk are observed during the aerial counts (J. Naderman, Idaho Fish and Game Department, Idaho Falls, personal communication). Population models suggest that the 1988 prehunt size of the greater Sand Creek elk herd, including peripheral areas, was about 6,200 (Vales and Peek 1993).

North of Yellowstone

The northern Yellowstone elk herd was reduced to less than 5,000 by 1968 due to population management reductions by trapping and shooting (Houston 1982). After discontinuing artificial reductions (Cole 1971), the northern Yellowstone elk herd nearly tripled through 1988, when the population was estimated at approximately 21,000 (Garton and Singer 1991; Mack and Singer 1993). The Gallatin herd was estimated through population modeling to be about 2,500 elk (Vales and Peek 1993). Recent aerial counts of the Madison–Firehole herd were about 800 elk, although Singer (1991b) estimated the actual herd had at least 1,200 elk due to heavy forest cover and low elk visibility.

East of Yellowstone

The three elk herds on Yellowstone's eastern boundary—North Fork Shoshone, Clarks Fork, and Carter Mountain—increased an average of 62% during the 1980's (Table 3). Each herd was estimated at approximately 2,800 to 3,000 elk in 1988 or 9,000 elk (total) in the 3 herds.

South of Yellowstone

Counts for the Jackson elk herd declined from 1981 to 1983 and averaged 9,573 elk. From 1984 to 1988, the animals counted increased dramatically and averaged 11,346. The higher counts reported in 1987 and 1988 may be because a helicopter was used for these counts. Population estimates reported in the yearly progress reports were much lower than estimates projected from a new population model developed in February 1989 (Lockman et al. 1989). The decline in population and subsequent steady increase from 1983 to 1988 was probably a result of three consecutive mild winters (Lockman et al. 1989) and more restrictive hunting regulations between 1984 and 1987.

Elk in the Jackson herd wintering in Buffalo Valley increased from approximately 30 in 1981 to 604 in 1988. This increase may have been due to mild winters, local public opposition to increased hunting, and feeding by private individuals (Lockman et al. 1989). Preliminary analysis of 12 radio-collared elk revealed that 67% of the individuals wintering in Buffalo Valley spent summer and fall in Yellowstone. The increase

of elk wintering in Buffalo Valley caused the public to favor establishing another feeding ground in this area. The Wyoming Game and Fish Department prefers not to establish another artificial feeding ground. Counts and classification data were not collected for the Targhee herd, and only rough population estimates are available from 1980 to 1986. Classification data from 1987 and 1988 indicated relatively high bull/cow and high cow/calf ratios. Buffalo Valley is remote, and we predict that wolf activity will occur there.

Northwest of Yellowstone

The Gallatin elk herd increased approximately 20% during the 1980's, and recent counts yielded 1,500 to 1,800 elk (Taylor 1978–86; Vales and Peek 1993). Goals of the State of Idaho and the Bureau of Land Management are to maintain a high harvest through late-winter hunts and to limit the herd to less than 1,500 (Vales and Peek 1993). Population modeling suggests that the elk population was considerably larger than counts indicated and was about 2,500 in 1988 (Vales and Peek 1993).

Madison Plateau

The nonmigrating Madison–Firehole elk herd was stable or declined slightly during the 1980's (Cole 1983; Singer 1991b). Recent herd counts were less than 800, and the estimated herd size is 1,200 to 1,400 elk (Singer 1991b).

Harvests

East of Yellowstone

Weather influences the timing and magnitude of elk migrations out of Yellowstone for the Clarks Fork and North Fork Shoshone herds. Snow depths have been significantly correlated with fall elk migrations (Rudd 1982; Rudd et al. 1983). As a result of variable snowfalls, harvests for the Clarks Fork and North Fork Shoshone elk herds were also variable (Table 4). Management strategies were implemented in the late 1980's to stabilize elk numbers for both of these herds (Hurley et al. 1988), including hunting seasons, increased antlerless permits, and reduced hunting pressure on mature bulls. Increasing elk hunts on nonmigratory herd segments has complicated the management of the Clarks Fork and North Fork Shoshone elk herds.

Elk harvests from the Clarks Fork and North Fork Shoshone herds increased dramatically from 1980 to 1982 and then remained relatively stable until 1987. Hunter harvest from 1982 to 1986 averaged 713 elk (32% hunter success) and 570 elk (31% hunter success) for the Clarks Fork and North Fork Shoshone herds, respectively (Table 3). The low harvest in 1987 was due to a mild winter. The harvest for both herds again increased in 1988 due to a more normal winter.

South of Yellowstone

Harvests from the Jackson elk herd have varied during the 1980's (Table 4). Average yearly harvests were 3,475 elk between 1980 and 1983 but, with more restrictive regulations beginning in 1984 (that is, no general either-sex or antlerless seasons), harvests were substantially reduced, particularly in the cow and calf groups; the average yearly harvest between 1984 and 1987 was 1,385 elk. In response to rapidly increasing elk numbers projected for 1987, harvests were liberalized, but the harvest was lower than desired due to mild weather conditions. The harvest in 1988 was greater than in 1987 but not enough to bring the population down to the desired level of approximately 11,000 elk (Straley et al. 1986).

Elk harvests on the Targhee herd steadily declined from 1980 to 1986 (Table 4). The average annual harvest from 1980 to 1986 was 50 elk and increased to 70 in 1987 and 1988 (Table 4). The reduced harvest in the mid-1980's was related to more restrictive hunting seasons that lowered the number of resident and nonresident hunters (Lockman et al. 1989). Increased harvests in 1987 and 1988 were probably a result of increased elk numbers and an increase in outfit hunting activity (Moody et al. 1988).

Southwest of Yellowstone

Idaho's Sand Creek elk herd was harvested at high levels (Table 4). Hunter densities were as high as 5.1 hunters/km^2 during the general season. Logging roads and timber cuts make elk more vulnerable to hunters (Parker et al. 1986). Parker et al. (1986) found a correlation between road density and percent yearling bulls in the harvest. They expressed concern that the harvest rates for bull elk may be approaching levels detrimental to herd productivity. They associated high harvests with severe weather.

The general season elk harvest declined from 1980 to 1983 and then increased to a high of 687 elk (Table 3). The legal harvest was composed entirely of antlered bulls during the general season. The number harvested has remained relatively stable since 1985.

Elk harvested during controlled hunts declined from 1981 to 1984. Starting in 1985, controlled-hunt harvests increased to a high of 737 elk in 1988 (Table 4).

Mule Deer

Seasonal Ranges and Distribution

Approximately 20,637 to 21,883 mule deer occupy areas adjacent to the park in eight herds (Table 5). Each herd used the park in summer (Foss 1987; Hurley et al. 1989; Kuck et al. 1989; Lockman et al. 1989; Singer 1991b), but the extent of their migrations into the park is unknown.

North of Yellowstone

Portions of the Gallatin and northern Yellowstone mule deer herds summer within the park (Table 5). The majority of the northern herd winters immediately outside Yellowstone; aerial counts of mule deer winter-

ing within the park on the northern range averaged less than 200 deer (Singer 1991b).

East of Yellowstone

Mule deer populations in the Clarks Fork, North Fork Shoshone, and South Fork Shoshone winter 27 to 48 km from the park. The number of deer summering within the park is unknown (Fig. 2; Table 5).

South of Yellowstone

Mule deer from the Jackson herd winter near the town of Jackson, 64 to 80 km from the park, well away from areas wolves would likely occupy. Summer migrations into Yellowstone are highly probable (Lockman et al. 1989).

Mule deer from the Targhee herd winter in Idaho (84% were seen in Idaho) or in Wyoming, straddling the state line in the Victor, Fox, Kiln, Teton, South Badger, and South Leigh creeks (Fig. 3; Lockman et al. 1989). Some of these deer probably summer in or near the park.

Southwest of Yellowstone

Mule deer from the northeastern area of Idaho adjacent to the park winter primarily in the Junipers–Sand Creek winter range. Deer from the Junipers–Sand Creek herd migrate during summer into the Island Park area, adjacent areas of the Targhee herd in Wyoming, and into Yellowstone.

Population Trends

North of Yellowstone

Since 1980, the mule deer population north of the park has been stable or increased. In response to the increasing populations, the Montana Department of Fish, Wildlife, and Parks increased the available number of antlerless licenses to harvest more of the productive doe segment. As early as 1981, concern developed that unpredictable influxes of elk on a winter range north of the park made managing the deer populations difficult (Foss 1985). Foss indicated that spring fawn/100 adults seemed to be negatively correlated with the number of elk present on the northern winter range. However, Houston (1982) reported that mule deer recruitment showed no significant association with elk numbers. Yearling recruitment on the east and west sides of the Yellowstone River averaged 29 and 33%, respectively, during the 1980's (Mack and Singer 1993).

East of Yellowstone

Mule deer populations in the Clarks Fork, North Fork Shoshone, and South Fork Shoshone herds were stable or increased slightly during the 1980's. Deer numbers were estimated from a computer model, which may have overestimated population numbers (Hurley et al. 1989). Buck/doe ratios in postseason classifications were less than 4, apparently due to the heavy harvest of bucks compared to does from 1980 to 1987. However, buck/doe ratios increased substantially in 1988 because a 4-or-more-points buck restriction was implemented (Hurley et al. 1989).

South of Yellowstone

Mule deer populations increased in the Jackson herd during the 1980's. Fawn/doe ratios for the north Jackson, Wyoming, area were relatively high, especially from 1984 to 1988. Buck/doe ratios increased since 1986 due to low harvest, limited hunter access, and more restrictive seasons (Lockman et al. 1989).

Classification data were collected for the Targhee herd from 1980 to 1986. Populations were stable or increased. Fawn/doe ratios were relatively high in 1987 and 1988 (Lockman et al. 1989).

Southwest of Yellowstone

Mule deer trend counts during December in the Sand Creek area averaged 1,599 during the 1980's. The population objective for this herd is 1,200 (J. Naderman, Idaho Fish and Game Department, personal communication).

December fawn ratios were high for the Sand Creek herd and averaged 95 fawns/100 does. Buck/100 does ratios declined from a high of 65 in 1979–80 to 23 in 1987–88.

Harvests

North of Yellowstone

From 1980 to 1986, an average of 1,762 deer were killed each year. Although the number of bucks killed each year declined, the number of antlerless deer increased, resulting in a relatively stable annual hunt since 1981. From 1980 to 1986, a yearly average of 83% of the total deer harvested from areas adjacent to Yellowstone came from Montana hunting districts 313 and 314. An average of 91% of the annual harvest consisted of mule deer (69% antlered, 22% antlerless). An average of 6% of the annual harvest consisted of antlered white-tailed deer (*Odocoileus virginianus*), and 3% consisted of antlerless white-tailed deer.

East of Yellowstone

From 1980 to 1988, the average annual deer harvests for the Clarks Fork, North Fork Shoshone, and South Fork Shoshone herds were 565 (31% hunter success), 242 (27% hunter success), and 792 (44% hunter success). Total harvests were relatively stable or increased slightly through 1985. Harvests declined from 1986 through 1988 for the Clarks Fork and South Fork Shoshone herds.

Bucks dominated the mule deer harvest from 1980 to 1987 for all three herds. In 1988, 130% more does than bucks were killed in the Clarks Fork and South Fork Shoshone herds. Doe and buck harvests in the North Fork Shoshone herd were nearly equal (81 and 85) for 1988. The change

in buck harvest was due to new hunting regulations allowing only the harvest of bucks with at least one antler of four points or more. In 1988, the 4-point rule and a 5-day reduction in the general season length contributed to a low deer harvest. These changes have all been designed to reduce the buck harvest (Yorgason et al. 1986; Hurley et al. 1988).

South of Yellowstone

From 1980 to 1984, the average mule deer harvest from the four hunt areas in the Jackson herd was 608 deer (Lockman et al. 1989). Yearly harvests declined during this period, primarily because of subdivision developments on deer winter range and landowner intolerance of hunting (Straley et al. 1981, 1982).

In 1983, biologists believed large numbers of deer spent summer and fall in hunt areas 148, 155, and 156 but wintered elsewhere (Straley et al. 1984). Poor hunter access, reduced opportunities for rifle hunting, and more restrictive hunting seasons contributed to a declining harvest from 1984 to 1988 (Moody et al. 1988; Lockman et al. 1989).

Harvests for the Targhee mule deer herd were relatively high and stable between 1980 and 1983. The average annual harvest during this period was 106 deer.

Southwest of Yellowstone

Deer harvests declined from 1,239 in 1980 to 238 in 1984. The low harvest in 1984 was due to a combination of high winter-kill in 1983–84 and the elimination of antlerless permits in 1984. Harvest levels increased in 1985 and continued to increase to 2,075 deer in 1988. White-tailed deer made up about 4% of the total deer harvest.

Moose

Seasonal Ranges and Distribution

North of Yellowstone

Portions of three Montana moose populations—the Hebgen Basin, Gallatin, and northern herds—winter and summer within the park (P. Schladweiler, Montana Department of Fish and Game, unpublished report; D. Tyers, Gallatin National Forest, Gardiner, Montana, personal communication). The Hebgen Basin group resides on tributaries of Hebgen Lake, including the lower Madison River, Duck Creek, and Cougar Creek in Yellowstone. Moose occur across the northern elk winter range (Houston 1982) throughout the year. Seasonal movements between summer and winter ranges typically involve elevation shifts and movements of only 5 to 8 km (D. Tyers, Gallatin National Forest, Gardiner, Montana, personal communication).

East of Yellowstone

Moose winter in the Crandall, Sunlight Basin, North Fork Shoshone, and Thorofare areas adjacent to the park. The Thorofare range straddles the park boundary. Moose from the Crandall, Sunlight Basin, and North Fork Shoshone ranges may migrate to the summer range in Yellowstone; however, no radiotelemetry studies investigating seasonal ranges have been conducted.

South of Yellowstone

Two moose herds—the Jackson and the Targhee—occur immediately south of the park. Moose range south of the park in the Jackson herd. Tagging and neckbanding studies conducted in the late 1960's and early 1970's (Houston 1968; Lockman et al. 1989) suggested that moose that winter along the Buffalo River summer in Yellowstone and Grand Teton national parks, the Teton Wilderness, and in upper Spread Creek.

Few moose from the Targhee herd winter in Wyoming. Most winter in Idaho within 10 km of the state line, from Teton Creek south to Bitch and Moose creeks (Lockman et al. 1989). These moose move east and north for the summer. They are joined by moose from the Fall River herd in Idaho, 15% of which summer in Wyoming and 39% of which summer in Yellowstone (Ritchie 1978; Lockman et al. 1989).

Southwest of Yellowstone

Moose from five wintering groups in Idaho migrate in a northeasterly direction in the spring (Ritchie 1978) to summer in areas east of U.S. Highway 20, southwest of Yellowstone and southwest of Montana. The Fall River moose herd summers and winters primarily east of U.S. Highway 20 and occupies Yellowstone lands more than other herds. Studies of tagged moose suggest that equivalent numbers of Fall River moose summered in Idaho and Wyoming (Ritchie 1978). A few moose winter in the Bechler Meadows in Yellowstone.

Population Trends

North of Yellowstone

Due to low visibility of moose remaining in the timber, aerial classification data were not collected for moose populations in Montana hunting districts surrounding the park. Hunter observations from Hellroaring, Buffalo Fork, Slough Creek, and upper Stillwater in the Absaroka high country suggest an increasing moose population since more restrictive hunting regulations were initiated in the mid-1970's. The number of moose seen per hunter significantly increased during 1979–86 compared to 1975–78 (Swenson 1985b; Swenson and Foss 1986). This increase, coupled with a lower reported calf/100 cows ratio (suggesting reduced quality or quantity of forage; P. Schladweiler, Montana Department of Fish and Game, unpublished report), justified issuing more antlerless-only permits in this area.

East of Yellowstone

The Thorofare herd contains the best moose habitat in District 2 and probably has more moose than the Crandall, Sunlight, North Fork Shoshone, and South Fork Shoshone herds combined. The North and South Fork Shoshone River areas support marginal moose habitat (Yorgason et al. 1982, 1983, 1986). Classification and count data are too limited to justify population models for any of these herds.

South of Yellowstone

Moose population estimates for the Jackson herd declined from 1980 to 1984 and increased from 1985 to 1988. Reduced harvests—particularly in the female segment—since 1982 and mild winters have probably increased moose in the Jackson herd (Lockman et al. 1989).

Classification data from hunter and aircraft surveys indicate relatively stable calf/cow ratios between 1980 and 1985. Bull/cow ratios from hunter surveys were lower than aircraft surveys. The relatively high bull ratios, in spite of the high bull harvest, may be because aerial surveys were conducted near Grand Teton National Park where moose are not subjected to hunting pressure (Straley et al. 1985, 1986, 1987; Moody et al. 1988).

High hunter success, even with increasing harvests, suggests that the population is increasing in the Targhee moose herd (Moody et al. 1988). Classification data were collected from hunter surveys between 1980 and 1985. Calf/cow ratios were variable but seemed to be increasing through 1985.

Southwest of Yellowstone

Moose populations in Idaho, adjacent to the park, are relatively productive, and bull/100 cow ratios are high. Twinning rates between 1969 and 1975 were relatively high and averaged 12% (Ritchie 1978).

Moose counts declined in the 1970's, and the hunting season was closed from 1977 to 1982. By 1982, the counts were increasing, and a controlled hunt was reinstituted in 1983.

Harvests

North of Yellowstone

The moose harvest remained relatively constant between 1980 and 1986, averaging 114 animals/year for seven areas. Hunter success was high and stable at about 84% per year. The majority of the harvest was bulls at 75% per year, with cows at 17% per year and calves at 8% per year.

East of Yellowstone

Since 1980, moose harvests along the park's eastern border were relatively stable and consisted of bulls. Hunters in the Crandall area have enjoyed about 96% success, although the number of permits increased from 5 to 10 animals starting in 1981. Annual harvests for the Sunlight area have remained at five bulls, and success rates have remained at 100%.

Despite this high success and because of lack of population data, illegal kills, and habitat changes on private land (Yorgason et al. 1984, 1985), biologists are taking a conservative approach to harvests based on counts. The harvests and success rates in the North Fork Shoshone and South Fork Shoshone herds have been irregular due to the large amount of effort required to kill a moose and the dispersed nature of moose in these areas (Fig. 3). Moose in the Thorofare area have received the most attention and management changes. Concerns that this herd was declining were expressed as early as 1981 (Yorgason et al. 1981). These concerns have led to reducing the number of permits issued, from 35 in 1980 to 24 in 1988. Total harvest of bulls, however, has not declined appreciably.

South of Yellowstone

The moose harvest in the Jackson herd in Wyoming decreased between 1980 and 1987 because fewer permits were offered. The Wyoming Game and Fish Department decreased permits to reverse a decline of moose population (Straley et al. 1985; Moody et al. 1988). Average annual harvest for 1980 and 1981 was 463 moose. Average harvest between 1982 and 1984 was 339 moose. The lowest number of permits and most restrictive regulations occurred between 1985 and 1987. During this period, the average moose harvest was 222 (Table 10). Bulls dominated the harvest from 1980 to 1988 and made up an average of 56% of the total harvest in 1980 and 1981. The proportion of bulls harvested increased between 1982 and 1988, and bulls made up 86% of the total harvest.

Harvests for the Targhee herd in Wyoming have steadily increased from 1980 to 1988 (Table 10). Increased harvests resulted from an increasing population and an increase in total permits offered (Lockman et al. 1989). The average annual harvest from 1980 to 1988 was 31 moose. Bulls dominated the harvest from 1980 to 1987 and made up 87% of the total harvest. The large increase in the cow harvest in 1988 reflects the substantial increase in antlerless moose permits offered to slow population growth of the herd (Moody et al. 1988).

Southwest of Yellowstone

From 1980 to 1982, a bulls-only moose harvest was allowed in only one of five moose hunt units southwest of the park in Idaho. This bull harvest averaged six per year. Moose aerial counts increased, and moose harvests were permitted beginning in 1983. From 1983 to 1988, an average of 58 moose was harvested per year (Trent et al. 1984; Chu et al. 1988).

Bighorn Sheep

Seasonal Ranges and Distribution

North of Yellowstone

In Montana, bighorns inhabit three winter ranges in and adjacent to northern Yellowstone. These winter ranges include the Mount Everts–Specimen Ridge, Cinnabar Mountain, and Tom Miner Basin ranges

(Keating 1982, 1985; Irby et al. 1986; M. Meagher, National Park Service, personal communication). The majority of bighorns in the Mount Everts and Specimen Ridge population reside within the park year-round. Bighorn sheep in the Cinnabar Mountain population winter outside Yellowstone but summer inside the park on Sepulcher Mountain, Electric Peak, Bannock Peak, and Quadrant Mountain (Keating 1982). Bighorns from the Tom Miner Basin population winter outside the park. Summer ranges for this population straddle the park boundary on Sheep Mountain, Ramshorn Peak, and Fortress Mountain (Keating 1982). The Spanish Peaks and Taylor–Hilgards bighorn sheep herds of the Madison Range occupy winter ranges 10–30 km from the Yellowstone boundary. Bighorns from the Stillwater and Rosebud populations winter 30–50 km from the park, but radio-collared individuals travel into the northeast boundary of the park each summer (S. Stewart, Montana Fish, Wildlife and Parks, Red Lodge, personal communication).

East of Yellowstone

Bighorns in the Clarks Fork, Trout Peak, and Yount's Peak areas (Fig. 4) primarily reside year-round outside the park (Hurley 1985; Hurley et al. 1989). However, all three sheep ranges lie between 8 and 24 km from the park, which may be reoccupied by wolves. The Wapiti Ridge population occupies summer and winter ranges in the southeastern corner of Yellowstone (Hurley 1985; Hurley et al. 1989).

South of Yellowstone

Sheep in the Jackson herd winter in the Gros Ventre and Hoback Valley winter ranges located 48 km south of the park. These wintering areas are unlikely to be inhabited by wolves.

One bighorn winter range in the Targhee herd is within 24 km of the park, but a second is 56 km south of the park (Fig. 4). A few sheep seen periodically on Mount Sheridan in Yellowstone may be from the Targhee bighorn herd.

Population Trends

North of Yellowstone

The Mount Everts–Specimen Ridge population is larger than the Cinnabar Mountain or Tom Miner populations. Bighorns on Mount Everts (excluding the Specimen Ridge area) increased from 63 in 1965 to 222 in 1978. The rate of increase from 1965 to 1978 was estimated to be 12% per year (Keating 1982).

The Mount Everts–Specimen Ridge bighorn sheep population was relatively stable from 1974 to 1981 at about 200 (Keating 1982). Meagher (of the National Park Service) estimated this population to be about 400 animals, but an infectious keratoconjunctivitis epidemic in 1982 reduced the population by 75–85% (Meagher 1982 and personal communication).

The population recovered to 136 to 180 individuals by 1988 (M. Meagher, National Park Service, personal communication).

Bighorns were extirpated from the Cinnabar Mountain population (Montana hunting district 300) in the late 1800's. Following colonization from Mount Everts in 1965, the herd rapidly grew from 11 in 1967 to 103 in 1980 (an 18% per year increase; Keating 1982). This population has continued to grow. Irby et al. (1986) estimated that 80–150 bighorns occupy the Cinnabar Mountain in winter. Lamb/ewe ratios have been negatively correlated to the number of ewes present in a population the previous year and may indicate that there are too many bighorns for the forage conditions (Swenson 1985b).

The Taylor–Hilgards area contains three small bands of bighorns. The most numerous band in the Hilgards area experienced a drastic decline (Swenson 1985a), which possibly resulted from competition with increasing numbers of elk on winter range or possibly from an increase in the mountain goat population in this area (Swenson 1985a).

The Stillwater bighorn population has declined since the mid-1980's. Low lamb/100 ewes ratios may be due to increased mining near their preferred winter range (Simmons et al. 1987).

The Rosebud population apparently increased slowly from 1980 to 1987. Poor survey conditions resulted in the unusually low number of observed individuals, except for 1983 and 1986, when adequate counts were obtained.

East of Yellowstone

Bighorn sheep populations for the Clarks Fork, Trout Creek, Wapiti Ridge, and Yount's Peak herds have been increasing slightly from 1980 to 1987. No population model exists for the Clarks Fork herd, but numbers are believed stable at approximately 500.

Population numbers for the Trout Peak herd have been increasing slightly since 1981 and were believed to be near 497 animals in 1988 (Hurley et al. 1989). Lamb/100 ewes ratios have been fairly stable and averaged 38 lambs/100 ewes between 1983 and 1988.

Before 1987, the Wapiti Ridge population was believed to be stable at approximately 875 sheep. After correcting the model, the population was believed to be increasing and near 1,000 animals by 1988. Classification data were more complete for the Wapiti Ridge herd. Except for 1981 and 1988, lamb production was relatively constant and averaged 37 lambs/100 ewes. Low lamb survival in 1988 was attributed to the harsh winter (Hurley et al. 1989).

The Yount's Peak herd was believed stable at approximately 900 animals from 1981 to 1987 (Irwin et al. 1988). This herd declined 13% in 1988 from 1987, primarily because of low lamb survival, poor forage conditions on the winter range (Hurley et al. 1989), and possibly a severe winter. Before 1988, lamb/100 ewes ratios averaged 42 lambs/100 ewes.

South of Yellowstone

Postseason classification data showed that lamb/ewe ratios steadily declined from 1980 to 1984 and averaged 46 lambs/100 ewes in the Jackson bighorn herd. The ratio increased dramatically in 1985, dropped in 1986, and remained relatively constant at 44 lambs/100 ewes between 1986 and 1988. The reasons for these declining ratios may be related to competition with other ungulates (Straley et al. 1982; Moody et al. 1988) and adverse weather conditions such as those in spring 1982 (Straley et al. 1982). Ram/100 ewes ratios steadily declined between 1980 and 1986 but stabilized between 1986 and 1988. This decline may be due to a slightly increased ram harvest and low lamb production, particularly between 1982 and 1984. Population estimates for the Jackson bighorn herd declined between 1980 and 1982 and slowly increased to approximately 550 sheep in 1988.

Between 38 and 58 sheep were counted in the Targhee herd from 1980 to 1987. The most complete helicopter count in 1988 yielded 89 sheep. No population model was developed for this herd, but population estimates averaged 100 sheep from 1980 to 1987, and the population was estimated at 105 in 1988 (Lockman et al. 1989). Preseason hunter survey data suggest ram/ewe ratios declined from 88 in 1980 to 18 in 1984.

Harvests

North of Yellowstone

The unlimited license harvest from six Montana areas bordering the park averaged 16 bighorns/year between 1980 and 1986. Hunter success from unlimited license holders averaged 5% per year. Hunters who obtained a license through a drawing averaged nearly 4 bighorns/year, and success for these individuals was higher, averaging 87% per year.

East of Yellowstone

Bighorn sheep harvests east of the park have been relatively stable or have increased slightly. The unusually low harvest and hunter success for the Clarks Fork herd in 1988 was probably due to forest fires in that area. The average annual harvest of rams (1980–88) was relatively high compared to other areas surrounding Yellowstone. Average ages of rams killed ranged between 5 and 8 years (Hurley et al. 1989).

Average annual hunter success (1980–88) for the four herds was Wapiti Ridge, 79%; Trout Peak, 60%; Clarks Fork, 55%; and Yount's Peak, 53%. Hunter success on Wapiti Ridge is the highest of any area east of Yellowstone and may be related to its easy access. Since 1986, some of the high success rates are partially due to some bighorn sheep hunters holding complimentary licenses.

South of Yellowstone

The annual harvest for the Jackson bighorn sheep herd was relatively stable and averaged 15 legal rams between 1981 and 1988. Average hunter success (45%) was lower between 1986 and 1988 compared to 1981–85 (61%) and is probably related to an increase in available permits (Lockman et al. 1989).

The annual harvest for Targhee bighorn sheep was variable and ranged from zero to two rams. Harvest success has also been variable, despite a decrease from eight permits between 1980 and 1984 to four permits between 1985 and 1988 (Lockman et al. 1989).

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Ecological Issues on Reintroducing Wolves Into Yellowstone National Park

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