ESTIMATING GRIZZLY BEAR DENSITY IN RELATION TO DEVELOPMENT AND EXPLOITATION IN NORTHWEST ALASKA

WARREN B. BALLARD, Alaska Department of Fish and Game, P.O. Box 1148, Nome, AK 99762
KATHRYN E. RONEY, National Park Service, Northwest Alaska Areas, P.O. Box 1029, Kotzebue, AK 99752
LEE ANNE AYRES, National Park Service, Northwest Alaska Areas, P.O. Box 1029, Kotzebue, AK 99752
DOUGLAS N. LARSEN, Alaska Department of Fish and Game, P.O. Box 689, Kotzebue, AK 99752

Abstract: Grizzly bear (*Ursus arctos*) densities within a 1,862 km^2 study area surrounding a lead/zinc mine in northwest Alaska were estimated using mark-recapture methods during late May and early June 1987. Radio collars were used to mark bears and assess population closure. Density estimates were 1 bear/66 km^2 for adults (>3-years-old) and 1 bear/51 km^2 for bears of all ages. Some of the biases and problems associated with the mark-recapture method were discussed. Density estimates were used to estimate population size within and near the bear study area, and this estimate was compared with reported and suspected annual harvests. Estimated annual harvest rates in recent years ranged from 8 to 16%. Current bear density and population estimates will be compared with estimates obtained after the mine is developed to assess impacts on the bear population.

Int. Conf. Bear Res. and Manage. 8:405–413

Conservation of brown/grizzly bears (*Ursus arctos*) in Alaska depends on the availability and use of assessment methods that allow game managers to monitor status of populations regularly. Historically, managers have relied on crude analyses of harvest data and miscellaneous observations to assess bear population trends and effects of harvest. However, the basis for use of harvest statistics for monitoring population status is not well documented and appears imprecise and unreliable (Harris 1984; Harris and Metzgar 1987*a*,*b*). In areas where unreported harvests are potentially large, reported harvests may not be representative of harvest mortality, and consequently, problems associated with use of harvest data for assessing population trends may be insurmountable. Fortunately, bear populations appear healthy and abundant in many areas of Alaska. If viable populations are to be maintained, appropriate methods must be developed so that managers can accurately identify and remedy population declines.

Increasing human populations have significantly reduced the abundance and distribution of grizzly bears in North America (Cowan 1972). Although current abundance and distribution of bears in Alaska is similar to historical levels, alteration of important habitats could significantly alter productivity and survival of affected bear populations. Current understanding of grizzly bear population dynamics in relation to human developments is inadequate for providing effective guidelines for minimizing and mitigating impacts to bear populations. This inadequacy exists because such impacts are often long term, research is usually of short duration, and many impacts are relatively recent (Peek et al. 1987).

This study was conceived in response to variations in estimates of bear abundance, and concern about potential adverse impacts from development and operation of the Red Dog Mine in northwest Alaska. This study sought to evaluate effects of human harvests by comparing bear density with known reported harvests, and to provide baseline data on bear density, structure, movements and reproductive parameters before large scale mine development. Significant changes in bear density due to the Red Dog mine will be assessed later by repeating the study using identical study methods. Background for this study was provided by Ballard (1987) and Ballard et al. (1988). This report presents and discusses use of mark-recapture methods for estimating pre-mining bear densities and estimating current minimum harvest rates.

The following individuals deserve recognition for their assistance during this study: L. Adams, J. Coady, A. Eliason, D. James, V. Karmun, R. Kemp, A. Lovaas, S. Machida, M. McNay, R. Nelson, S. Patten, D. Reed, J. Rood, F. Sandegren, J. Schoen, M. Shaver, R. Sheldon, and P. Walters. C. Hepler prepared figures and maps. S. Miller provided valuable advice in use of mark-recapture methods. Constructive criticism of this manuscript was provided by A. Cunning, S. Machida, S. Miller, J. Schoen, and 3 anonymous reviewers. The study was funded by the National Park Service, the Alaska Department of Fish and Game (ADF&G), and several Federal Aid in Wildlife Restoration Projects.

STUDY AREA

Dynamics, movements, and habitat use of grizzly bears were studied during 1986 through 1988 within a 6,700 km^2 area (Noatak River Study Area [NRSA]) (Fig. 1). The NRSA was located within Game Management Unit (GMU) 23, an area of approximately 111,370 km^2, herein referred to as northwest Alaska.

The Red Dog Mine project will consist of an open pit lead/zinc mine located on Red Dog Creek 131 km north

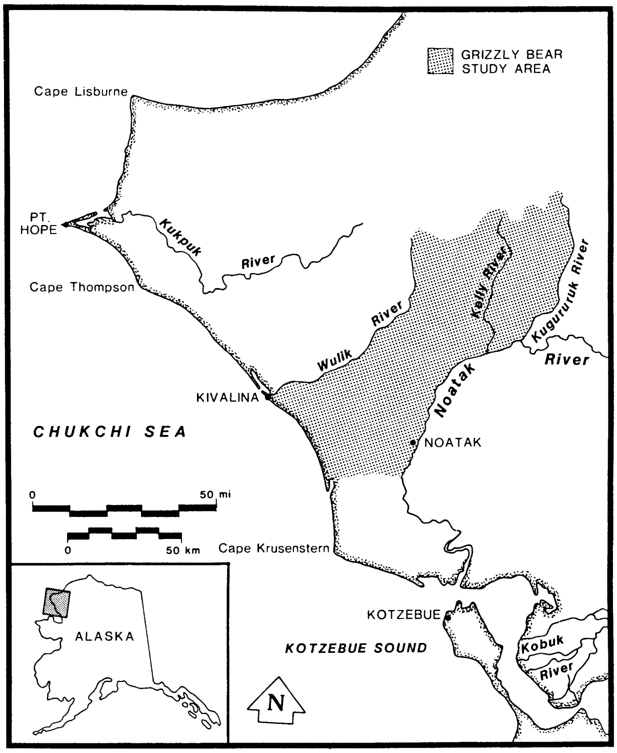

Fig. 1. Boundaries of the Noatak River Study Area in northwest Alaska where grizzly bears were studied from 1986 through 1988.

of Kotzebue, Alaska (Fig. 2). In addition to the mine, the project will include tailing ponds, a mill, power plant, worker housing, a saltwater port, water reservoir, over 90 km of gravel road, and several gravel borrow sites (U.S. Environmental Protection Agency and U.S. Dep. of Interior 1984). The facilities will occupy at least 35 km^2. The project is expected to last 40 years and longer if 18,000 other mining claims are developed. The site will be occupied by 225-250 employees. A transportation corridor from the mine site to the coast may accommodate a railroad in future years. Improved access will result in increased human use and additional mining exploration and development.

The NRSA boundaries were selected to encompass an area receiving a moderate amount of bear harvest pressure. Because this area was too large for an intensive mark-recapture program (herein referred to as a census), a smaller area was selected based upon movements of radio-collared bears in 1986 and location of the mine and roads (Fig. 2). This smaller area is referred to as the mine census area (MCA).

The MCA was divided into 10 sample units (SUs) ranging in size from 161-202 km^2 and totalling 1,862 km^2 (Fig. 2). Natural landmarks such as streams and ridges were used as boundaries between SUs.

The MCA was characterized by steep, mountainous terrain traversed by several major rivers and creeks. Vegetation types ranged from riparian stands of willow (*Salix* spp.), birch (*Betula nana* and *B. glandulosa*), and cottonwood (*Populus balsamifera*) along the streams and rivers, grading into closed tall shrub, low shrub, open low shrub, tundra, and then bare rock and ice at higher elevations. Relatively thick stands of white spruce (*Picea glauca*) occurred within the southern half of SUs 3, 4, 8, and 10. Elevations ranged from 60 m along the southern boundary to 1,190 m along the northern boundary. Less than 5% of the MCA contained areas >915 m elevation. All of the MCA contained usable bear habitat and was used in calculations of density estimates.

The NRSA is characterized by a polar maritime climate along the coast and a continental type climate inland. Summer temperatures range from 2 to 32 C and winter temperatures range as low as -26 to -47 C. Annual precipitation averages from 25 cm along the coast, to 51-76 cm in the mountains, with half occurring during July through September. Snow cover usually occurs from mid-October to mid-May. Caribou (*Rangifer tarandus*), moose (*Alces alces*), and Dall sheep (*Ovis dalli*) occur within the study area and serve as carrion or prey for grizzly bears. Arctic char (*Salvelinus alpinus*), grayling (*Thymallus arcticus*), and chum salmon (*Oncorhynchus keta*) all occur within the major rivers and their drainages, and are an important source of bear food. Salmon migration usually occurs from July through September each year.

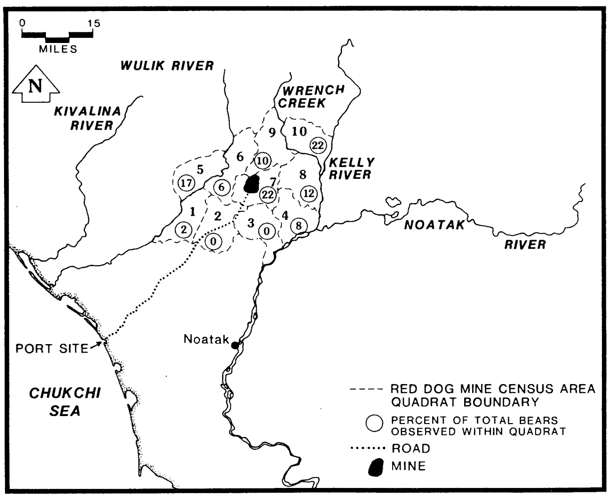

Fig. 2. Boundaries of sample units used to census grizzly bears in relation to the Red Dog Mine in northwest Alaska from 29 May through 4 June 1987.

METHODS

Bears were captured for marking using standard helicopter immobilization procedures (Spraker et al. 1981, Ballard et al. 1982, Reynolds and Hechtel 1985, Miller et al. 1987). Bears were immobilized with a mixture of tiletamine hydrochloride and zolazepam hydrochloride (Zoletil 100, Wildlife Laboratories, P.O. Box 8938, Fort Collins, Colo. 80525), which was delivered from either a projectile dart or by hand injection (Taylor et al. 1989). Each captured bear was sexed, weighed, measured, and individually marked with 1-3 lip tattoos, ear-tagged, and radio-collared if judged to be ≥5-years-old. Three subadult (3.5-4.5-year-olds) bears were radio-collared during the census with collars designed to fall off within 1 year. Premolars were extracted from each immobilized bear >1.0-year-old. Extracted teeth were aged using methods described by Goodwin and Ballard (1985).

Methods used for calculating mark-recapture density estimates were identical to those described by Miller et al. (1987). This involved use of mark-recapture methods with radio telemetry to correct for population closure. Fixed-wing aircraft were used to search (without aid of telemetry) individual SUs thoroughly until a bear or group of bears was spotted. Once sighted, radio telemetry was used to determine whether the animal(s) was marked, i.e., radio-collared. Sightings of bears with functioning radio collars were considered recaptures of marked individuals except for total population estimates, young accompanied by their mothers were considered to have the same status as their marked or unmarked mothers. Adult bears that did not possess functioning radio collars were considered unmarked. If unmarked, the animal was marked and available as a recapture in subsequent searches. All observed unmarked adults were captured, with the exception of 1 adult female accompanied by 1 yearling. The census occurred during the breeding season, and consequently adults were sometimes observed together. These sightings were treated as independent observations. Because sexual maturity varies in each population we also provided estimates of adult bears >2- and >3-years-old, respectively, so that density estimates from other studies can be compared. Equations for calculating population size, density, and associated confidence intervals were provided by Miller et al. (1987). The bear-days estimator was used rather than standard Lincoln-Petersen estimates.

Twenty people participated in the census from 29 May through 4 June 1987. Six fixed-wing aircraft and 1 helicopter (Bell Jet Ranger 206B) were used during the census. Fixed-wing aircraft included: 3 PA-18's, 1 PA-12, 1 Arctic Tern, and 1 Cessna 185. The Cessna was used each day for radio-tracking to determine degree of population closure (number and identification of individual radio-collared bears that were either in or out of individual SUs). For 2 days it was also used for surveying. Both times, population closure was assessed after assigned SUs were searched. During other days, radio-tracking occurred simultaneously with surveys. Tracking aircraft also maintained visual contact when survey aircraft spotted unmarked bears that needed to be captured and radio-collared. The remaining fixed-wing aircraft were used exclusively for surveys.

Survey aircraft pilot-observer teams and assigned SUs were rotated daily. Pilot-observer teams were directed not to discuss the location of sighted bears during or after the census so that search efforts would not be biased in succeeding days.

RESULTS AND DISCUSSION

Population Estimates and Density

During 29 May through 4 June 1987, 6 fixed-wing aircraft flew 198 hours searching for grizzly bears within the MCA. Search effort averaged 0.9 min/km²/day. Search effort per SU varied from 0.8 min/km²/day for a SU characterized by relatively flat terrain and low elevational relief where sightability should have been optimum (SU 2), to 1.1 min/km²/day for a rugged, mountainous area in the north (SU 9) where observability was difficult. In retrospect, a larger area could have been surveyed by reducing search effort or having tracking aircraft participate earlier in the survey. Average search effort per airplane was 5.6 hours/day, not including commute time or assisting during immobilization. Search efforts were not longer because of fatigue. Consensus among surveyors indicated this was the maximum effort that should be attempted with 6 aircraft.

Twelve radio-collared grizzlies (8 females and 4 males), which had been captured and radio-collared in 1986, were available as marks during the census in 1987. Home ranges of the 12 bears overlapped the MCA, and 7 bears denned within its boundaries. Three males and 6 females marked in 1986 were resighted at least once during survey days 2 through 7. No marked bears were observed during the first day of the census.

Five adults originally captured in 1986 were recaptured to replace radio collars before or during the census, and 7 adults were radio-collared outside but near the periphery of the census area in an effort to increase potential marks. An additional 6 adult males and 12 adult females previously unmarked were captured and radio-collared within the MCA as part of the survey effort. Of the 12 adult females, 8 were unaccompanied by young, 1 was accompanied by 3 cubs-of-the-year (COY), 2 were accompanied by 3 yearlings, and 1 was accompanied by 3 2.5-year-olds. Yearlings and COY composed 31% of the population in 1987 (Table 1). Ratio of adult (>5-years-old) males to females was 61/100.

One of the key assumptions in mark-recapture estimates is that all individuals have an equal chance of being captured (Otis et al. 1978, White et al. 1982). This assumption may have been violated in this study. Several studies have suspected differences in sightability between sows with COY and other age-sex classifications (Spraker et al. 1981, Miller and Ballard 1982, Ballard et al. 1982, Miller et al. 1987). Although we did not statistically test differences in sightability (number of times seen divided by number of times within the area) among sex and age classes because of small sample sizes, there appeared to be a sightability bias against sows with COY. Two radio-collared sows with COY were within the census area on 11 of 14 possible bear days but were only observed twice (Table 2), thus providing support for the hypothesis of low sightability for sows with COY. Sightability among other groups was similar ranging from 29% for females accompanied by young (>1-year-old) to 34% for single females. Sightability of all bears was 31%. Males that had been captured and radio-collared before the census had an average sightability of 29% whereas those captured during the census had an average sightability of 38%. Single females captured before the census had an average sightability of 40% whereas those captured during the census averaged 24%.

A preliminary analysis of sightability in several Alaskan study areas indicated that there were no significant differences ($P > 0.05$) in capture sightability of marked bears by family and age class, or area (Becker 1988). There were no differences in capture homogeneity by day or area for this study ($P = 0.316$) or among 4 Alaskan study areas ($P = 0.449$) where mark-recapture estimates have been made (southcentral Alaska - Miller et al. 1987, Miller 1990; northwest Alaska - this study; Admiralty Island - Schoen and Beier 1987; and Karluk Lake on Kodiak Island - Barnes et al. 1988). These results suggest that bear sightability among areas and sex-age classes may not be as variable as previously suspected by Miller and Ballard (1982) and Miller et al. (1987).

Two types of population estimates were developed from this study: (1) numbers of adult bears >3-years-old and (2) total numbers of bears including COY and other offspring. The former estimate was the most statistically valid because it violated fewer assumptions. The adult (>3-year-olds) population estimate was 28 bears and the total population estimate was 37. The 80% confidence interval (CI) of the adult estimate was 25-35 (95% CI = 23-38), while the 80% CI of the total estimate was 33-43 (95% CI = 31-46). Density estimates were 1/66 km^2 for adults (80% CI = 53-74) and 1/51 km^2 (80% CI = 44-57) for total bears. The adult (>3-years-old) estimate was close to the total number of individual radio-collared adult and subadult bears (29) that were known to have been present on 1 or more occasions within the MCA during the 7-day search effort. The total estimate (37) using mark-recapture methods was slightly lower than the number of radio-collared and uncollared adults (40) and young that were known to be within the area on ≥1 days during the survey. If we correctly aged 3 2.5-year-olds based on body size, that accompanied 1 adult sow, the estimated numbers of adult bears (>2.0-years-old) was 32 with an 80 and 95% CI of 29-40 and 27-44, respectively.

Similar to other bear population estimates (Miller et al. 1987, Reynolds et al. 1987, Schoen and Beier 1987, Barnes et al. 1988, Smith and Van Daele 1988), CIs con-

Table 1. Sex and age structure of grizzly bears in and adjacent to the Red Dog Mine census area in northwest Alaska during 29 May through 4 June 1987.

Age	Males	Females	Unknown	Total	%
0.5	2	5	2	9	12.7
1.5		2	11	13	18.3
2.5		1	2	3	4.2
3.5 - 4.5	3	6		9	12.7
5.5 - 10.5	11	16		27	38.0
>11.0	3	7		10	14.1
Totals	19	37	15	71	100.0

Table 2. Sightability of radio-collared grizzly bears by age, sex and family class during a census of the Red Dog Mine study area in northwest Alaska from 29 May through 4 June 1987.

Sex and family class	Age (yrs)	No. bears	No. days in area	No. days observed	% sightability
Single females	<5	5	12	3	25.0
	≥5	9	3	13	37.1
Subtotal		14	47	16	34.0
Females w/COY	≥5	2	11	2	18.2
Females w/young >1-yr-old	≥5	3	14	4	28.6
All females		19	72	22	30.6
Males	<5	3	9	2	22.2
	≥5	7	28	10	35.7
All males		10	37	12	32.4
Total bears		29	109	34	31.2

verged as survey effort progressed. Population estimates and associated CIs leveled off by day 6 (Fig. 3).

Because grizzly bear populations have been extirpated or are threatened with extinction in many areas of the United States, and Alaska contains about 65% of the continental population (Peek et al. 1987), particular care should be taken to reduce and minimize development impacts on grizzly bear populations. Historically, declining trends in grizzly bear populations have been difficult to detect because of our inability to monitor population status accurately and in a timely and cost-effective manner. Typically, by the time a change in status of a bear population has been identified, needed remedial actions are severe and often ineffective. For these reasons, we recommend that the 80% CI be used to evaluate impacts of developments on grizzly bear populations. This would partially prevent making a Type II error of falsely concluding that there has been no change in the population (Snedecor and Cochran 1973) as a result of development. The risk of this approach is that management actions may be taken when, in fact, no change has actually occurred. However, if errors are made in the other direction, a valuable and formerly renewable resource may be sacrificed.

A large portion of the expense of conducting a mark-recapture study on grizzly bears has been associated with marking new individuals during the census. We compared the adult and total bear population estimates and respective CIs for this study if no new individuals had been radio-collared. The resulting population estimate of adults would have been only 2% less than the estimate obtained by marking new individuals. However, the resulting CI would have been much wider if no new bears had been marked (95% CI = -29 to +64% of estimate in comparison to -17 to +39% of estimate obtained by additional marking). In contrast, the total population estimate had no new bears been captured and marked would have been 30% larger than the estimate obtained by using new marks. Similar to the adult estimate, the CI on the total estimate would have been much wider had no new bears been captured and marked (-31 to +67% of estimate in comparison to -16 to +26% of the estimate obtained during this study). We concluded that the primary benefit of capturing and marking new bears was a reduction in the width of the CIs, and perhaps, a more accurate total estimate. However, because the total population estimate violates independence of capture assumptions (i.e., treating young as same status as adults - marked or unmarked), the latter conclusion should be viewed with caution. Similar results were reported by Miller et al. (1987).

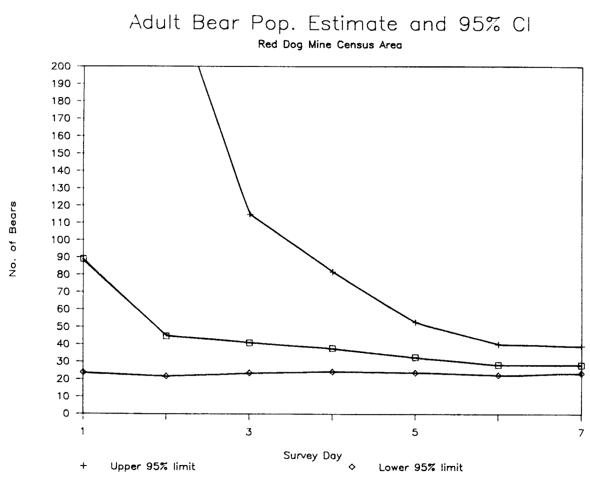

Fig. 3. Daily adult (>3-years-old) grizzly bear population estimates and associated 95% confidence intervals derived from using bear-days estimator during a census in northwest Alaska during 29 May through 4 June 1987.

Total operational cost (excluding salaries) of the Noatak bear survey was $64,713 (U.S.). Nearly half the expense involved capturing and radio-collaring 25 adult bears. If we had not been interested in permanently marking bears, costs could have been reduced several thousand dollars by exclusively using break-away collars or some other temporary method of attachment. Expenses for the density estimation procedure could have been higher without the benefit of a contract for helicopter costs and use of government-owned or leased aircraft. With commercial aircraft at commercial rates, expenses for the census could have been as high as $108,000.

Otis et al. (1978) and White et al. (1982) list 4 assumptions that must be met for capture-recapture population estimation methods to be valid: (1) the population is closed, (2) animals do not lose their marks during the experiment, (3) all marks are correctly noted and recorded at each trapping occasion, and (4) each animal has a constant and equal probability of capture on each trapping occasion. This also implies that capture and marking do not affect the catchability of the animal.

In this study these assumptions were either met or were sufficiently reduced to allow confident use of mark-recapture methods for estimating grizzly bear population size in a relatively small area. Use of radio collars to monitor which bears (bear-days estimate) were present or absent in the MCA eliminated or substantially reduced violations of population closure. Assumption 2 was met even when an animal lost its mark because loss of radio collars could be detected daily. For example, during this study 1 bear shed its collar on the 6th day of the census. This loss of mark was identified on the day of occurrence and the bear was subsequently treated as an unmarked individual. We believe assumption 3 was met in all cases.

The largest potential problem of use of mark-recapture in this study was potential violation of assumption 4, which has hampered all mark-recapture studies (Otis et al. 1978). If Becker's (1988) preliminary analyses that there were no significant differences in capture sightability among areas or sex-age classes are valid and accurate, and if substantiated by future replications, they have significant ramifications for the use of mark-recapture methods for estimating bear numbers. Perhaps the statement by White et al. (1982) that equal catchability is an unattainable ideal in natural populations may require modification for grizzly bears in certain areas under specific sets of conditions.

One additional assumption not mentioned above was that all observations are independent. Because this assumption is violated when unmarked young are given the same status as their mothers (marked or unmarked), the total population estimate, which includes bears of all ages, must be used with caution. Similar problems could also occur during the mating season when a second adult is sighted because of the first observation. A problem with including these sightings and/or age classes in the estimate is that it will inflate the sample size and cause the variance of the estimate to be biased towards the low side, although point estimates should be similar (E. Becker, Alas. Dep. Fish and Game, pers. commun.).

Use of mark-recapture procedures in this study was successful partially because >50% of the population was marked and bear densities were relatively high. At lower bear densities, the method has a number of biases and sample size problems that may be overcome with further refinement (Reynolds et al. 1987, Miller 1990).

Recently, Eberhardt (1989) evaluated the mark-recapture procedure used in this study and concluded that use of the mean of the daily Petersen estimates may be preferable to the "bear-days" estimator. If correct, the bear population estimates calculated in this study could actually be larger. For example, using Eberhardt's approach, the adult (>3-years-old) population estimate would have been 35 with a 80% CI of 22 to 48 (95% CI = 13-57) while the total estimate would have increased to 49 ± 20 (80% CI).

Density Comparisons

Our reported total density estimate lies within the range of published density estimates for arctic study areas in North America (Table 3). Reynolds (1982) reported that for North Slope Alaskan populations, high bear densities in optimum habitat approached 1 bear/50 km^2

Table 3. Comparison of reported grizzly bear densities in arctic areas of North America.

Area	Density (km^2/bear)	Source
Northern Yukon	33-39	Nagy et al. 1983*a*
Northern Yukon	48	Pearson 1976
Western Brooks Range, AK	42-44	Reynolds 1984
NW Alaska	51(44-57)[a]	This study
Eastern Brooks Range, AK	83-304	Quimby 1974 Quimby and Snarski 1974 Curatolo and Moore 1975 Reynolds 1976
Northwest Territories	211-262	Nagy et al. 1983*b*

[a] 80% confidence interval.

and low density in lower quality habitats was about 1 bear/207 km^2. Most grizzly bear density estimates are based on the additive total numbers of bears observed over several years of study and, consequently, contain no measure of precision and no objective estimate of area occupied by the estimated population. A high proportion of our census area was composed of denning habitat and may not be representative of average bear densities in northwest Alaska. Ninety percent of the marked and unmarked bears observed during the survey period were located in the mountainous portions of the study area (Fig. 2: SUs 5-10). Only 10% of the bears observed during the surveys were found in the lower elevation, southern SUs (1-4), and 80% of those observations were within SU 4. Typically, bears move out of the mountainous terrain and inhabit lower lying areas as spring and summer progress (Ballard et al. 1988). A similar distribution of bears was evident during 1986 when we captured bears for studies of movement and demography.

During spring 1986, we captured 48 bears, 31 of which were subsequently radio-collared, in part to aid in defining a census area boundary for 1987 and to minimize potential capture biases for sows with COY. During that capture effort, we attempted to search all portions of the NRSA equally. Thirty-one bears were captured in the mountainous portions of the NRSA and 17, or 45% fewer, were captured in the southern half. We conclude that our reported bear density estimates are probably representative of high quality denning habitat in an arctic ecosystem.

Assessment of Harvest Impacts

One objective of this study was to resolve conflicting views over the status of grizzly bears in northwest Alaska.

Some local residents have expressed concerns about losses of property and potential threats to human life (Larsen 1988). Some residents also believe bears are currently numerous and more abundant than observed historically (Loon and Georgette 1989). Many believe there are too many bears and would prefer a smaller population (Loon and Georgette 1989). Because of these concerns and because grizzly bears are classified as a subsistence use species (defined by Federal Law as customary and traditional uses by rural Alaska residents for direct personal or family consumption as food, shelter, fuel, clothing, tools, or transportation and for the making and selling of handicraft articles for barter, customary trade, and sharing) in northwest Alaska, some local residents have advocated liberalizing grizzly bear hunting seasons and bag limits.

Alaskan hunting regulations currently require that hide and skull of all grizzly bears harvested be presented to officials of ADF&G within 30 days of the date of kill for sealing. Sealing of bear hides and skulls is required but compliance in some areas, especially northwest Alaska, has been low. Annual reported harvests of grizzly bears in northwest Alaska have gradually increased over the years (Fig. 4) ranging from 8 in 1962 to a high of 57 in 1979. Since 1979, annual reported harvests have ranged between 22-48. Annual reported harvests within the bear study area have fluctuated similarly to those of northwest Alaska but an increasing proportion of the total area harvest has come from NRSA (Fig. 5).

Use of grizzly bears for food is reportedly widespread in portions of northwest Alaska (Loon and Georgette 1989). Based on key respondent interviews in selected villages, Loon and Georgette (1989) estimated that only 14-18% of actual harvests of grizzly bears are reported to ADF&G. Most of the reported harvests were by nonlocal Alaska residents and nonresidents (Larsen 1988). Compliance with sealing regulations by guides and nonlocal residents is thought to be high. Although Loon and Georgette's (1989) estimates contain no measure of accuracy or precision, if assumed correct, then actual annual harvests could be from 103-142% larger than reported. Use of harvest statistics for assessing population status is at best marginal even when the sex and age structure of a high proportion of the kill is known (Harris 1984; Harris and Metzgar 1987*a,b*). The use of such data when ≥50% of the harvest is unreported would be even less reliable. Because of these problems, other methods were used to evaluate the status of the population and the potential for allowing higher harvests.

To assess the potential impacts of human harvests on this bear population, the bear density estimate from MCA was extrapolated to a much larger area, and compared with known minimum harvests. We estimated the total bear population within the NRSA and adjacent areas that encompassed nearly all of the home ranges of radio-collared bears from this study. Based upon the distribution of bears within the study area in 1986 and 1987, we assumed bear densities in the mountainous portions of the NRSA were similar to those in the census area (1/51 km^2). For the lower lying southern areas, we assumed densities were 50% lower or about 1/101 km^2. The latter assumption was based upon the distribution of bear sightings and captures in 1986 and 1987. These densities were then extrapolated to the study area based on our stratification into 1 of 2 density strata. We classified 5,947 km^2 as high density habitat and 6,932 km^2 as low density habitat. The

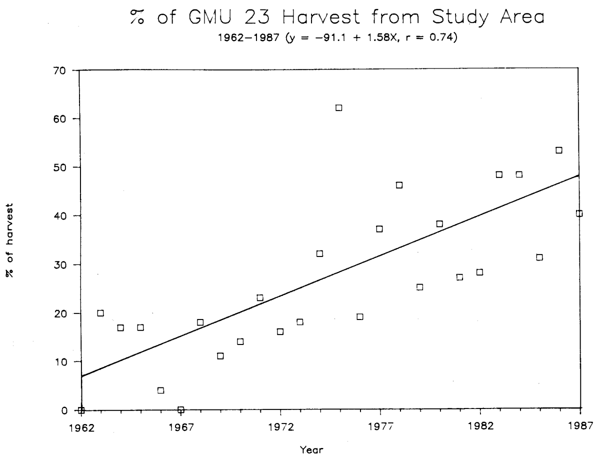

Fig. 5. Proportion of reported GMU 23 grizzly bear harvests occurring within the Noatak River Study Area in northwest Alaska from 1962 through 1987.

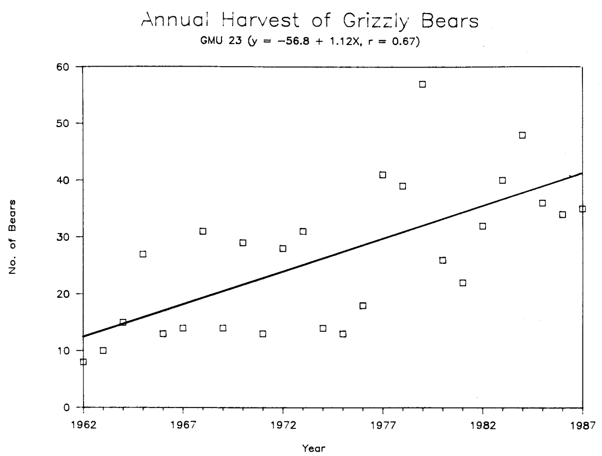

Fig. 4. Reported annual harvest of grizzly bears within GMU 23 of northwest Alaska from 1962 through 1987.

extrapolated bear population for the 12,879 km^2 area was 188 bears in 1987.

Minimum reported annual harvests within the NRSA from 1959 through 1987 have ranged from 0 to 23. From 1983 through 1987, reported harvests have ranged from 11 to 23. If estimated unreported harvests from communities within or adjacent to the NRSA (100% of Noatak, 100% of Kivalina, and 25% of Kotzebue kills [Loon and Georgette 1989]) were added to known reported harvests, then the estimated annual harvest rates during 1983 through 1987 would increase to 8-16%. These rates may also be low because some bears were known to have been killed and not retrieved or reported (unpubl. data) in Loon and Georgette's (1989) sample. If we had used Eberhardt's (1989) approach for estimating density, our total bear population estimate would have been 248 and harvest rates would have ranged from 6 to 12%.

Although our harvest rate estimates are admittedly crude, comparison with harvest rates reported from elsewhere in North America (LeFranc et al. 1987) suggests that current harvests approach or exceed the maximum allowable harvest. All of our estimates are in excess of the conservative exploitation rates of 2-4% recommended for northerly latitudes by Reynolds (1976), and Sidorowicz and Gilbert (1981). Even if our estimates are only a rough approximation of actual harvest rates, they suggest that hunting seasons and bag limits cannot be liberalized without causing a reduction in the bear population.

SUMMARY

Despite real and potential problems and biases associated with the use of the mark-recapture method described by Miller et al. (1987) for estimating bear density, the method allows managers to estimate population size and density quickly and objectively within relatively small areas. More importantly, the resulting estimates are repeatable and include a measure of precision. Other methods to date have relied largely on the experience and expertise of the investigator, have been expensive, time consuming, and usually contain no measure of precision. By applying density estimates obtained from mark-recapture procedures, current annual harvest rates in relation to human exploitation could be assessed.

LITERATURE CITED

BALLARD, W.B. 1987. Demography of Noatak grizzly bears in relation to human exploitation and mining development. Alas. Dep. Fish and Game, Fed. Aid in Wildl. Restoration Prog. Rep. Proj. W-22-5 and W-22-6. Juneau. 45pp.

_____, S.D. MILLER, AND T.H. SPRAKER. 1982. Home range, daily movements, and reproductive biology of brown bear in southcentral Alaska. Can. Field-Nat. 96(1):1-5.

_____, K.E. Roney, D.N. Larsen, and L.A. Ayres. 1988. Demography of Noatak grizzly bears in relation to human exploitation and mining development. Alas. Dep. Fish and Game, Fed. Aid in Wildl. Restoration Prog. Rep., Proj. W-22-5 and W-22-6, Job 4.20. Juneau. 100pp.

BARNES, V.G., JR., R.B. SMITH, AND L.J. VAN DAELE. 1988. Density estimates and estimated population of brown bears on Kodiak and adjacent islands, 1987. Kodiak brown bear research and habitat maintenance trust, 15 April 1988. 34pp. (mimeo).

BECKER, E. 1988. Appendix C. *In* S.D. Miller. 1989. Impacts of increased hunting pressure on the density, structure, and dynamics of brown bear populations in Alaska's Game Management Unit 13. Alas. Dep. Fish and Game, Fed. Aid in Wildl. Restoration. Final Rep., W-22-6, Job 4.21. 67pp.

COWAN, I.M. 1972. The status and conservation of bears (Ursidae) of the world - 1970. Int. Conf. Bear Res. and Manage. 2:343-367.

CURATOLO, J.A., AND G.D. MOORE. 1975. Home range and population dynamics of grizzly bear in the eastern Brooks range, Alaska. Chapter 1. *In* R.D. Jakimchuk, ed. Studies of large mammals along the proposed Mackenzie Valley Gas Pipeline Route from Alaska to British Columbia. Arctic Gas Biol. Rep. Ser. Vol. 32.

EBERHARDT, L.L. 1989. Using radiotelemetry for mark-recapture studies with edge effects. J. Appl. Ecol. 27:In press.

ENVIRONMENTAL PROTECTION AGENCY AND U.S. DEP. OF INTERIOR. 1984. Impact statement - Red Dog Mine Project. U.S. Environ. Protection Agency. Seattle, Wash. 290pp.

GOODWIN, E.A., AND W.B. BALLARD. 1985. Use of tooth cementum for age determination of gray wolves. J. Wildl. Manage. 49:313-316.

HARRIS, R.B. 1984. Harvest age-structure as an indicator of grizzly bear population status. M.S. Thesis, Univ. of Mont., Missoula. 204pp.

_____, AND L.H. METZGAR. 1987*a*. Harvest age structures as indicators of decline in small populations of grizzly bears. Int. Conf. Bear Res. and Manage. 7:109-116.

_____, AND _____. 1987*b*. Estimating harvest rates of bears from sex ratio changes. J. Wildl. Manage. 51(4):802-811.

LARSEN, D.N. 1988. Brown/grizzly survey and inventory progress report, FY 1988. Pages 65-70 *in* S.O. Morgan, ed.. Annual report of survey-inventory activities, Vol. XVIX, Part V. Brown/Grizzly Bear. Alas. Dep. Fish and Game, Fed. Aid in Wildl. Restoration Prog. Rep., Proj. W-22-5 and W-22-6, Job 4.0.

LEFRANC, M.N., JR., M.B. MOSS, K.A. PATNODE, AND W.C. SNUG, III, EDS. 1987. Grizzly bear compendium. The Natl. Wildl. Fed. Washington, D.C. 540pp.

LOON, H.B., AND S.E. GEORGETTE. 1989. Contemporary brown bear use in northwest Alaska. Alas. Dep. Fish and Game, ANILCA Fed. Aid Funds. Tech. Pap. 163. Div. of Subsistence, Kotzebue. 48pp.

MILLER, S.D. 1990. Detection of differences in brown bear density and population composition caused by hunting. Int. Conf. Bear Res. and Manage. 8:393-404.

_____, AND W.B. BALLARD. 1982. Density and biomass estimates for an interior Alaskan brown bear population. Can. Field-Nat. 96(4):448-454.

_____, E.F. BECKER, AND W.B. BALLARD. 1987. Black and brown bear density estimates using modified capture-recapture techniques in Alaska. Int. Conf. Bear Res. and Manage. 7:23-35.

NAGY, J.A., R.H. RUSSELL, A.M. PEARSON, M.C. KINGSLEY, AND B.C. GOSKI. 1983*a*. Ecological studies of the grizzly bear in arctic mountains, Northern Yukon Territory, 1972 to 1975. Can. Wildl. Serv. 104pp.

_____, _____, _____, _____, AND C.B. LARSEN. 1983*b*. A study of grizzly bears on the barren grounds of Tuktoyaktuk Peninsula and Richards Island, Northwest Territories, 1974 to 1978. Can. Wildl. Serv. 136pp.

OTIS, D.L., K.P. BURNHAM, G.C. WHITE, AND D.R. ANDERSON. 1978. Statistical inference from capture data on closed animal populations. Wildl. Monogr. 62. 135pp.

PEARSON, A.M. 1976. Population characteristics of the arctic mountain grizzly bear. Int. Conf. Bear Res. and Manage. 3:247-260.

PEEK, J.M., M.R. PELTON, H.D. PICTON, J.W. SCHOEN, AND P. ZAGER. 1987. Grizzly bear conservation and management: a review. Wildl. Soc. Bull 15:160-169.

QUIMBY, R. 1974. Grizzly bear. Chapter II. *In* R.D. Jakimchuk, ed. Mammal studies in northeastern Alaska with emphasis within the Canning River drainage. Arctic Gas Biol. Rep. Ser., Vol. 24.

_____, AND D.J. SNARSKI. 1974. A study of fur-bearing mammals associated with gas pipeline routes in Alaska. Chapter 2. *In* R.D. Jakimchuk, ed. Distribution of moose, sheep, muskoxen and furbearing mammals in northeastern Alaska. Arctic Gas Biol. Rep. Ser., Vol. 6.

REYNOLDS, H. 1976. North slope grizzly bear studies. Alas. Dep. Fish and Game, Fed Aid in Wildl. Restoration. Final Rep. Proj. W-17-6 and 7. Jobs 4.8R, 4.11R. Juneau. 20pp.

_____. 1982. Alaska range grizzly bear studies. Alas. Dep. Fish and Game, Fed. Aid in Wildl. Restoration Prog. Rep., Proj. W-21-1, Job 4.1R. Juneau. 10pp.

_____. 1984. Grizzly bear population biology in the western Brooks Range, Alaska. Appendix A, pages 2-19 *in* H.V. Reynolds, and J.L. Hechtel. Structure, status, reproductive biology, movement, distribution, and habitat utilization of a grizzly bear population. Alas. Dep. Fish and Game, Fed. Aid in Wildl. Restoration Final Rep.. Juneau.

_____, AND J.L. HECHTEL. 1985. Population structure, reproductive biology, and movement patterns of grizzly bears in the northcentral Alaska Range. Alas. Dep. Fish and Game, Fed. Aid in Wildl. Restoration Prog. Rep., Proj. W-22-1. Job 4.16R. Juneau. 29pp.

_____, _____, AND D.J. REED. 1987. Population dynamics of a hunted grizzly bear population in the northcentral Alaska Range. Alas. Dep. Fish and Game, Fed. Aid in Wildl. Restoration Prog. Rep., Proj. W-22-5. Juneau. 55pp.

SCHOEN, J.W., AND L.R. BEIER. 1987. Brown bear habitat preferences and brown bear logging and mining relationships in southeast Alaska. Alas. Dep. Fish and Game, Fed. Aid in Wildl. Restoration Prog. Rep., Proj. W-22-5, Job 4.17R. Juneau. 48pp.

SIDOROWICZ, G.A., AND F.F. GILBERT. 1981. The management of grizzly bears in the Yukon, Canada. Wildl. Soc. Bull. 9(2):125-135.

SMITH, R.B., AND L.J. VAN DAELE. 1988. Terror Lake hydroelectric project, Kodiak Island, Alaska. Alas. Dep. Fish and Game, Spec. Rep. to Alas. Power Authority. Anchorage. 182pp. (mimeo).

SNEDECOR, G.W., AND W.G. COCHRAN. 1973. Statistical methods. Iowa State Univ. Press, Ames. 593pp.

SPRAKER, T.H., W.B. BALLARD, AND S.D. MILLER. 1981. Game Management Unit 13 brown bear studies. Alas. Dep. Fish and Game, Fed. Aid in Wildl. Restoration Final Rep. Proj. W-17-10, W-17-11, and W-21-1. Job 4.13R/ 57pp.

TAYLOR, W.P., JR., H.V. REYNOLDS, and W.B. BALLARD. 1989. Immobilization of grizzly bears with tiletamine hydrochloride and zolazepam hydrochloride. J. Wildl. Manage. 53:978-981.

WHITE, G.C., D.R. ANDERSON, K.P. BURNHAM, AND D.L. OTIS. 1982. Capture-recapture and removal methods for sampling closed populations. Los Alamos Natl. Lab. LA-8787-NERP, UC-11. 235pp.