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BIOLOGICAL CONSEQUENCES OF RELOCATING GRIZZLY BEARS IN THE YELLOWSTONE ECOSYSTEM

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Abstract: Relocating grizzly bears (*Ursus arctos*) from human/bear conflict situations has been a standard management procedure. Using data from Yellowstone National Park, we present components of situations that may affect the outcome of a relocation. Survival rates of transported bears were lower ($l_x = 0.83$) ($P = 0.001$) than those not transported ($l_x = 0.89$). Survival was largely affected by whether the bear returned to the capture site ($P = 0.029$). Return rate was most affected by distance transported ($P = 0.012$) and age-sex group ($P = 0.014$). Return rates decreased at distances ≥ 75 km, and subadult females returned least ($P = 0.050$) often. Because of low survival and high return rates, transporting grizzly bears should be considered a final action to eliminate a conflict situation. However, transporting females must be considered a viable management technique because transports of some individuals have resulted in contributions to the population through successful reproduction.

Grizzly bears tenuously exist with humans in the lower 48 United States. Management agencies are mandated to protect threatened animals and their habitat. At times, situations arise that potentially endanger lives of humans and/or bears. Short-term solutions of these immediate crises include transporting the bear to a remote site while the problem creating the conflict is resolved. Transporting a bear is only a short-term management technique with a high return

rate due to the homing ability of bears (Judd and Knight 1980, Miller and Ballard 1982).

We discuss components of the transport situation that may affect its outcome. Several analyses of transport results in the Yellowstone ecosystem have been conducted using radio- and nonradio-marked bears (Cole 1974, Meagher and Phillips 1983, Brannon 1987, Meagher and Fowler 1989). Because results of transport involving nonradio-marked bears can only be determined if bears are recaptured, we evaluate transport results for radio-marked bears only.

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STUDY AREA AND METHODS

The 20,000-km² study area was centered on Yellowstone National Park and included portions of 5 national forests, Grand Teton National Park, and privately owned land. The area was largely in the subalpine zone and described by Blanchard and Knight (1991). We captured and fitted grizzly bears with radio collars from 1975 through 1993. Blanchard (1985) described capture and telemetry techniques. Handling methods followed approved guidelines (Am. Soc. Mammal. 1987). We determined sex from capture data and estimated ages by extracting, sectioning, and counting cementum annuli of rudimentary premolars and from known date of birth. We classified bears ≥5 years old as adults.

Management agencies transported bears from capture sites to locations 3–128 km away. We monitored subsequent movements from fixed-wing aircraft approximately once per week. We classified bears as returned if they returned to the capture site or their home ranges (determined from radio telemetry prior to transport). We estimated transport distances by straight-line measurements between capture and release sites. We identified seasons as spring (Mar–Jun), summer (Jul–Aug), and fall (Sep–Nov). We determined whitebark pine (*Pinus albicaulis*) cone production from permanent transects monitored since 1980 (Blanchard 1990). Seeds of whitebark pine were the most important late summer and fall food for Yellowstone grizzly bears (Mattson et al. 1991), and the majority of

management actions and human-caused mortalities occurred during years of low seed availability (Mattson et al. 1992). We estimated survival rates by following individual bears and annually determining survival according to age-specific rates described by Knight and Eberhardt (1985). We did not treat young accompanying their mothers independently except to estimate survival.

We analyzed the relationships between 2 variables in contingency tables with Fisher's exact test and, when noted, the Chi-square test for homogeneity for samples of $n \geq 75$. Variables used in analyses were age-sex group, conflict situation, distance moved (<75 km, ≥75 km), number of times transported, season, return rate, and survival. Conflict situations were concentrations of human activity, livestock depredations, hunting camps, and roadsides. We used log-linear models to assess interactions in tables of ≥3 dimensions (Sokal and Rohlf 1995). Main effect variables were those with individual contributions of $P \leq 0.05$ to the model. We tested for association between annual numbers of bears transported and availability of whitebark pine cones with Spearman's coefficient of rank correlation (r_s). We assessed different return rates (km/day) among age-sex groups with the Kruskall-Wallis 1-way analysis of variance (Chi-square approximation).

RESULTS

From 1975 to 1993, 81 individual grizzly bears were captured in management actions, fitted with radio transmitters, and transported 138 times. Sex of transported individuals did not differ in frequency from 169 individuals captured during research efforts during the same period (Fisher's exact, 1 df, $P = 0.684$) (Table 1). Age class of 38 transported females did not differ from the 74 females captured for research (Fisher's exact, 1 df, $P = 0.426$). However, age class of 43 transported males differed from 95 male research captures (Fisher's exact, 1 df, $P = 0.044$). Subadults accounted for 67% of male transports and 48% of male research captures.

Age-sex class of the initial 81 transports did not differ from that expected based on total population composition (Fisher's exact, 3 df, $P = 0.671$) as estimated by Knight et al. (1988) or from that recorded in the total 138 transports (Fisher's exact, 3 df, $P = 0.648$). Adult females were transported 38 times: 13 were with <1-year-old cubs, 9 were with yearlings, and 16

Table 1.   Frequency of initial captures of individual grizzly bears during management actions involving transport compared with captures for research purposes not involving transport, and frequency of cumulative captures involving transport by season (spring = Mar–Jun, summer = Jul–Aug, fall = Sep–Nov) in the Yellowstone ecosystem, 1975–93.

Age-sex group	Initial captures of individuals		Cumulative frequency of transports			
	Transports	Research	Spring	Summer	Fall	Total
Ad F with <1-yr-old cubs	5	11	1	4	8	13
Ad F with yearlings	4	9	2	2	5	9
Lone ad F	6	18	3	4	9	16
Subad F	23	36	3	15	15	33
Ad M	14	49	1	14	7	22
Subad M	29	46	8	18	19	45
Total	81	169	18	57	63	138

were alone. Nearly 90% of transports occurred during summer and fall (Table 1).

Of 81 conflict situations resulting in initial transport of a bear, 83% were associated with concentrations of human activity, including developments (32), private residences (23), refuse dumps (8), and campgrounds (4). Developments included towns and sites of human activity where tourists and/or administrative, support, and maintenance personnel lived in permanent structures. Remaining situations included livestock depredations (8), hunting camps (3), use of roadsides (2), and nontarget capture (1). Type of conflict situation did not vary by age-sex group, but did vary by season (log-linear model, $\chi^2 = 25.59$, 24 df, $P = 0.374$). Season was the main effect variable ($P = 0.035$). Conflicts were most frequent at developments during all 3 seasons, followed by refuse dumps and use of roadsides during spring and conflicts on private land during summer and fall.

Survival

Survival rates of transported bears were lower than those of bears not transported (Fisher's exact, 2 df, $P = 0.001$) (Table 2). Males and adult females had lower survival rates when transported, whereas subadult female survival was similar for transported and nontransported bears. Survival of transported bears was largely ex-

plained by whether the bear returned to the capture site, age-sex group, and type of conflict situation (log-linear model, $\chi^2 = 40.87$, 40 df, $P = 0.432$). Main effect variable was whether the bear returned to the capture site ($P = 0.029$). We monitored 42 bears ≥ 1 year after transport and knew the fates of 26. Only 1 survived of the 16 that returned to the capture site compared with 5 alive of the 10 that did not return (Fisher's exact, 2 df, $P = 0.018$). No males transported and monitored ≥ 1 year survived ($n = 11$), while 1 of 3 adult females and 5 of 12 subadult females survived. Four of 20 captured at developments, refuse dumps, and private residences survived, compared with 2 of 6 involved in livestock, hunting camp, roadside, and nontarget situations.

Return Rates

Return rate of transported bears was most affected by distance transported, age-sex group, number of times transported, and season (log-linear model, $\chi^2 = 38.88$, 37 df, $P = 0.385$). Distance moved and age-sex group were main effect variables ($P = 0.012$ and 0.014, respectively). Of 41 initial transports that returned to the capture site, 83% were moved <75 km, whereas >50% that did not return (20 of 37) were moved ≥ 75 km. Subadult females were most affected by distance transported with 79% of all transports returning from distances <50 km and only 13% returning from ≥ 75 km (Fisher's exact, 1 df, $P = 0.007$) (Fig. 1). Adult males were least affected by distance with 50% returning from distances >100 km (Fisher's exact, 1 df, $P = 0.162$). Frequency of return for adult females (Fisher's exact, 3 df, $P = 0.040$) and subadult males (Fisher's exact, 1 df, $P = 0.002$) was reduced at distances ≥ 75 km.

The longest transport distance was 128 km for a 2-year-old male who did not return to the

Table 2.   Survival rates (l_x) of transported and nontransported grizzly bears in the Yellowstone ecosystem, 1975–93.

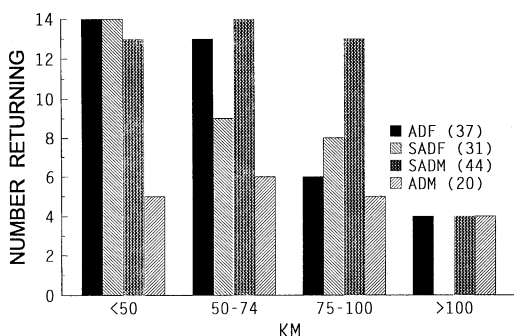| Age-sex group	Transported		Nontransported	
	l_x	n	l_x	n
Ad M	0.77	43	0.89	123
Subad M	0.71	48	0.87	99
Ad F	0.80	84	0.94	164
Subad F	0.89	61	0.87	68
Total	0.83	236	0.89	454

Fig. 1. Frequency of return to original capture site by transported grizzly bears by transport distance for adult females (ADF), subadult females (SADF), subadult males (SADM), and adult males (ADM) in the Yellowstone ecosystem, 1975–93. Sample sizes are given in parentheses.

capture area during the subsequent 56 months monitored. For individuals that returned to the capture site, females with <1-year-old cubs returned the fastest and subadults the slowest (χ^2 = 6.641, 5 df, P = 0.249) (Table 3).

Subadult females returned least often (28%) (Fisher's exact, 4 df, P = 0.05). Of the 18 subadult females relocated, 8 died and fates of 6 were unknown. Four, none of which were moved with their mothers or returned to the capture site, were known to be alive in 1993. One was moved when <1 year old with a sibling in 1977. She was recaptured in a research effort when 15 years old with ≥2 yearlings. One was moved as a yearling in 1986 and had ≥2 <1-year-old cubs. Two yearling siblings were moved independently in 1990 and were still alive as 4 year olds in 1993.

Of the 81 individuals transported, 50 were moved once, 15 twice, 9 3 times, 4 4 times, and 3 5 times. Bears transported 1 time returned 38% of the time (47), while 66% (15) of those moved twice returned, and 81% (16) moved ≥3 times returned.

Annual Variation and Productivity

Frequency of transports from 1980 to 1993 varied by year, averaging 9/year and ranging from 0 to 24 (Table 4). We did not include transports prior to 1980 in this dataset because bears captured in management actions were not routinely radiomarked until that year.

A negative correlation existed between annual number of bears transported and availability of whitebark pine cone production (P = 0.036, r_s = −0.563; Table 4). Two adult females were transported 4 and 3 times, but only during

years of low whitebark pine production. Both returned to the capture site. One produced ≥8 cubs during 12 years, 5 of which were females. None of the female young were captured in management actions after weaning. The other female produced ≥6 cubs in 4 years, 5 of which were females. Two of these 5 females were subsequently involved in management actions.

Females with young were transported together 18 times. The majority (16) stayed together, but ≤1-year-old cubs were abandoned twice as the female returned to the capture site. Twenty-one females produced 60 young during and after the year they were transported.

DISCUSSION

Largely because of high return rates and low survival, transport of a grizzly bear to eliminate a problem situation should be considered a final action with death of the bear the only remaining likely outcome. Reducing frequency of transports would involve elimination of food sources

Table 3. Average rate of return by age-sex group for individual grizzly bears returning to the capture site in the Yellowstone ecosystem, 1975–93. Rate = distance transported (km)/duration to return (days).

Age-sex group	n	Rate (km/day)	SE	Range
F with <1-yr-old cubs	8	4.95	4.35	0.08–11.33
F with yearlings	8	3.97	3.46	0.26–9.60
Lone ad F	12	4.27	3.82	0.07–14.00
Subad F	15	3.03	2.98	0.12–7.00
Subad M	17	1.81	2.23	0.11–6.38
Ad M	16	3.77	5.94	0.12–25.00

Table 4. Annual frequency of grizzly bear transports compared with the mean number of whitebark pine cones per tree in the Yellowstone ecosystem, 1975–93.

Year	$\bar{x}$ cones/tree	SE	Transports
1980	26	24	4
1981	13	23	24
1982	17	28	14
1983	17	17	10
1984	6	7	15
1985	27	32	2
1986	1	2	19
1987	3	5	8
1988	2	6	13
1989	49	57	2
1990	2	7	9
1991	16	20	4
1992	16	19	0
1993	10	17	6

attracting bears to the most frequent sites of conflict situations, developments and private residences. Even without food reward, bears will be attracted to these sites by food odor. Alternatives to transport could include aversive conditioning for specific individuals, although this technique is labor and cost intensive with low and unpredictable success rates (Gillin et al. 1992).

Transport situations in the Yellowstone ecosystem predominantly involve nutritionally stressed individuals, largely due to annual or seasonal native food shortages during seasons of hyperphagia. Few transport situations occurred during spring, likely because that is the season of lowest food ingestion (Mattson et al. 1991). Consideration should be given to situating the receiving site where native foods are abundant.

Subadult males are the most frequently transported age-sex group due not only to searching for food in poor food years, but also because their extensive movements after weaning bring them in contact with conflict situations more often (Blanchard and Knight 1991). Adult females with young, especially those with <1-year-old cubs, were most often involved in fall transports most likely a result of the nutritional demands of lactation. During years of limited whitebark pine seed availability, subadult males and females with <1-year-old cubs and yearlings avoid adult males by selecting less productive habitats (Blanchard and Knight 1991) that are most often near human facilities (Mattson et al. 1992), thereby increasing chances of conflict with humans.

Some researchers have indicated that transporting a lone adult female may have negative effects on her productivity the following year (Miller and Ballard 1982, Brannon 1987). This was not supported by this study, in which 6 individuals were transported 8 times as lone adult females. Although sample sizes were too small to test statistically, all but 1 produced cubs the next year. The majority of transports during this study occurred during summer and fall when conception would have already occurred, whereas all transports reported by Miller and Ballard (1982) in south-central Alaska occurred during May–June, which may have disrupted breeding activities and resulted in the observed lower production the following year (S. D. Miller, Dep. Fish and Game, Anchorage, Alas., pers. commun.). Brannon (1987) reported that only 3 of 10 lone adult females transported during

1968–84 produced cubs the year following transport in the Yellowstone area. We do not know why Brannon's results and ours differ, although his data included a majority of nonradio-marked animals.

Return rate of grizzly bears appears to be determined largely by distance transported and age-sex class of the individual. No distances <75 km should be considered because the return rate increases at these distances. Even at distances >100 km, adult males will return 50% of the time. Adult females will return 50% of the time when transported ≥75 km (88–120 km). Subadult return rates were reduced at distances ≥75 km with only 26% of females and 39% of males returning. Ideally, transports would be >100 km to further reduce return rates. Other researchers have documented the importance of relocating bears long distances to reduce return rate and have recommended distances >120 km in the Northern Continental Divide Ecosystem (Thier and Sizemore 1981) and >258 km in south-central Alaska (Miller and Ballard 1982).

Although success rates are low, transports of some individuals have resulted in contributions to the population through successful reproduction. When the difference between a positive and negative trend of a population depends on the survival of as few as 2 adult females/year (Knight and Eberhardt 1985), transport of females must be considered a viable management technique.

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EFFECTS OF CANINE PARVOVIRUS ON GRAY WOLVES IN MINNESOTA

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Abstract: Long-term effects of disease on wild animal population demography is not well documented. We studied a gray wolf (*Canis lupus*) population in a 2,060-km^2 area of Minnesota for 15 years to determine its response to canine parvovirus (CPV). The CPV had little effect ($P > 0.05$) on wolf population size while epizootic during 1979–83. However, after CPV became enzootic, percentage of pups captured during summer–fall 1984–93 and changes in subsequent winter wolf numbers were each inversely related to the serological prevalence of CPV in wolves captured during July–November ($r^2 = 0.39$ and 0.72, $P = 0.05$ and < 0.01, respectively). The CPV antibody prevalence in adult wolves increased to 87% in 1993 ($r^2 = 0.28$, $P = 0.05$). However, because population level remained stable, CPV-induced mortality appeared to compensate for other mortality factors such as starvation. We predict that the winter wolf population will decline when CPV prevalence in adults consistently exceeds 76%. The CPV may become important in limiting wolf populations.

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Wolf densities reflect the densities of their primary prey (Keith 1983, Fuller 1989, Dale et al. 1994), whereas changes in wolf populations tend to parallel changes in numbers of their

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vulnerable prey (Packard and Mech 1980, Peterson and Page 1988). During 1968–79, wolf population changes in our Minnesota study area generally followed changes in white-tailed deer (*Odocoileus virginianus*) numbers (Mech 1986, Nelson and Mech 1986). However, we documented serological evidence of CPV, a disease of domestic dogs and coyotes (*C. latrans*) (Tho-