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Division of Wildlife Conservation
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Research Progress Report

DEMOGRAPHY OF NOATAK GRIZZLY BEARS IN RELATION TO HUMAN EXPLOITATION AND MINING DEVELOPMENT

by
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Project W-23-1
Study 4.20
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PROGRESS REPORT (RESEARCH)

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SUMMARY

During 1988, 45 grizzly bears (*Ursus arctos*) were immobilized with a mixture of tiletamine hydrochloride and zolazepam hydrochloride. Immobilization data from this study were combined with those from other Alaska studies and prepared for technical publication. A total of 99 bears have been marked since inception of the study; their current status is described. Six adult females that had previously been radio-collared with conventional collars were fitted with satellite collars. Satellite collars were programmed to transmit annually for 6 hours/day from 25 May through 10 October; their expected life span is 2 years. Forty bears wearing conventional radio-collars were relocated on 329 occasions. Average litter size at den emergence during the years 1986 through 1988 was 2.29 (N = 17). Density estimates obtained in 1987 were used to estimate population size in the study area, and these estimates were compared with known and reported harvests. Results of these analyses were summarized in a manuscript presented at the 8th International Conference on Bear Research and Management at Victoria, British Columbia in February 1989.

Key Words: grizzly bear, *Ursus arctos*, harvest rates, density, population, estimates, mining development, Noatak, productivity, mortality, satellite telemetry.

CONTENTS

BACKGROUND

Background and earlier findings for this study were provided by Ballard (1987) and Ballard et al. (1988). Briefly, this study was designed to (1) evaluate effects of human harvests of grizzly bears by comparing bear density with known reported harvests and (2) provide baseline data on bear density, population structure, movements, and reproductive parameters prior to large-scale development of the Red Dog Mine. Actual impacts from the mine and other associated developments are to be assessed at a later date by repeating the study using identical study methods. Obtaining an accurate and precise estimate of bear density in the potential impact area was a high priority and key objective of this research effort. The last progress report focused on the estimation of bear density in the study area in 1987 (Ballard et al. 1988).

OBJECTIVES

To estimate density, population structure, movements, and reproductive parameters of grizzly bears in the western Brooks Range. During 1988 this study was modified to include the following objectives:

1. To estimate reproductive and mortality rates of grizzly bears within a selected study area in and adjacent to the Noatak National Preserve.

2. To determine daily and seasonal-use patterns of adult grizzly bears in relation to development of the Red Dog Mine.

3. To determine short-term changes in behavior and habitat use of bears as a result of development and operation of the Red Dog Mine and associated roads.

4. To compare the utility of conventional telemetry with satellite telemetry for determining seasonal habitat use and home range sizes.

STUDY AREA

From 1986 through 1988, we studied bears within a 2,600-mi^2 (6,700 km^2) area that encompassed the Red Dog mine (see Appendix A, Fig. 1). This large area is herein referred to as the Noatak River Study Area (NRSA). A brief description of the proposed mine development and study area, as well as the study design, was provided by Ballard (1987). A thorough description of the proposed mine was provided in an environmental impact statement (EPA and USDI 1984). The NRSA boundaries were also selected to encompass an area receiving a moderate amount of harvest pressure. Because the NRSA was too large for conducting an intensive census, a smaller area was selected, based upon movements of radio-collared bears in 1986 and location of the mine and associated roads (see Appendix A, Fig. 2). This smaller area is referred to as the Red Dog Mine Census Area or just census area. For this report, we refer to the bear density estimation procedure described by Miller et al. (1987) as a census.

METHODS

Bears were captured for radio-collaring and/or marking using standard helicopter immobilization procedures that have become widely used in Alaska (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, Colorado 80525) that was delivered by a dart projectile fired from a Cap-Chur gun (Palmer Chemical Equipment Co., Douglasville, Georgia 30134) or hand injection. This drug combination is commonly referred to by the trade name Telazol, and it will be identified as such in this report.

RESULTS AND DISCUSSION

Forty-five grizzly bears were successfully immobilized with Telazol in early June 1988. Drug dosages were identical to those used in 1987 (Ballard et al. 1988). Immobilization data collected from this study in 1987 were combined with those from several other Alaskan studies and the efficacy of Telazol for immobilizing grizzly bears was evaluated. A copy of this evaluation has been accepted by the Journal of Wildlife Management for publication (Appendix B). Of the 45 bears immobilized in 1988, 20 (4 males and 16 females) were adults that had been recaptured to either replace radio collars or remove collars from males (N = 4). Because the study will now focus on long-term reproductive success, radio-collared males are no longer needed for telemetry studies. Also, because many of the males captured earlier were relatively young and still growing, we chose to remove the collars to reduce the potential of rub marks or lacerations caused by the collar. Seven new adult females were tattooed and ear-tagged but not collared. Sixteen cubs-of-the-year (COY; 9 males and 7 females) accompanying radio-collared sows were also immobilized and marked with ear tags and tattoos.

Six adult females that had been monitored for 1 or 2 years with conventional radio collars were recaptured and fitted with satellite collars manufactured by Telonics (Mesa, Arizona). Each satellite collar also contained a separately packaged conventional VHF transmitter that allows each animal to be located with conventional tracking methods. The Argos Data Collection and Location System (DCLS) has been used for receiving signals and processing of data. The Argos system is a cooperative effort among the French Centre National d'Etudes Spatiales (CNES), the National Oceanic and Atmospheric Administration (NOAA), and the National Aeronautics and Space Administration (NASA). History and current use of satellite transmitters on wildlife was described by Fancy et al. (1988).

Satellite transmitters were programmed to transmit for 6 hours per day from 25 May through 10 October annually and are expected to operate through 2 field seasons. Relocation and activity data obtained in 1988 have not yet been analyzed.

During 1988 eleven adult males and 29 adult females were relocated on 71 and 258 occasions, respectively (Tables 1 and 2). Twenty-nine females and 6 males had functioning radio collars when last relocated in late October 1988. All bear radio relocations were digitized and, along with associated descriptive data, entered into DBASE computer files to facilitate future analyses.

A total of 99 bears have been marked since inception of this study. A summary of their known status through 1988 is provided in Table 3. The status of 47 adult grizzlies (excluding capture mortalities, slipped collars, and missing bears) has been known since late October 1988. Forty-one percent ($\underline{N}$ = 7) of 17 adult males and 3% ($\underline{N}$ = 1) of 30 adult females have died. Hunting accounted for all but 1 mortality.

Two noteworthy observations occurred during 1988. First, sow No. 021, accompanied by 2 yearlings, was observed copulating with an unmarked male on 21 May 1988. Second, sow No. 028 was observed with 2 COY in late May 1987 but apparently had lost 1 COY by 23 July 1987. She may have lost the second COY by 13 October 1987, when she was last observed before entering the 1987-88 den. At den emergence in 1988, she was observed alone. One of her COY (i.e., male No. 048) marked and perceived as dead in 1987 was killed by

Table 1. Summary of numbers of relocations, reproductive history, and status of female grizzly bears captured in the southwest Brooks Mountain Range of GMU 23 during 1986, 1987, and 1988.

Bear ID (tattoo)	No. of relocations 1986	No. of relocations 1987	No. of relocations 1988	Status	Reproductive history
001*	13	10	11	Active, 1987 den located on 10/21/88	w/3 cubs at capture, w/2 cubs 5/86, 10/86, w/2 1.5 yr olds 5/87, 10/87, alone 5/88, 10/88
002*	12	15	11	Active, 1988 den site not located	Alone - 5/86, 10/86, 5/87, 10/87, 6/88. 9/88
004*	13	18	11	Active, 1987 den site on 10/28/87	w/2 cubs 6/86-10/86, w/2 1.5 yr olds 5/87-10/87, w/2-2.5 yr olds
005				Cub of sow 04, separated by 6/8/88	4/88, alone 10/88
006				Cub of sow 04, separated from sow by 6/8/88	
008*	14	19	10	Active, 1988 den site located on 10/22/88	Alone-6/86, 10/86, 5/87, 9/87, w/1 COY 6/88, 9/88
009*	11	14	6	Active, 1988 den site located on 10/21/88	Alone -6/86,10/86, 5/87, 10/87, w/2 COY-5/88, 10,88
011				Missing after capture (possible post-capture mortality)	
013				Capture mortality 6/86	

- continued -

Table 1. Continued

Bear ID (tattoo)	No. of relocations 1986	1987	1988	Status	Reproductive history
014*	11	15	14	Active, 1988 den site located on 10/21/88	w/3 cubs at cap, lost 2, w/1 cub 10/86, w/1 1.5-yr old 5/87, lost after 5/28,87, alone 5/88, 10/88
018*	10			Suspect shot between 9/26-10/02/86 (radio at guide camp)	
020*	10	22	13	Active, 1988 den site located on 10/21/88	Alone 6/86, 10/86, 5/87, 10/87, w/2 COY 5/88, 10/88
021*	8	11	10	Active, 1988 den site located on 10/21/88	Alone 6/86, 10/86, w/4 cubs 5/87, lost 1 5/28 and 6/18, w/3 cubs 10/87, w/2 yrls 6/88[a], 9/88
022*	10	21	13	Active, 1988 den site located on 10/21/88	w/1 1.5 yr old 6/86, 10/86, w/1 2.5 yr old 5/2/87, missing 5/2 and 5/16/87. Alone 10/87, w/2 COY 5/88, w/1 COY 10/88
025*	11	8	7	Active, 1988 den site located on 10/21/88	Alone 6/86, 10/86, 5/87, 10/87, w/2 COY 5/88, 10/88
026				Unknown after capture	

- continued -

Table 1. Continued

Bear ID (tattoo)	No. of relocations 1986	1987	1988	Status	Reproductive history
028*	13	22	9	Active, 1988 den site located on 10/22/88	Alone 6/86, 10/86; w/2 cubs 5/87 lost 1 7/7-7/16, may have lost other 9/30-10/13, alone 5/88, 9/88
032*		7		Recap 6/87 w/breakaway collar, off by 8/12/87 Unknown	
033				Unknown after capture	
036				Capture mortality	
038				Unknown after capture	
039*	9	16	12	Active, 1988 den site located on 10/21/88	Alone 6/86, 10/86, 5/87, 10/87, w/3 COY 5/88, 9/88
041*	8	13	12	Active, 1988 den site located on 10/21/88	Alone 6/86, 10/86, 5/87, 10/87, w/2 COY 5/88, 10/88
0043*	5	20	11	Active, 1988 den site located on 10/22/88	Alone 6/86, 10/86, 5/87, 1/87, 5/88, 9/88
047				Unknown after capture	
049				Cub of sow 28, unknown in 1988	
0051*		2		Slipped collar between 5/30 and 6/4/87, unknown	Unknown after capture

- continued -

Table 1. Continued

Bear ID (tattoo)	No. of relocations 1986	1987	1988	Status	Reproductive history
052*		7	4	Active, 1988 den site lcoated on 10/22/88	w/2 1.5 yr olds 5/87, 8/87 w/2 2.5 yr olds 5/88, 9/88
053*		15	7	Active, 1988 den site located on 10/22/88	w/1 1.5 yr old 5/87, 10/87, w/1 2.5 yr old 5/88, Alone 9/88
054				Capture mortality	
055*		17	11	Active, 1988 den site located on 10/21/88	w/3 1.5 yr olds 5/87, lost 1 9/15 and 10/8/87, 2 yrls 10/87, w/1 2.5 yr old 5/88, alone 9/88
058*		16	10	Active, 1988 den site located on 10/22/88	w/3 1.5 yr olds 5/87, 10/87, w/3 2.5 yr olds 5/88, alone 10/88
059*		9	7	Active, 1988 den site located on 10/21/88	w/2 cubs 5/87, 10/87, w/2 yrls 6/88, 9/88
060				Cub of sow 059	
061				Cub of sow 059	
062				Cub of sow 059	
063*		19	11	Active, 1988 den site located on 10/22/88	w/2 1.5 yr olds, 5/87 and 10/87, w/2 2.5 yr olds 5/88, alone 9/88

- continued -

Table 1. Continued

Bear ID (tattoo)	No. of relocations 1986	1987	1988	Status	Reproductive history
065*		16	5	Active, 1988 den site located on 10/22/88	Alone 5/87, 10/87, 5/88 10/88
066*		9		Breakaway collar, dropped 8/19 and 9/9/87, unknown	Unknown after 8/19/87
067*		17	10	Active, 1988 den site located on 10/22/88	Alone 5/87, 10/87, w/2 COY 5/88, 9/88
069*		16	12	Active, 1988 den site located on 10/22/88	Alone 6/87, 10/87, w/2 COY 5/88, 9/88
070*		16	8	Active, 1988 den site located on 10/22/88	Alone 6/87, 10/87, 5/88 10/88
071*		12		Missing after 9/15/88	Alone 6/87
074*		14		Active, 1988 den site located on 10/22/88	Alone 6/87, 10/87, w/3 COY 5/88, 10/88
075				2.5 yr old of sow 58, unknown after capture	
077				Cub of sow 69	
079				Cub of sow 25	
0080				Cub of sow 25	

- continued -

Table 1. Continued

Bear ID (tattoo)	No. of relocations 1986	1987	1988	Status	Reproductive history
081*			7	Missing after 8/24/88	Alone 6/88
085				Cub of sow 20	
086				Cub of sow 20	
087				Unknown after capture	
092				Cub of sow 21	
095*			4	Active, 1988 den site located on 10/22/88	Alone 6/88, 10/88
096*			5	Active, 1988 den site located on 10/22/88	Alone 6/88, 10/88
097*			4	Active, 1988 den site located on 10/21/88	Alone 6/88, 9/88
098*			3	Active, 1988 den site located on 10/21/88	w/1 COY 6/88, 9/88
099				Cub of sow 98	
Total	158	416	258		

*Radio-collared
[a]Observed copulating with unmarked male on 5/21/88

Table 2. Summary of number of relocations and status of male grizzly bears in the southwest Brooks Mountain Range of GMU 23 during 1986, 1987, and 1988.

Bear ID (tattoo)	No. of relocations 1986	1987	1988	Status of den entrance 1988
003*	11	15	9	Active, den site not located
007*	10	1		Hunting mortality 09/16/87
010*	10	9		Slipped collar 5/87, recap 5/87, slipped 10/87
012*	5			Slipped collar 6/86, recap 6/86, slipped 8/86
015				Cub of sow 14, missing after capture - capture mortality
016				Cub of sow 14, assumed dead, missing after 5/28/87, see sow 014
017				Unknown after capture
019*	2			Slipped collar by 6/8/86
023				Unknown after capture
024*	6	9		Slipped collar 8/12/87
027*	4			Missing after 7/3/86
029*	10			Hunting mortality 4/21/87
030*	3			Hunting mortality 4/19/87
031*		10	1	Collar removed on 6/8/88

- continued -

Table 2. Continued.

Bear ID (tattoo)	No. of relocations 1986	1987	1988	Status of den entrance 1988
034*	10	21	1	Collar removed on 6/5/88
035*	6	6		Suspected mortality from unknown causes by 10/9/87
037				Hunting mortality 9/87
040*	10	16	9	Active, 1988 den site located 10/21/88
042*	10	18	11	Recap, active, 1988 - den site not located 10/21/88
044*	5			Hunting mortality 4/23/87
045*	8	13		Slipped collar 7/1 and 7/6/87
046*	10	15	10	Active, 1988 - den site located on 10/21/88
048				Cub of sow 28, killed by hunter on 9/19/88
050*		2	3	Collar removed on 6/9/88
056*		15	12	Active, 1988 - den site not located
057*		10		Hunting mortality 9/88
064*		18	6	Slipped collar between 7/15 and 7/27/88

- continued -

Table 2. Continued.

Bear ID (tattoo)	No. of relocations 1986	1987	1988	Status of den entrance 1988
068*				Slipped collar between 6/2 and 6/3/87
072*		10	5	Active, 1988 - den site located on 10/22/88
073*		9	4	Collar removed on 6/8/88
076				Cub of sow 69
078				Cub of sow 22
082				Unknown after capture
083				Unknown after capture
084				Cub of sow 8
088				Cub of sow 39
089				Cub of sow 39
090				Cub of sow 39
091				Cub of sow 21
093				Cub of sow 41
094				Cub of sow 41
Total	120	197	71	

*Radio-collared

Table 3. Summary of known status of 99 marked grizzly bears from 1986 through 1988 in the southwest Brooks Mountain Range, Alaska.

		Status unknown						
	Alive	Slipped collars	Missing	Collars removed	Capture mortality	Hunting mortality	UNID mortality	Natural separation
Radio-collared adults								
Males	6	7	1	4	0	5	1	N/A
Females	29	1	2	0	3	1	0	N/A
Marked adults (uncollared)								
Males	0	0	4	0	0	1	0	N/A
Females	0	0	9	0	0	0	0	N/A
Marked young (uncollared)								
Males	9	N/A	1	N/A	1	1	0	0
Females	9	N/A	2	N/A	0	0	0	2
Totals								
All males	15	7	6	4	1	7	1	0
All females	38	1	13	0	3	1	0	2
All bears	53	8	19	4	4	8	1	2

a hunter in September 1988. This yearling appears to have survived the winter as a COY without its sow and was harvested by a hunter who thought the animal was legal because it was alone.

Known reproductive histories of adult female grizzly bears are presented in Table 4. Average litter size at den emergence was 2.29 ($\underline{N}$ = 17, SD = 0.77). Eleven litters were produced by radio-collared females in 1988, a considerable increase from those in 1986 and 1987.

During 1988-89 we estimated numbers of grizzly bears within the study area based upon the 1987 density estimate. We also assessed harvest rates based upon population estimates and minimum reported harvests. This information formed the basis for a manuscript that was presented at the 8th International Conference on Bear Research and Management at Victoria, British Columbia from 20-25 February 1989 (Appendix A).

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Table 4. Summary of litter sizes and subsequent losses of offspring for radio-collared adult (3 yr old) female grizzly bears captured in the southwest Brooks Mountain Range of GMU 23 during 1986, 1987, and 1988.

Bear ID	Year	Age	Barren		Cubs		Yearlings		2.5 yr olds	
			EM[a]	ENT[b]	EM[a]	ENT[b]	EM[a]	ENT[b]	EM[a]	ENT[b]
001	1986	5.5			3[c]	2				
	1987	6.5					2	2		
	1988	8.5	x	x						
002	1986	5.5	x	x						
	1987	6.5	x	x						
	1988	7.5	x	x						
004	1986	6.5			2	2				
	1987	7.5					2	2		
	1988	8.5		x					2	
008	1986	13.5	x	x						
	1987	14.5	x	x						
	1988	15.5			1	1				
009	1986	14.5	x	x						
	1987	15.5	x	x						
	1988	16.5			2	2				
013	1986	7.5	x	Dead						
014	1986	9.5			3[c]	1				
	1987	10.5					1	0		
	1988	11.5	x	x						
018	1986	8.5	x	Dead						
020	1986	5.5	x	x						
	1987	6.5	x	x						
	1988	7.5			2	2				

- continued -

Table 4. Continued

Bear ID	Year	Age	Barren		Cubs		Yearlings		2.5 yr olds	
			EM[a]	ENT[b]	EM[a]	ENT[b]	EM[a]	ENT[b]	EM[a]	ENT[b]
021	1986	12.5	x	x						
	1987	13.5			4	3				
	1988	14.5					2	2		
022	1986	8.5					1	1		
	1987	9.5							1	x
	1988	10.5			2	1				
025	1986	12.5	x	x						
	1987	13.5	x	x						
	1988	14.5			2	2				
026	1986	3.5	x							
028	1986	9.5	x	x						
	1987	10.5			2	0				
	1988	11.5	x	x						
032	1986	3.5	x	x						
	1987	4.5	x	x						
033	1986	7.5	x							
036	1986	Ad.	x							
038	1986	3.5	x							
039	1986	8.5	x	x						
	1987	9.5	x	x						
	1988	10.5			3	3				

- continued -

Table 4. Continued

Bear ID	Year	Age	Barren EM[a]	Barren ENT[b]	Cubs EM[a]	Cubs ENT[b]	Yearlings EM[a]	Yearlings ENT[b]	2.5 yr olds EM[a]	2.5 yr olds ENT[b]
041	1986	6.5	x	x						
	1987	7.5	x	x						
	1988	8.5			2	2				
043	1986	17.5	x	x						
	1987	18.6	x	x						
	1988	19.6	x	x						
047	1986	Unk							2[d]	
051	1987	4.5	x							
052	1987	14.5					2[d]	2		
	1988	15.5							2	
053	1987	7.5					1[d]	1		
	1988	8.5		x						
054	1987	5.5	x							
055	1987	6.5					3[d]	2		
	1988	7.5		x					1	
058	1987	6.5					3[d]	3		
	1988	7.5		x					3	
059	1987	15.5			3	3				
	1988	16.5					3	2		
063	1987	12.5					2[d]	2		
	1988	13.5		x					2	

- continued -

Table 4. Continued

Bear ID	Year	Age	Barren EM[a]	Barren ENT[b]	Cubs EM[a]	Cubs ENT[b]	Yearlings EM[a]	Yearlings ENT[b]	2.5 yr olds EM[a]	2.5 yr olds ENT[b]
065	1987	9.5	x	x						
	1988	10.5	x	x						
066	1987	3.5	x	x						
067	1987	.4.5	x	x						
	1988	5.5			2	2				
069	1987	10.5	x	x						
	1988	11.5			2	2				
070	1987	3.5	x	x						
	1988	4.5	x	x						
071	1987	3.5	x	x						
074	1987	9.5	x	x						
	1988	10.5			3	3				
081	1988		x							
087	1988		x							
095	1988		x	x						
096	1988		x	x						
097	1988		x	x						
098	1988				1	1				
		X(SD)	2.29 (0.77)	1.88 (0.86)	2.0 (0.77)	1.73 (0.79)	1.75 (0.71)			

- continued -

Table 4. Continued

[a]EM = Size of litter at emergence from den in spring.

[b]EN = Size of litter at den entrance in autumn.

[c]Capture related mortalities.

[d]Offspring age estimated.

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Appendix A. Copy of paper prepared for the 8th International Conference on Bear Research and Management held at Victoria, British Columbia during 20-25 February 1989.

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APPLICATION OF MARK-RECAPTURE TECHNIQUES AND RADIOTELEMETRY FOR ESTIMATING GRIZZLY BEAR DENSITY IN RELATION TO MINING DEVELOPMENT AND HUMAN EXPLOITATION IN NORTHWEST ALASKA

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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/66.0 km^2 for adults (>3 yrs age) and 1 bear/50.5 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 7.5 to 15.7%. Current bear density and population estimates will be compared with estimates obtained after the mine is developed to assess impacts on the bear population.

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Conservation of brown/grizzly bears (Ursus arctos) in Alaska is partially dependent on the availability and use of assessment methods which allow game managers to monitor status of populations on a regular basis. Historically, managers have primarily relied on gross analysis 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 to be imprecise and unreliable (Harris 1984, Harris and Metzgar 1987*a*,*b*). In areas where unreported harvests are potentially large, reported harvests may not even be representative of trends in total mortality, and consequently, problems associated with analysis of harvest data for assessing population trend may be insurmountable. Fortunately, bear populations appear healthy and abundant in many areas of Alaska (Peterson 1987). If the status quo is to be maintained, however, appropriate methods must be developed and tested so that managers can accurately identify and remedy population declines as well as allow opportunities for additional harvest.

Increasing human populations have significantly reduced the abundance and distribution of grizzly bears in North America (Cowan 1972). Although abundance and distribution of bears in Alaska has changed little from historical times, significant changes in the environment could permanently alter the productivity and survival of some bear populations. Current understanding of the effects of resource development activities on grizzly bear population dynamics is inadequate for providing effective guidelines to agencies or private companies for minimizing and mitigating impacts to bear populations. This inadequacy exists because such impacts are usually long term, research is usually of short duration, and many impacts are relatively recent (Peek et al. 1987).

This study was conceived due to wide ranging estimates of bear abundance and concern about potential adverse impacts from development and operation of the Red Dog Mine in northwest Alaska. Objectives of this study were to evaluate effects of human harvest on bears by comparing bear density with known reported harvests, and to provide baseline data on bear density, structure, movements, and reproductive parameters prior to large-scale mine development. These objectives were to be attained through a combined use of conventional radiotelemetry, satellite telemetry, and density estimates obtained with mark-recapture techniques. Actual changes in bear density due to the Red Dog mine, should they occur, will be assessed at a later date by repeating the study using identical study methods. This design is similar to that reported by Miller (this volume). Additional background for this study was provided by Ballard (1987) and Ballard et al. (1988). The use of mark-recapture methods for estimating pre-mining bear densities and estimating current minimum harvest rates is discussed.

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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]) which encompassed the Red Dog mine (Fig. 1). The NRSA was located within Game Management Unit (GMU) 23 of northwest Alaska, an area of approximately 111,370 km^2.

A thorough description of the proposed mine was provided in an environmental impact statement (EPA and USDI 1984). Briefly, the Red Dog Mine project is a joint venture between NANA (an Alaskan Native Regional Corporation) and Cominco Alaska, Inc. The project will consist of an open pit lead/zinc mine located on Red Dog Creek 131 km north of Kotzebue, Alaska (Fig. 1). 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 (EPA and USDI 1984). The facilities will occupy at least 8,975 hectares. The project is expected to last a minimum of 40 years and much longer if other mining claims are developed. At least 18,000 mining claims exist in the area. The site will be occupied by 225-250 employees at any one time. The transportation corridor may accommodate a railroad in future years. Improved access is expected to result in increased human use and additional mining exploration and development.

The NRSA boundaries were also 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 site surrounding the mine and associated roads was selected based upon movements of radio-collared bears in 1986. This site is referred to as the Red Dog mine Census Area (Fig. 2) or just census area.

The census area was divided into 10 sample units, referred to as count areas (CAs), 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 CAs.

The census area was characterized by steep mountainous terrain traversed by several major rivers and creeks. Vegetation types ranged from riparian stands of willow (<u>Salix</u> spp), birch (<u>Betula nana</u> and <u>B. glandulosa</u>), and cottonwood (<u>Populus balsamifera</u>) along the streams and rivers, grading into closed tall shrub, low shrub, open low shrub, tundra, and then bare rock and ice as elevations increased. Relatively thick stands of white spruce (Picea glauca) occurred within the southern half of CAs 3, 4, and 8 along the Noatak and Kelly Rivers in CA 10. Elevations within the census area ranged from approximately 60 m along the southern boundary to 1,190 m along the northern boundary. A relatively small portion of the census area contained areas >915 m elevation. The census area included the den sites of 7 of 12 radio-collared bears captured in 1986 prior to the survey. Although habitat use by bears has not yet been quantified for the NRSA, nearly all of the census area was considered useable bear habitat. Consequently, the entire area was used for 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 degrees C and winter temperatures range as low as -26 to -47 degrees C. Extremely low winter temperatures occur less frequently in the mountains due to temperature inversions. 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. No black bears (Ursus americanus) have been observed in the area. All of the major rivers and their drainages provide habitat for fish, which seasonally are an important source of food for bears. Arctic char (Salvelinus alpinus), grayling (Thymallus arcticus), and chum salmon (O. keta) are among the most important species. Salmon migration usually occurs from July through September each year. Late autumn chum salmon runs appear to be particularly important because they are an abundant source of high-quality bear food just prior to denning. The late chum runs in the Noatak area are some of the latest in North America (C. Lean, pers. commun.), which may have some relevance to bear densities mentioned later in this report.

METHODS

Bears were captured for radio-collaring and/or marking using standard helicopter immobilization procedures which have become widely used in Alaska (Spraker et al. 1981, Ballard et al. 1982, Reynolds and Hechtel 1985, Miller et al. 1987, and many others). Bears were immobilized with a mixture of tiletamine hydrochloride and zolazepam hydrochloride (Zoletil100, Wildlife Laboratories, P. O. Box 8938, Fort Collins, Colorado 80525) which was delivered from either a dart projectile fired from a Cap-Chur gun (Palmer Chemical Equipment Co., Douglasville, Georgia 30134) or by hand injection (Taylor et al. 1989). Each captured bear was sexed, weighed, measured, and individually marked with 1-3 lip tattoos, roto ear tags, and radio-collared, if judged to be $\geq$5 years of age, with radios manufactured by Telonics (Mesa, Arizona). Three subadult (3.5-4.5 year-olds) bears were radio-collared during the census with collars designed to fall off after several weeks. These collars were of the same design as standard Telonics collars except that the collar was modified to allow it to eventually fall off by using surgical tubing between 2 attachments. Premolars were extracted from each immobilized bear judged to be >1.0 year of age. Extracted teeth were used for aging and processed similar to methods described by Mundy and Fuller (1964).

Except where specifically stated, methods used for the mark-recapture density estimation procedure were identical to those described by Miller et al. (1987). This involved use of mark-recapture methods with use of radiotelemetry to correct for population closure (an assumption frequently violated in the use of mark-recapture methods for population estimation). Fixed-wing aircraft thoroughly searched (without aid of telemetry) individual CAs until a bear or group of bears was spotted. Telemetry was then used to determine whether the animal(s) was marked (i.e. radio-collared). Sightings of bears with functioning radio collars were considered as recaptures of marked individuals except that for total population estimates young accompanied by their mothers were considered to have the same status as their marked or unmarked mothers.

Adult bears which did not possess functioning radio collars were considered unmarked. If unmarked, the animal was marked and available as a recapture in subsequent searches. Effort was made to capture all unmarked adult bears but not subadults accompanying their mothers. All observed unmarked adults were captured, with the exception of 1 adult female accompanied by 1 yearling (estimated based on size) which escaped. The census occurred during the breeding season, and consequently adults were sometimes observed together. These sightings were treated as independent observations.

Equations for calculating population size, density, and associated confidence intervals were provided by Miller et al. (1987). We used the bear-days estimator rather than standard Lincoln-Peterson estimates. Like Miller (this volume), we did not use Clopper-Pearson graphs as described by Miller et al. (1987) to calculate binomial confidence intervals but used a program developed by D. Reed and J. Venable. The values for the desired confidence level were entered on a lotus worksheet developed by S. Miller, and confidence intervals for bear-days, numbers of bears, and density were calculated automatically.

Twenty individuals from 3 agencies, 2 private companies, and the community of Noatak participated in the density estimate procedure which was conducted 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 were composed of 3 PA-18's, 1 PA-12, 1 Arctic Tern, and 1 Cessna 185. The Cessna, herein referenced as the tracking aircraft, was used primarily for radio-tracking each day to determine degree of population closure (number and identification of individual radio-collared bears which were either in or out of individual CAs), but it was also used on 2 days for surveying. In both instances, population closure was assessed after it searched the assigned CAs. During other days, radio-tracking occurred simultaneously with surveys. Depending on location of search aircraft and helicopter availability, the tracking aircraft also maintained visual contact with unmarked bears spotted by survey aircraft which needed to be captured and radio-collared. This relieved the survey planes of the task of maintaining visual contact with unmarked bears until arrival of helicopter and allowed them to continue the survey with minimum delay. The tracking aircraft was careful not to transmit over the radio the identity or location of any of the marked or unmarked bears. The remaining fixed-wing aircraft were used exclusively for surveys.

Survey aircraft pilot-observer teams and assigned CAs were rotated daily. Pilot-observer teams were careful not to discuss the location of sighted bears during or after the census so that search efforts would not be biased in succeeding days. Personnel in the tracking aircraft were not rotated. One biologist was assigned permanently to the helicopter to insure consistency in immobilization and handling procedures. All search aircraft personnel, except professional pilots and tracking personnel, were rotated into the tagging team to provide breaks.

RESULTS AND DISCUSSION

Population Estimates and Density

During 29 May through 4 June 1987, up to 6 fixed-wing aircraft searched 198.4 hours for grizzly bears within the 1,862 km^2 Red Dog Mine census area (Table 1). Search effort averaged 0.91 $min/km^2/day$. Search effort per CA varied from 0.80 $min/km^2/day$ for optimum sightability areas characterized by relatively flat terrain and low elevational relief (CA 2), to 1.05 $min/km^2/day$ for a rugged, mountainous area in the north (CA 9) where observability was difficult. In retrospect, we may have been able to have surveyed a larger area by reducing search effort or having tracking aircraft participate earlier in the survey. However, search efficiency declines with fatigue, and it appeared desirable to not extend search effort beyond 4-5 hours without several breaks. Average search effort per airplane was 5.62 hours/day, not including commute time or assisting during immobilization. Concensus of crew members suggested that this was close to the maximum effort that should be attempted with 6 aircraft.

Prior to the census, 12 radio-collared grizzlies (8 females and 4 males) which had been captured and radio-collared in 1986 were available as marked bears. The home ranges of these 12 bears overlapped the census area boundaries, and 7 bears denned within the census area boundaries. Three of the previously marked males and 6 of the previously marked females were resighted at least once during survey days 2 through 7. No marked (radio-collared) 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 in the population. An additional 6 adult males and 12 adult females previously unmarked were captured and radio-collared within the census area as part of the survey effort. Of the 12 adult females, 8 were unaccompanied by young, 1 was accompanied by 3 COY, 2 were accompanied by 3 yearlings, and 1 was accompanied by 3 2.5-year-olds. The intensive capture efforts in 1986 and 1987 allowed us to estimate the sex and age structure of the bear population in and near the Red Dog mine area (Table 2). Yearlings and COY composed 30.9% of the population in 1987. Ratio of adult (>5 years age) 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 (sighted in our case). 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, and 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 the various 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 12 possible days but were only observed twice (Table 3). The latter was the lowest sightability of the groups examined providing additional support for the hypothesis of low sightability for sows with COY. Sightability for other groups was similar ranging from 28.6% for females accompanied by young (>1 year of age) to 34.0% for single females. Sightability for all bears was 31.2%. There did not appear to be differences in sightability between males which had been captured and radio-collared prior to the census (28.6%) and those captured during the census (37.5%). There may have been a bias against observing single females during the census, but this difference was not statistically significant ($\underline{P} > 0.05$). The sightability for single females captured before the census was 40.0% and for those captured during the census sightability averaged 23.5%.

Data from this study will be combined with several Alaskan studies where mark-recapture techniques have been utilized (Miller et al. In Prep.). With larger sample sizes, we anticipate that statistically significant differences among sex, age, and family groups can be properly tested. A preliminary analysis indicated that there were no significant differences ($P > 0.05$) in capture sightability of marked bears by family class, age class, or area for several Alaskan study areas (Becker 1988). Becker also tested for capture homogeneity by day and individual and was unable to detect any differences for the Noatak area ($P = 0.316$) or among 4 Alaskan study areas ($P = 0.449$) where mark-recapture estimates have been made (Southcentral Alaska - Miller et al. 1987 and this volume, northwest Alaska - this study, Admiralty Island - Schoen and Bier 1987, and Karluk Lake on Kodiak Island - Barnes et al. 1988). One study area, Terror Lake also on Kodiak Island (Smith and Van Daele 1988), was significantly different ($P = 0.005$) but reasons for that difference have not yet been examined. These results suggest that bear sightability may not be as variable among areas and sex-age classes as previously thought.

Two groups of population estimates were developed from this study: (1) numbers of adult bears >3 years of age and (2) total numbers of bears including COY and other offspring. The most statistically valid estimate was the former because it violated fewer crucial assumptions. The adult (>3 year-olds) population estimate within the 1,862 km^2 area was 28.2 bears and the total population estimate was 36.9. The 80% confidence interval (CI) for the adult estimate was 25.2-35.4 (95% CI = 23.6-39.1), and for the total estimate the 80% CI was 32.8 to 42.8 (95% CI = 31.1-46.3). Density estimates were 1/66.0 km^2 for adult bears (80% CI 52.6-74.0) and 1/50.5 km^2 (80% CI 43.5-56.7) for total bears, which includes young assigned the same status (marked or unmarked) as their mothers. The adult estimate was quite similar to the total number of individual radio-collared bears (29) that were known to have been present on ≥1 occasions within the census area during the 7 day search effort. The total bear population estimate (37) using mark-recapture methods was slightly lower than the number of radio-collared and uncollared young (40) that we knew were in the area on ≥1 days during the survey period. If we correctly aged 3 2.5-year-olds based on body size which accompanied one adult sow, the estimate for adult bears (>2.0 years age) was 32.4 with an 80 and 95% CI of 28.9-40.1 and 27.2-44.1, respectively.

Similar to other bear population estimates (Barnes et al. 1988, Miller et al. 1987, Reynolds et al. 1987, Schoen and Bier 1987, and Smith and Van Daele 1988), CIs converged as survey effort progressed. Population estimates and associated CIs leveled off by day 6 (Fig. 3). We surveyed 1 additional day to confirm that result and terminated the census effort after day 7.

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 reverse. Throughout their range, management of grizzly bears has been hampered by an inability to accurately monitor population status in a timely and cost-effective manner. Typically, by the time a change in status of a bear population is identified, needed remedial actions are severe and often ineffective. For these reasons, we recommend that the 80% CI be used for evaluation of 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 is associated with marking new individuals during the census. We compared the adult and total bear population estimates and respective CIs had no new individuals been radio-collared (Fig. 4) with those obtained in this study which included new marked individuals (Fig 3). If no new bears had been radio-collared during the census, the resulting adult population estimate would have been only 1.8% less than the estimate obtained by including 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). The total population estimate if no new bears had been captured and marked would have been 29.8% larger than the estimate obtained. The difference in CI was similar to that obtained for adult bears in that the CI 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 conclude that the primary benefit of capturing and marking new bears as encountered was a reduction in the CIs and perhaps a more accurate total estimate. Similar results were reported by Miller et al. (1987).

Total operational cost (excluding salaries) of the Noatak bear survey was $64,713 (Table 4). Approximately half that cost was for capturing and radio-collaring 25 adult bears. We were interested in continuing to relocate the radio-collared individuals after the census effort so some of these costs would have occurred anyway. If we had not been interested in permanently marking the bears, costs could have been reduced several thousand dollars by exclusively using break-away collars or some other temporary method of attachment. If we had used that approach, the radio collars could have been retrieved and used elsewhere once they had fallen off. Expenses for the density estimation procedure could have been substantially higher without the benefit of a contract for helicopter costs and use of government-owned or leased aircraft. With commercial aircraft at commercial rates, the projected cost of the census would have approached $108,000 (Table 4).

Otis et al. (1978) and White et al. (1982) list 4 assumptions which must be met for capture-recapture population estimation methods to be valid. The 4 assumptions are: (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.

We suggest that the above assumptions are either met completely or that violations are sufficiently insignificant to provide for reasonable use of mark-recapture methods for estimation of grizzly bear population size in relatively small areas. Use of radio collars to monitor which individual bears (bear-days estimate) are present or absent from the census area eliminates or substantially reduces violations of population closure. Assumption number 2 is met even if an animal loses its mark because with radio collars and subsequent visual identification, the loss would be detected before the animal was included in daily calculations. For example, during this study 1 bear shed its collar on the sixth day of the census. This was identified on the day that it occurred and the bear was subsequently treated as an unmarked individual after the loss of its mark. Thus we believe that assumption number 3 was met in all cases.

The largest potential problem with the method used by Miller et al. (1987) is potential violation of assumption number 4. This particular assumption has hampered all mark-recapture studies and was the principal topic of the Otis et al. (1978) monograph. If Becker's (1988) preliminary analyses are valid and accurate, and if substantiated by future replications, they have significant ramifications for the use of this method for estimating bear numbers. Perhaps White et al's. (1982) statement that equal catchability is an unattainable ideal in natural populations may require re-evaluation for grizzly bears in certain areas under specific sets of conditions.

An additional assumption is that all observations are independent of one another. Because that assumption is violated when unmarked young are treated in the same manner 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 adults are sighted in breeding pairs. The largest 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 but point estimates should be similar (E. Becker, pers. commun.).

Use of mark-recapture procedures in this study was successful in part because a relatively high (>50%) proportion 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 which may be overcome with further refinement (Reynolds et al. 1987, Miller this volume).

Density Comparisons

Our reported total density estimate falls near the midpoint of published density estimates for arctic study areas in North America (Table 5). Reynolds (1982) reported that for North Slope Alaskan populations, high bear densities in optimum habitat approached 1 bear/50 km^2 and low density in lower quality habitats was about 1 bear/207 km^2. Most grizzly bear density estimates are based on 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 is not 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: CAs 5-10). Only 10% of the bears observed during the surveys were found in the lower elevation, southern CAs (1-4), and 80% of those observations were within CA 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 movements and demographic studies.

During spring 1986, we captured 48 bears, 31 of which were radio-collared, to aid in defining a census area boundary but also to minimize potential observability 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 of the objectives 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 of GMU 23 believe bear populations are currently higher than historical levels (Loon 1988). Because of these concerns and because grizzly bears are classified as a subsistence use species (defined as customary and traditional uses by rural Alaska residents of wild, renewable resources for direct personal or family consumption as food, shelter, fuel, clothing, tools, or transportation and for the making and selling of inedible portions for handicraft articles for barter, customary trade, and sharing [ANILCA, P. L. 96-487, Title 8, 1980]) in northwest Alaska, a number of local residents have advocated liberalizing grizzly bear hunting seasons and bag limits. Many local residents of GMU 23 believe there are too many bears now and would prefer a smaller population (Loon 1988).

Alaskan hunting regulations currently require that the hide and skull of all grizzly bears harvested be presented to officials of the Alaska Department of Fish and Game (DF&G) within 30 days of the date of kill for sealing. Sealing of bear hides and skulls has been required since statehood but compliance in some GMUs, especially GMU 23 has been low. Annual reported harvests of grizzly bears in GMU 23 have gradually increased over the years (Fig. 5) 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 paralleled those of the unit but an increasing proportion of the total GMU harvest has come from NRSA (Fig. 6).

Use of grizzly bears for food is reportedly widespread in GMU 23 (Loon 1988). Based on key respondent interviews in selected villages, Loon (1988) estimated that only 14-18% of actual harvests of grizzly bears are reported to the DF&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's (1988) estimates contain no measure of accuracy or precision, if assumed correct then actual annual harvests in GMU 23 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 1987a,b). The use of such data when $\geq$50% of the harvest is unreported would probably be even less reliable. Because of unreported harvests and problems with using harvest data to assess status of the bear population it was necessary to evaluate the status of the population and the potential for allowing higher harvests with other methods.

To assess the potential impacts of human harvests on the study area population, it was necessary to extrapolate the bear density estimate from the census area to a much larger area, and compare this estimate with known minimum harvests. We estimated the total bear population within the NRSA and adjacent areas, which encompassed nearly all of the home ranges of radio-collared bears, based upon by the apparent distribution of bears within the study area in 1986 and 1987. For this analysis, we assumed bear densities in the mountainous portions of the NRSA were similar to those in the census area (1/50.5 km^2) and in the lower lying southern areas we assumed densities were 50% lower or about 1/100.5 km^2. This 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 of the NRSA and adjacent areas into 1 of 2 density strata. Approximately 5,947 km^2 were classified as high density habitat and 6,932 km^2 as low density habitat. The extrapolated bear population for the 12,879 km^2 area was 188 bears.

Minimum reported annual harvests within the NRSA have ranged from 0-23. From 1983 through 1987, reported harvests have ranged from 11-23. Comparison of these latter annual harvests with the estimated bear population results in annual harvest rates ranging from 5.9-12.2% of the bear population (Fig. 7). If estimated unreported harvests from communities within or adjacent to the NRSA (Noatak, Kivalina, and 25% of Kotzebue kills from Loon [1988]) were added to known reported harvests, then the estimated annual harvest rates during 1983 through 1987 would increase to 7.5-15.7% . These rates may also be low because some bears are known to have been killed and not retrieved (unpubl. data) and were probably not represented in Loon's (1988) sample.

Although our harvest rate estimates are admittedly crude, comparison with harvest rates reported from elsewhere in North America (Grizzly bear compendium 1987:81 - LeFranc et al. 1987) suggests that current harvests approach or possibly exceed the maximum allowable harvest. They certainly are well in excess of the conservative exploitation rates of 2-4% recommended for northerly latitudes by Lortie (unpubl. data), Reynolds (1976), and Sidororowicz and Gilbert (1981). Even if our estimates are only a rough approximation of actual harvest rates, they suggest that hunting seasons and bag limits can not be liberalized without causing a reduction in the bear population.

Summary

In spite of 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 quickly and

objectively estimate population size and density within relatively small areas. More importantly, the resulting estimates are repeatable and include a measure of precision. Other methods to date have relied to a large extent on the experience and expertise of the investigator, have been expensive, time consuming, usually contain no measure of precision, and may have other unknown problems. Application of density estimates obtained from mark-recapture procedures in association with radiotelemetry data allowed assessment of current annual harvest rates in relation to human exploitation.

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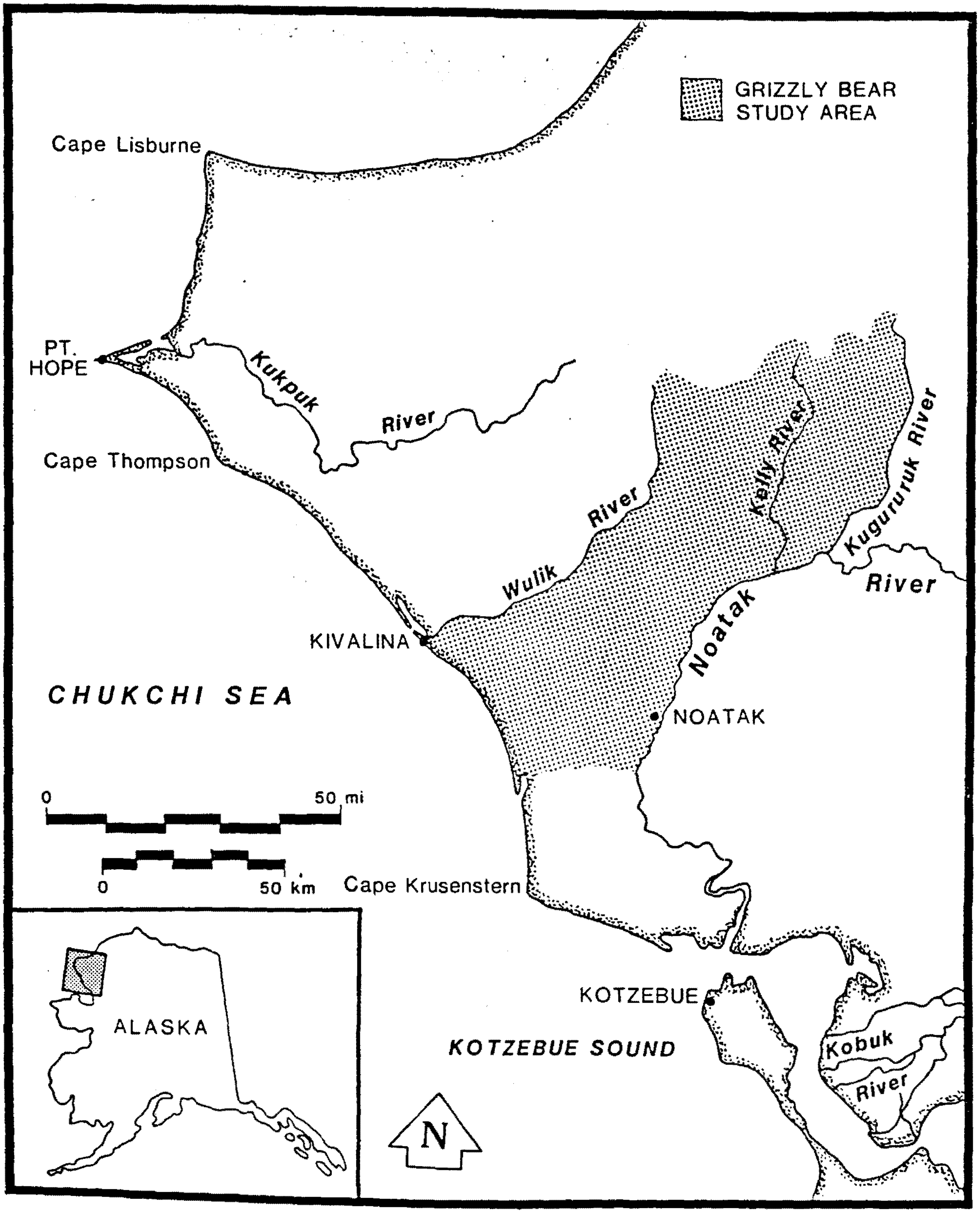

Fig. 1. Boundaries of the Noatak River Study Area in relation to the Red Dog Mine and associated facilities in northwest Alaska where grizzly bears were studied from 1986 through 1988.

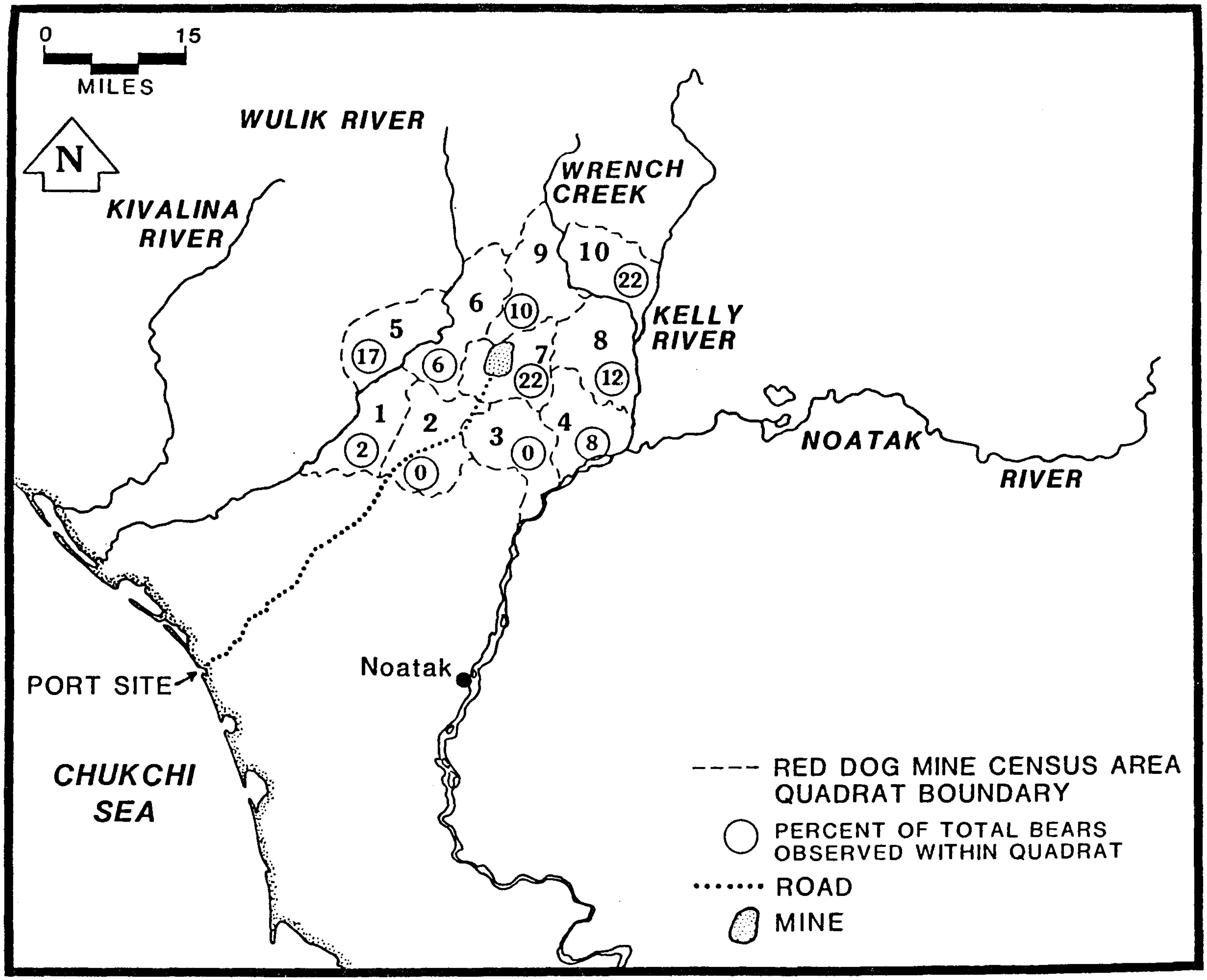

Fig. 2. Boundaries of Count Areas used to census grizzly bears within the Red Dog Mine Census Area of northwest Alaska from 29 May through 4 June 1987.

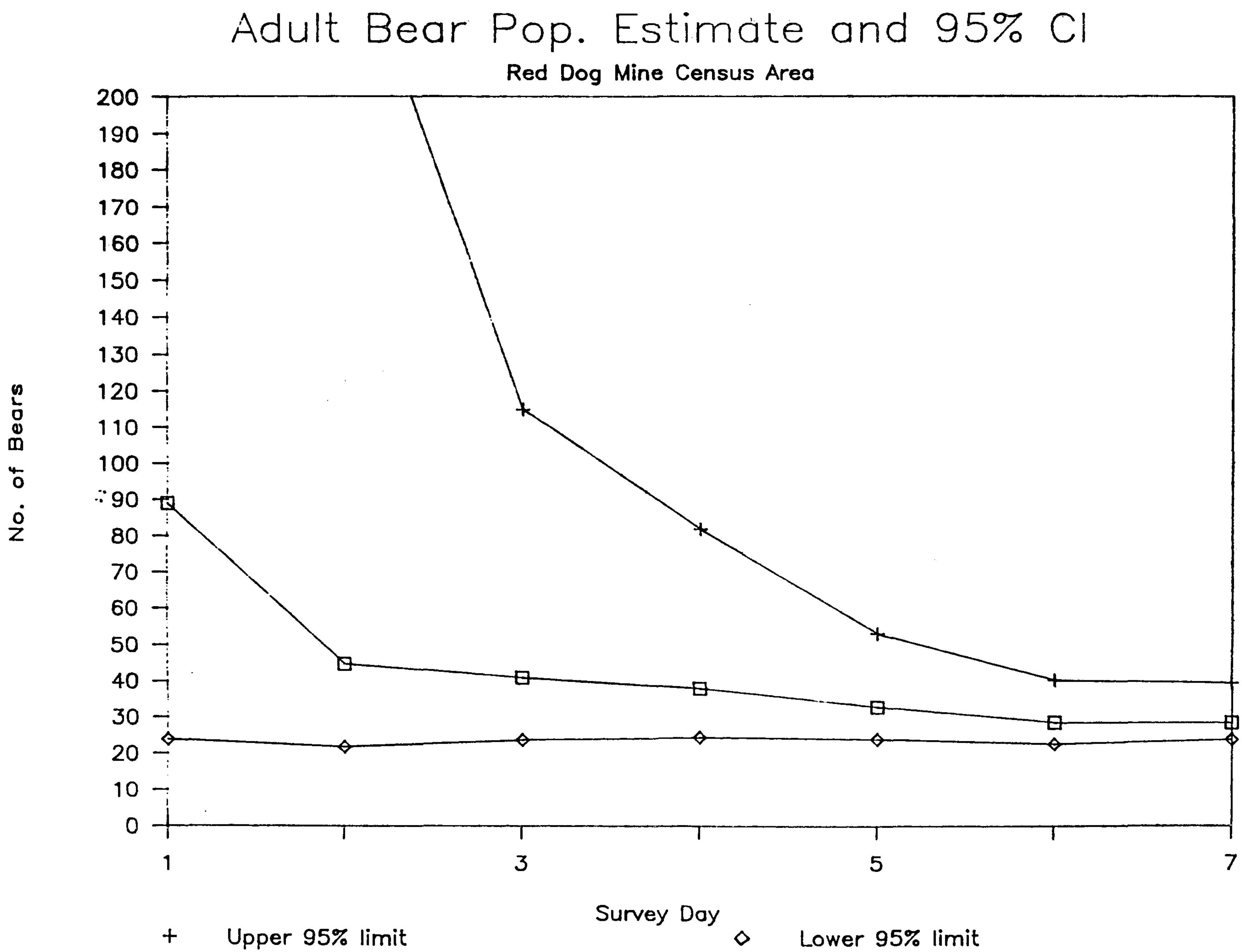

Fig. 3. Daily adult (>3 years age) grizzly bear population estimates and associated 95% confidence intervals derived from using bear-days estimator (Miller et al. 1987) during a census within the Red Dog Mine Study Area of northwest Alaska during 29 May through 4 June 1987.

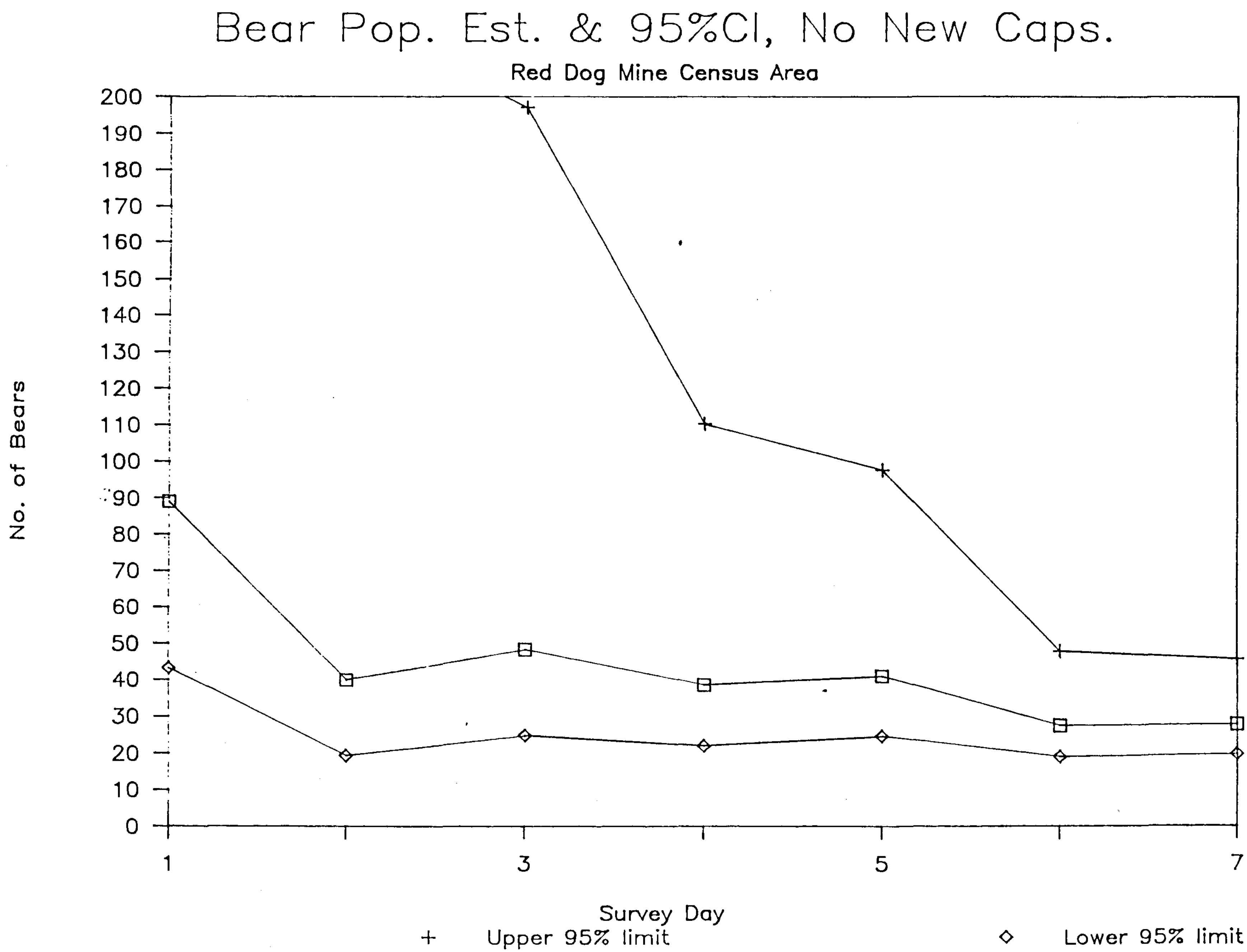

Fig. 4. Daily adult (>3 years age) grizzly bear population estimates and associated 95% confidence intervals for the Red Dog Mine Study Area in northwest Alaska had no new bears been captured and radio-collared during the census from 29 May through 4 June 1987.

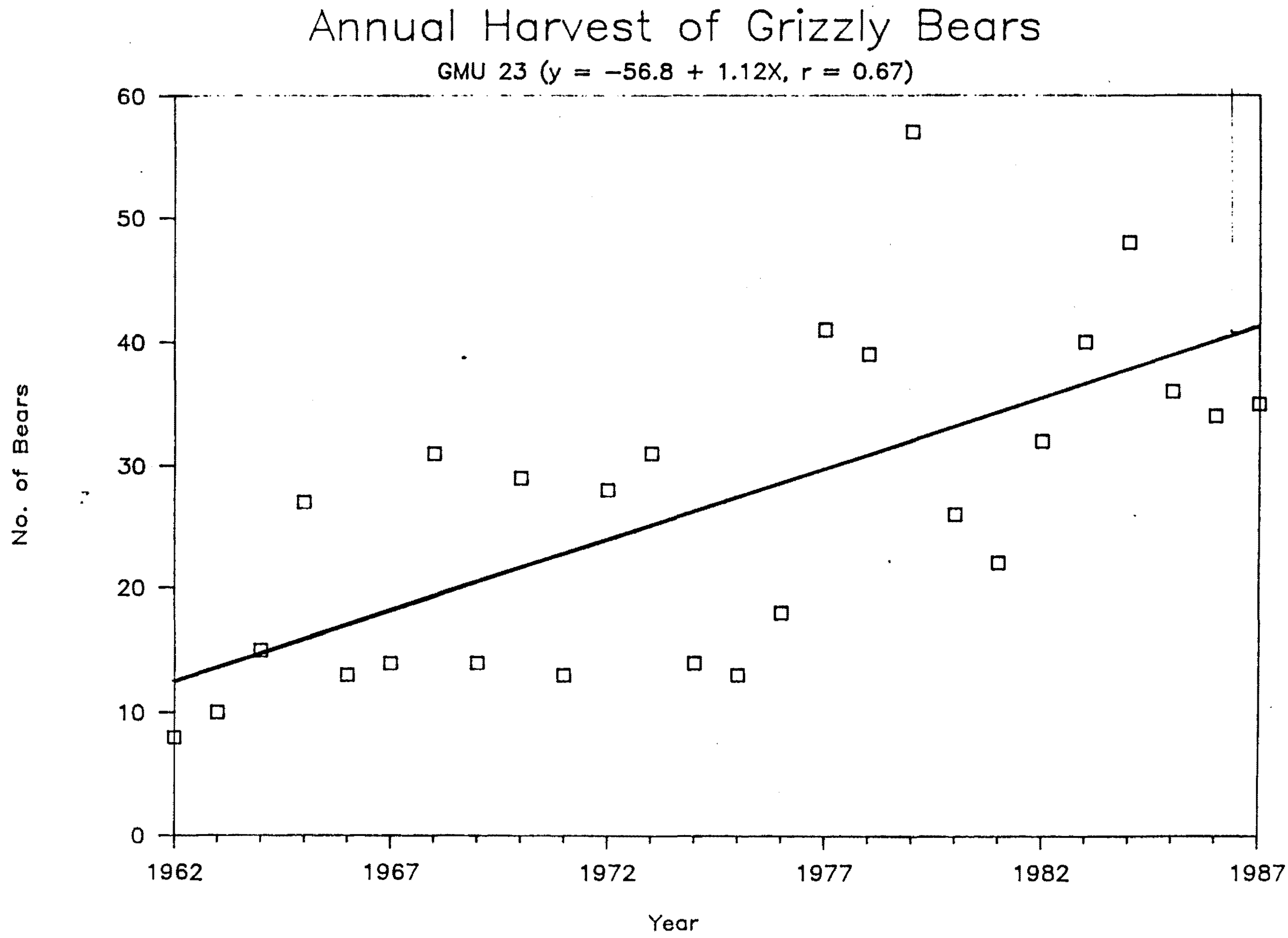

Fig. 5. Reported annual harvest of grizzly bears within GMU 23 of northwest Alaska from 1962 through 1987.

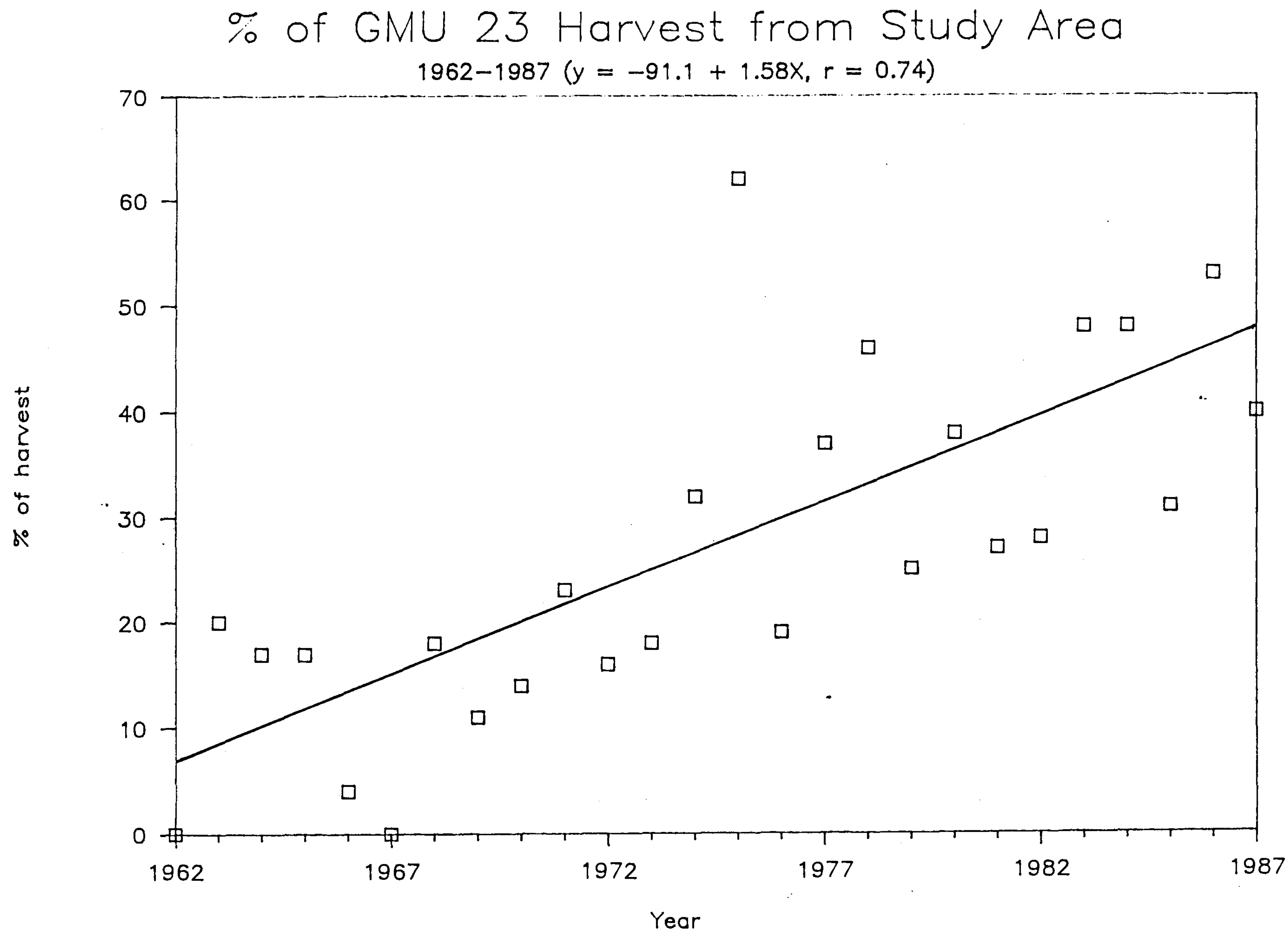

Fig. 6. Proportion of reported GMU 23 grizzly bear harvests occurring within the Noatak River Study Area in northwest Alaska from 1962 through 1987.

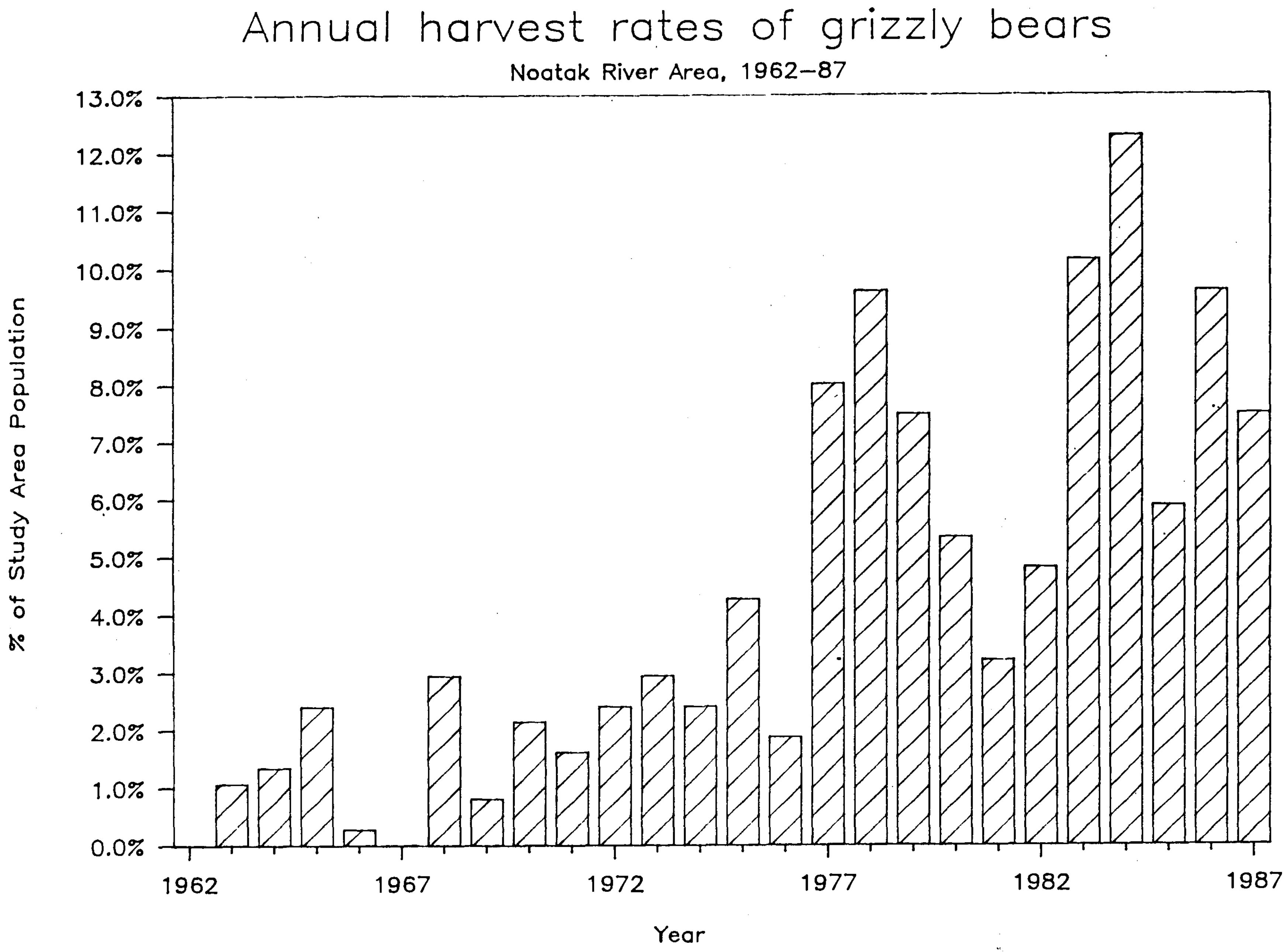

Fig. 7. Estimated annual harvest rates of grizzly bears within a 12,879 km^2 area which encompassed the Noatak River Study Area from 1962 through 1987. The estimates assume a stable bear population of 188 (see text for methods) and consider only known reported harvests.

Table 1. Summary of survey effort (min/km^2) during a census of grizzly bears conducted from 29 May through 4 June 1987 near Red Dog Mine in northwest Alaska.

Count area	Km^2	Min/day 1	2	3	4	5	6	7	Total min	Min/Km^2	Min/Km^2 day
1	160.6	179	181	115	183	111	140	135	1044	6.5	0.93
2	202.0	215	159	180	130	130	154	165	1133	5.6	0.80
3	191.7	237	163	160	150	205	150	140	1205	6.3	0.90
4	183.9	158	148	120	173	195	140	175	1109	6.0	0.86
5	186.5	171	131	125	116	210	170	185	1108	5.9	0.85
6	181.3	117	161	210	190	165	175	160	1178	6.5	0.93
7	181.3	150	180	159	200	150	202	135	1176	6.5	0.93
8	196.8	170	180	225	205	135	180	175	1270	6.5	0.92
9	199.4	185	180	170	180	184	399	165	1463	7.3	1.05
10	178.7	188	165	225	195	113	146	185	1217	6.8	0.97
Totals	1,862	1770	1648	1689	1722	1598	1856	1620	11903	6.4	0.91
Min/Km^2/day		0.95	0.89	0.91	0.92	0.86	1.00	0.87	0.91		

Table 2. 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 3. 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	35	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

Table 4. Summary of actual and projected costs for censusing grizzly bears within the Red Dog Mine census area of northwest Alaska from 29 May through 4 June 1987.

Item	$/hr	No. hours	Government costs: Survey w/o capture	Government costs: Capture costs	Projected costs at commercial rates: $/hr	Projected costs at commercial rates: costs
Helicopter	$177/hr and $678/day	42.1 25.4[a]		$16,685.	$395.	$26,662.
Fuel				3,100.		
Fixed-Wing						
PA-18 - State lease	71.	75	5,376.		135.	10,125.
CA-185 - State lease	84.	96	8,022.		180.	17,280.
PA-18 - State	--	70			135.	9,450.
PA-12 - State	--	70			135.	9,450.
Arctic Tern - NPS	48.	50	2,400.		135	6,750.
PA-18 - (NW Aviation)	135.	52	7,060.	2,025.	135	7,060.

- continued -

Table 4. Continued

Item	$/hr	No. hours	Government costs: Survey w/o capture	Government costs: Capture costs	Projected costs at commercial rates: $/hr	Projected costs at commercial rates: costs
Miscellaneous						
Radio-Collars	340. ea	25		8,500.		8,500.
Drugs				1,500.		1,500.
Fuel			5,390.			5,390.
Travel			2,166.			2,166.
Groceries			2,320.			2,320.
Lodging			440.			440.
Maps			441.			441.
Darting/other equipment			1,313.	650.		1,313.
Totals			$34,928.	$32,460.		$108,847.

a Number of hours to commute from Anchorage to Kotzebue and return.

Table 5. 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. 1983a
Northern Yukon	48	Pearson 1976
Western Brooks Range, AK	42-44	Reynolds 1984
NW Alaska	50(44-57)[a]	This study
Eastern Brooks Range, AK	83-304	Quimby 1974 Quimby and Snarshi 1974 Curatolo and Moore 1975 Reynolds 1976
Northwest Territories	211-262	Nagy et al. 1983b

[a] 80% confidence interval.

Appendix B. Copy of manuscript accepted for publication in the Journal of Wildlife Management.

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RH: Immobilization of Grizzly Bears . Taylor et al.

IMMOBILIZATION OF GRIZZLY BEARS WITH TILETAMINE HYDROCHLORIDE AND ZOLAZEPAM HYDROCHLORIDE.

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Abstract: We successfully immobilized 185 grizzly bears (*ursus arctos horribilis*) with tiletamine hydrochloride (HCl) and zolazepam HCl during May-June 1986-87. One hundred eighty bears were captured in several areas in Alaska by darting from a helicopter; 5 were immobilized from traps or snares in Banff National Park in Alberta, Canada. Use of the recommended dose for immobilizing grizzly bears (7-9 mg/kg) resulted in a mean induction time of 4.1 $\pm$ 1.8 (SD) minutes and a safe handling period of 45-75 minutes. Tiletamine HCl/zolazepam HCl was an excellent drug for immobilizing grizzly bears because of rapid induction, timely and predictable recovery, wide safety margin, and few adverse side effects.

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Key words: grizzly bears, immobilization, tiletamine HCl/zolazepam HCl, (*Ursus arctos horribilis*).

A 1:1 mixture of tiletamine HCl and zolazepam HCl (TZHCL) has been used to immobilize several wildlife species (Schobert 1987). Appropriate dosages have been established for free-ranging polar bears (Haigh et al. 1985, Stirling et al. 1985) and black bears (Stewart et al. 1980). However, the literature only mentions its use on captive grizzly bears (Gray et al. 1974, Bush et al. 1980).

Tiletamine HCl is a cyclohexamine dissociative anesthetic agent, with a pharmacological action characterized by cataleptoid anesthesia, analgesia, normal pharyngeal-laryngeal reflexes, and muscle rigidity. Eyes normally remain open with the pupils dilated; however, corneal reflex is maintained. Zolazepam HCl is a diazepinone tranquilizer with central nervous system depressant actions characterized by muscle relaxation, anticonvulsant, and hypnosis (A. H. Robins Co., Telazol, package insert, Richmond, Va. 1987). Combining the 2 products results in the manifestation of desirable characteristics of each while minimizing undesirable side effects. Even though TZHCL is classified as a general anesthetic, the eyelids usually remain open and, at lower dosages, the following reflexes persist: corneal, palpebral, laryngeal, pharyngeal, pedal, and pinnal. The pedal and pinnal reflexes diminish at higher dosages (Gray et al. 1974).

The objective of this study was to establish effective dosages of TZHCL (Telazol, A. H. Robins Company, Richmond, Va; Zoletil, Reading Laboratories, L'Hay-les-Roses, France) and determine the benefits and disadvantages associated with its use to immobilize free-ranging grizzly bears. We thank S. D. Miller and B. H. Campbell for providing additional opportunity for testing this drug. They also assisted in data collection and review of the manuscript.

STUDY AREA

This evaluation of TZHCL to immobilize grizzly bears was conducted in 5 areas in Alaska ranging from southern coastal delta inhabited by typically large bears at moderate densities to north slope mountains and foothills inhabited by much smaller bears at very low densities (LeFranc 1987:52-53). The areas included the west side of the Copper River Delta in the Gulf of Alaska, mountains and foothills of the upper Susitna River drainage in the southcentral Alaska Range, mountains and foothills of the northcentral Alaska Range between the Wood River and Delta Creek, portions of the Noatak River drainage and De Long Mountains in the southwestern Brooks Range, and mountains and foothills of the upper Utukok River and Kokolik River drainages in the northwestern Brooks Range.

METHODS

One hundred eighty grizzly bears were immobilized with TZHCL in Alaska during May-June 1986-87. Bears were first located from a fixed-wing aircraft and then darted from a helicopter. To minimize stress to bears, the helicopter moved >1 km after darting until immobilization was confirmed from fixed-wing aircraft. However, if bears approached precipitous or wet terrain, they were hazed from such potentially hazardous sites by the helicopter. Five additional bears were trapped or snared in Banff National Park, Canada and administered the drug with a jab stick or dart gun (R. Kunelius, Banff National Park, unpubl. data).

The TZHCL mixture was supplied in powdered form in 500 mg vials and was reconstituted with sterile water to make a 200 mg/mL concentration (20% solution) for most of the bears. A 300 mg/mL concentration was used for a few large male bears to allow the recommended minimum dose to be given in a single 7 mL or smaller-sized dart.

Induction was defined as the time from intramuscular injection until the bears were in sternal or lateral recumbency with little or no head movement. Recovery was the time from induction until bears could stand.

All bears, except those captured on the Copper River Delta, were processed where immobilized, which usually took <30 minutes. Attempts were made to cool bears with body temperatures >41 C by placing them in water or packing snow or wet moss on their pads and groins. Yearlings and 2-year-old cubs captured with females were placed with the females for recovery to prevent separation of family groups. Sixteen bears captured on the Copper River Delta were transported to a staging area, where they were processed prior to translocation to a new release site (Campbell et al. 1988). Light anesthesia was maintained during the translocation with as needed supplemental intramuscular injections of TZHCL dosed at 2-3 mg/kg.

RESULTS

One hundred eighty-five free-ranging grizzly bears >1 year of age were immobilized with TZHCL. One hundred sixty-eight were successfully immobilized with a single dose, providing 166 accurate induction times and a median induction time of 4.0 minutes (Table 1). Seventeen bears required a second or third dose before they were adequately immobilized. Of these, 11 were initially underdosed (<6 mg/kg), 3 were darted in a poor location (foot, tail, or bone), and 3 required additional darting for unknown reasons.

Induction times decreased as dosages were increased. Initially, 18 bears were dosed at approximately 5 mg/kg, but this dosage was inadequate to ensure rapid induction (<10 min) and safety for capture personnel. Thirteen of these bears required supplemental doses by dart or hand injection to complete processing. Therefore, dosage was increased to approximately 8 mg/kg. Sixty-three bears received between 7-9 mg/kg and 61 were successfully immobilized with a single dose in a mean of 4.1 $\pm$ 1.8 (SD) minutes. Six bears received dosages ranging from 17.5 to 22.2 mg/kg. The immobilization periods for these bears were characterized by shorter induction times (x = 1.6 $\pm$ 0.7 min), deeper anesthesia, and uneventful recoveries. Induction times for bears immobilized in traps or snares in Banff National Park were similar to helicopter-captured bears equivalently dosed (Table 1).

Sixteen bears, translocated from the Copper River Delta, were immobilized for a mean of 2.7 hours (range = 1.6-4.2 hr). Supplemental doses of TZHCL dosed at 2-3 mg/kg provided an additional 45-60 minutes of light anesthesia.

Behavioral responses observed during induction in the order they appeared were: disoriented gait, high stepping, loss of use of hindlegs, licking lips, loss of use of forelegs, loss of head and neck movement, nystagmus, and loss of tongue movement. These responses are consistent with those described for polar bears (Haigh et al. 1985).

Depth and length of anesthesia varied with drug dose. At 7-9 mg/kg, approximately 60 minutes (range = 45-75 min) of safe handling time were available to process bears. Occasional head movement occurred in some individuals, suggesting that this dosage would not provide adequate analgesia for major surgery. No antagonist is currently available for this drug; however, recovery is rapid and predictable. Recovery phases mimic in reverse order the signs observed during induction but occur at a much slower rate. Recovery occurred between 85 and 160 minutes postinduction (n = 21). As a result of the helicopter chase, body temperatures and respiration rates were elevated and heart rates slightly elevated 5-15 minutes following immobilization (Table 2). However, consistent with observations in polar bears (Haigh et al. 1985, Stirling et al. 1985), thermoregulation was not impaired. Within 30-45 minutes, body temperatures and respiration rates in most bears had decreased to levels considered normal for resting bears: 37.5-38.3 C and 15-25 breaths/minute, respectively (Wallach 1978). Fifteen bears had body temperatures $\geq$40 C and respiration rates $\geq$40 breaths/minute when measured 5-10 minutes postinduction. Both parameters had significantly decreased (P < 0.05) when measured 25-45 minutes postinduction. Physiological parameters of bears translocated from the Copper River Delta were initially measured 30-45 minutes postinduction (Table 2). These parameters were at or near normal values at that time and remained so during translocation (1.6-4.2 hr postinduction).

Tiletamine HCl/zolazepam HCl appears to have an acceptable safety margin (Table 1). Only 1 of 185 bears died as a result of immobilization with TZHCL. A 3-year-old emaciated female weighing 57 kg was immobilized following a prolonged chase characterized by continuous running. She received 15.1 mg/kg of TZHCL because of overestimation of body weight. Induction was normal and took 3 minutes. At 21 minutes postinduction, her body temperature and respiratory rate were within normal limits. She expired 41 minutes postinduction.

DISCUSSION AND MANAGEMENT IMPLICATIONS

Grizzly bears immobilized with TZHCL dosed at 7-9 mg/kg are safe for capture crews to approach and handle. The nonaggressive, predictable patterns of recovery, and ability to give supplemental doses make it potentially useful for bears requiring translocation. Because of the difficulty in estimating weights of grizzly bears, especially when locating and darting from aircraft, we recommend dosing at 9 mg/kg. Bears receiving slightly higher doses tended to be immobilized more quickly, and recovery times were not adversely affected. Those receiving doses <6 mg/kg often caused problems.

Few adverse side effects were apparent. No convulsions were observed with dosages <22.2 mg/kg. One common side effect was excessive salivation. This was not a problem during handling since pharyngeal and laryngeal reflexes are maintained. If necessary, it could be controlled with atropine sulfate. Because the eyes often remain open, application of a sterile, ophthalmic ointment may be necessary to prevent drying from wind or sun. Occasional brief tremors were observed in a few bears, usually <30 minutes following immobilization. Many bears defecated 1 or more times, usually >30 minutes after receiving the initial injection or after receiving supplemental injections.

Death of the young female may have resulted from the relatively high dose (15.1 mg/kg) of TZHCL; however, poor body condition and stress associated with capture were contributing factors. Although no indication of respiratory depression was noted in this bear, Gray et al. (1974) and Schobert (1987) indicated it may occur at higher dosages. Six bears received higher dosages (17.5-22.2 mg/kg) with no observed respiratory depression and normal recoveries.

One of the physical characteristics of TZHCL in solution is it forms a sticky film on surfaces it contacts. When darts are used as the delivery system for this drug, they should be well lubricated and should not be held for >1 day before being used or disassembled.

We found TZHCL an excellent drug to immobilize/anesthetize grizzly bears. The advantages far outweigh the disadvantages. Primary among the disadvantages is TZHCL is a controlled substance, Schedule III drug requiring Drug Enforcement Administration registration. Other disadvantages include short storage life once in solution (4-14 days) and small quantity availability (500 mg vials).

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Table 1. Effective single doses and induction times for grizzly bears immobilized with tiletamine HCl/zolazempam HCl in Alaska, 1986-87.

Study area	n	Tiletamine/zolazepam (mg/kg) median	x	SD	range	Induction time (min) median	x	SD	range
Copper River Delta[a]	14	7.4	9.1	4.9	5.1-22.2	3.4	4.0	3.7	0.3-15.4
Noatak River	18	6.7	6.9	2.3	4.4-15.1	3.5	3.9	1.4	2-8
Susitna River[b]	35	7.6	9.4	4.1	4.0-22.2	3.6	3.7	2.6	0.6-11
Western Brooks Range and northern Alaska Range	94	7.3	7.4	1.9	3.4-13.6	4.0	4.6.	2.4	1-14
Banff Nat'l Park[c]	5	7.2	7.6	1.0	6.5-8.9	3.0	3.2	1.7	2-5
Total	166	7.4	7.9	3.0	3.4-22.2	4.0	4.3	2.8	0.3-15.4

[a] Data contributed by B. H. Campbell.

[b] Data contributed by S. D. Miller.

[c] Source: R. Kunelius, Banff National Park, P. O. Box 900, Banff, Alberta TOL OCO.

Table 2. Temperature, respiration rate and heart rate of grizzly bears immobilized with tiletamine HCl/zolazepam HCl in Alaska, 1986-87.

Study Area	n	x	SE	range	n	x	SE	range	n	x	SE	range
Copper River Delta[a]	16	37.3	0.2	36.2-38.7	16	17	0.9	10-22	16	98	2.4	80-120
All other areas combined[b]	133	39.1	0.1	34.0-41.9	112	30	1.5	6-68	61	100	2.7	60-170

[a] Data obtained following transport to a processing area, usually 30-+45 min after immobilization.

[b] Data obtained within 5-15 min of immobilization.

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