

RESPONSES OF GRIZZLY BEARS TO SEISMIC SURVEYS IN NORTHERN ALASKA

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Abstract: Responses of denning grizzly bears (*Ursus arctos*) to noise associated with winter seismic surveys and small fixed-wing aircraft were studied on the north slope of Alaska during the years 1978–81. Changes in signal amplitude and collar temperature were monitored in 4 bears denned near seismic lines. Heart rates monitored by implanted transmitters, were measured in 1 of these bears and in a 2nd bear not subjected to seismic exploration activities. None of the bears left their dens as a result of seismic exploration activities. In undisturbed midwinter conditions, heart rates of 2 denned bears ranged 12–26 beats/min, but rose to 30–50 beats/min for brief periods at least once or twice in 24 hours. Signal amplitudes and collar temperatures, monitored in 1 bear, did not vary. During 3 days when seismic crews were working near 1 den, changes in signal amplitude and collar temperatures, accompanied by increases in heart rate to a maximum of 64 beats/min, indicated that the bear moved several times. Heart rates of 2 bears recorded during midwinter overflights were the same as those measured in midwinter from the ground in undisturbed conditions. About the time of emergence, heart rates were higher than those recorded in midwinter and during undisturbed resting behavior in mid-June.

Int. Conf. Bear Res. and Manage. 6:169–175

Oil and gas exploration and development activities have rapidly expanded during the past decade in northern Alaska, increasing the potential for adverse impacts on wildlife. Grizzly bear populations north of the Brooks Range are particularly vulnerable at this northern extent of their range because of limited food and cover, low reproductive potential, and requirements for large individual home ranges (Reynolds 1980).

In 1977 a natural resources inventory program began in the National Petroleum Reserve-Alaska (NPR-A) in northern Alaska between the western Brooks Range and the arctic coast. One portion of this program involved petroleum explorations using seismic detonations; another included biological studies of fish and wildlife inhabiting NPR-A (U.S. Dep. Int. 1979). Winter ground-based seismic surveys were conducted from January to May 1978–80. Potential sources of disturbance to denned bears included sounds of operating vehicles (track-mounted drill rigs, geophone trucks, surveyor Bombardiers, snow machines, support trains), sounds and shock waves associated with the detonation of about 40 kg of dynamite at approximately 30 m below the surface, and sounds of aircraft.

Seismic surveys operated under conditions of land use permits authorized by the U.S. Dep. Int., Bur. of Land Manage. Permit stipulations designed to minimize impacts on wildlife were formulated as part of a program to monitor the effects of seismic surveys and the drilling of exploratory wells. One stipulation required that no construction, vehicle traffic, or seismic detonations could take place within 0.8 km of any known bear den (U.S. Dep. Navy 1977). Objec-

tives of this study were to test the feasibility of using changes in radio signal amplitude, collar temperature, and heart rate of radio-instrumented grizzly bears to detect movement of bears in dens and to monitor bears before, during, and after seismic surveys and aircraft overflights.

Thanks are due L. M. Philo, M. Terry, and J. Everitt for their surgical skills and advice in implanting heart rate transmitters and to anonymous reviewers of an earlier draft of this manuscript. Special recognition for support of the study concept is due to John Santora, U.S. Dep. Int., Bur. of Land Manage. This work was funded by the Bur. of Land Manage., Arctic Resource Area; Alaska Dep. of Fish and Game; Naval Arctic Res. Lab.; and the Office of Naval Res. Contract N00014-79-C-0605 to the Univ. of Alaska-Fairbanks. Field facilities during winter seismic exploration periods were provided by Geophysical Services Incorporated.

STUDY AREA

The study area is approximately 300 km southwest of Barrow and 240 km northeast of Kotzebue in the northern foothills of the Brooks Range in northwestern Alaska. Investigations of grizzly bear ecology that used marked and radio-collared bears had been conducted in this area since 1977 (Reynolds 1980). The physiography of the southern one-quarter of the area is mountainous; elevations range from about 600 m in river or creek valleys to 1,300 m for the highest peaks. The northern three-quarters of the area is char-

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acterized by a series of east- and west-oriented ridges, buttes, and rolling hills of 600–900 m elevation; these were cut through by 2 major north-flowing rivers, the Utukok and Kokolik. The area contains no roads or permanent airstrips. The nearest human habitation is the Eskimo village of Point Lay, 130 km northwest. Tussock tundra characterized by cottongrass (*Eriophorum* spp.) and sedges (*Carex* spp.) is the predominant vegetative type in the study area. In addition, wet sedge meadow communities are found in poorly drained sites, and dryas (*Dryas* spp.)-fell-field communities are found on ridge slopes and mountains. Patches of willows (*Salix* spp.) 0.5–2.5 m high are found along broad braided river channels (Spetzman 1959).

METHODS

Grizzly bears monitored during this study were radio-collared or had heart-rate transmitters implanted subcutaneously during other research (Reynolds 1980, Follmann et al. 1982). Because these transmitters were already in place, we were able to cost-effectively monitor some responses of grizzly bears to potential disturbance related to winter seismic surveys.

We measured grizzly bear movement within dens from changes in signal amplitude and interpulse period. Signal amplitude was measured with a digital processor (in 0.2-dB units) connected to a radio receiver (Telonics, Inc., Mesa, Ariz.). Receiving antennas were mounted in a stationary position so that if the radiocollar on the bear were also stationary within the den, signal amplitude was stable; if the bear or its young moved, amplitude would fluctuate. Interpulse period (milliseconds), also measured by the digital processor, reflected the temperature of 3 previously calibrated radiotransmitters that contained thermistors. Interpulse periods were converted to temperature using a regression developed from temperature calibration points. Signal amplitude was recorded for 3 bears denning near seismic lines in 1978 and 1 in 1980; interpulse period was recorded for 2 of these bears in 1978 and 1 in 1980.

Heart-rate transmitters were implanted subcutaneously (Follmann et al. 1982) on 1 bear in September 1979 and 2 bears in August 1980. These long-range transmitters enabled us to monitor the heart rates of grizzly bears without our presence influencing their behavior, except when the effect of aircraft overflights on bears was being determined.

Heart rates, signal amplitudes, and collar temper-

atures were measured in 1 bear subjected to seismic exploration activities in 1980. In 1981, when no seismic activities were present, heart rates were recorded from a 2nd bear. Both bears were females denning with 2 young-of-the-year. Signal amplitude and collar temperature data were collected from the ground within 0.5 km of dens when seismic vehicles were working near dens and when seismic crews were absent. Heart rates were monitored from the ground and from a deHavilland turbine Beaver or Piper Super Cub 150 at altitudes of 70–300 m above ground level. When seismic crews were absent in March 1981, we also recorded 1 bear's heart rate for 2 min/hour for 72 hours using a remote instrument package left near the den. Other heart rate samples were recorded over 1-min periods.

RESULTS

Seismic Exploration Activities

Before detonation of seismic shots, signal amplitudes and interpulse periods of 3 radio-collared grizzly bears denning near seismic lines were stable during all but 1 observation on 18 and 30 March 1978 (Table 1). On 30 March, variability in signal amplitude, followed by a 2 C change in collar temperature of bear 1085, was observed between 0940 and 1000 hours, suggesting that the bear moved enough to expose the radiocollar to a different temperature.

On 20 March, the signal amplitude was stable for 35 min before and after detonation of a seismic shot 1.8 km from the den of bear 1105. During detonation of another seismic shot 1.4 km west of its den, amplitude was erratic for about 7 min, after which the digital readout disappeared (Table 1). Change in amplitude and eventual signal loss was probably caused by the bear moving within the den and assuming a position that attenuated the radio signal. Sounds associated with most detonations were soft "whooshing" noises due to snow settling, but detonation of the shot point nearest the den sounded like a rifle shot.

Seismic shots detonated about 1.6 km west of the den of bear 1085 on 1 April 1978 were also followed by changes in signal amplitude and interpulse period (Table 1). Temperature of the radiocollar changed 8 C, indicating that the bear moved inside the den.

Vehicles operating in the vicinity of dens were another source of potential disturbance to denning bears. Vehicles and track-mounted drills worked a

Table 1. Signal amplitude and temperature fluctuations of radio collars on denned grizzly bears before and during seismic detonations in northwest Alaska, 1978.

Date	Time	Bear no. and sex	No. of 1 min. obs.	Maximum change in signal amplitude (dB) ^a	Maximum change in collar temperature (C)
Before detonations					
18 Mar	1300–1330	1099 M	— ^b	0	0
18 Mar	1045–1115	1105 F	— ^b	0	— ^c
30 Mar	0845–1000	1085 F	5	50	2
During detonations					
20 Mar	1400–1600	1105 F	7	30 ^d	— ^c
1 Apr	1130–1245	1085 F	13	16	8

^a Each unit change indicates a 0.2-dB change in signal amplitude.

^b Periodic readings during 15-min interval.

^c No thermistor on this collar.

^d Signal lost after 7 min.

shotline within 1.4 km of the den of bear 1105, and tractors pulling sledges and tracked vehicles came within about 100 m of this den in mid-March 1978. Noise from these activities did not cause the bear to leave its den. However, in March 1980 a seismic crew in the study area reported what appeared to be a deserted bear den within 200 m of a seismic line. An unmarked bear was seen about 16 km east of this site during -29°C weather 2 days after surveyors marked the seismic line. Few radio-collared bears in the study area have been observed out of dens in midwinter, and winter sightings of bears in the Arctic are rare. This bear may have left its den in response to nearby seismic activities.

Variations in heart rate were also used to assess the response of denning bears to vehicle noise and seismic detonations. During March 1981, when no seismic exploration was conducted in the study area,

the mean heart rate of bear 1097 (a female with 2 cubs-of-the-year) was 17.6 when monitored 2 min/hour for 27 consecutive hours (Table 2). Heart rates ranged from 12 to 22 beats/min except during 2 periods when they increased to 31–35 beats/min. Heart rates recorded during short intervals on 8 December and 21 March in the absence of seismic activities were also 12–6 beats/min ($\bar{x} = 14.0 \pm 1.8$ SD, $N = 6$).

By comparison, on 7–9 March 1980, when seismic crews were working near (0.8–2.4 km) its den, mean heart rates of bear 1086, a female with cubs-of-the-year, ranged from 13 to 64 beats/min ($\bar{x} = 27.6 \pm 10.3$ SD, $N = 245$) and collar temperatures varied (Table 3). On 7 March, track-mounted rigs drilled 6 shot holes about 0.8–2.4 km north and west of the den. Throughout most of this period (between 1200 and 1600 hours), heart rates ranged from 13 to 37

Table 2. Heart rates of denning grizzly female 1097 measured 2 min/hour for 27 consecutive hours on 22–23 March 1981 in undisturbed conditions in northwest Alaska, 1981.

Time of day	N	Heart rate (beats/min)		
		\bar{x}	SD	Range
1010–1718	16	16.2	2.3	12–20
1818–1819	2	33.0	2.8	31–35
1919–0732	26	16.9	2.6	13–23
0832–0835	2	31.0	1.4	30–32
0933–1237	8	16.0	1.9	13–19
Total	54	17.6	4.7	12–35

beats/min ($\bar{x} = 21.3 \pm 5.6$ SD, $N = 74$), but 2 periods of higher heart rates were observed. At 1430 hours the heart rate increased to 50–60 beats/min and remained elevated for about 7 min. The heart rate again increased to 45–60 beats/min for a 3-min period at 1515 hours. During both times drills were working along the seismic line within 1.0 km of the den but were not visible nor audible by the observer from the observation point. Both increases in heart rate corresponded with fluctuations in signal amplitude and collar temperature, indicating that the bear or its cubs moved enough to change the temperature of its radio collar. At about 1600, when the vehicles were closest (0.8 km) to the den, the heart rate signal became faint and then no longer audible, indicating that the bear and/or its cubs moved so that the signals from the implanted transmitter were attenuated. Attempts to monitor heart rates throughout the night were unsuccessful because the signal was no longer audible.

On 8 March, rigs resumed drilling shot holes 0.8–.6 km west and south of the den between 0800 and 1600 hours. The heart rate signal was very weak and intermittent or not audible during much of the day, and the collar temperature and amplitude also fluctuated, again suggesting movement of 1 or more bears within the den. Heart rates ranging from 16 to 64 beats/min ($\bar{x} = 36.6$) were recorded only 15 times during the day (Table 3). On 9 March, seismic charges within 0.8–.6 km of the den were detonated. Exact time of the detonations could not be determined, but the shot points nearest the den were det-

onated between 0900 and 1430. Drillers were also working on a line 6–7 km east of the den. Unlike the 2 previous days, the wind was calm, and the sounds of drill trucks and other vehicles were audible from the observation point. Between 0930 and 1430 hours heart rates ranged from 33 to 47 beats/min ($\bar{x} = 40.2 \pm 4.7$ SD, $N = 13$); between 1700 and 1730, when vehicles passed within 1.0 km of the den, heart rates reached a maximum of 47 beats/min ($\bar{x} = 33.0 \pm 2.6$). Heart rate and collar temperature variability recorded on 7–9 March 1980, when seismic crews were near the den, were similar to those recorded in early May 1980, 3–0 days before the bear emerged from its den (Table 3). Collar temperatures were much higher in early May (-12 to $+11$ C) compared to February and March (-23 to -18 C), as were air temperatures outside the den. Winter collar temperatures of bear 1086 were colder than winter collar temperatures of other denned bears (Follmann, unpubl. data). When the den was examined in summer 1980, the radiocollar was found on the floor of the den. The collar of bear 1086 may have been shed by the bear early in the denning period. If true, this would not invalidate conclusions concerning movements of bears in the den because collar temperature and signal amplitude would still vary with changes occurring close to the female and her 2 cubs.

When seismic vehicles were absent or operating at least 3.0 km from the den in January through March 1980, heart rates of bear 1086 averaged 18.7 beats/min (SD = 4.1, $N = 250$) and ranged 12–32 beats/min, except for a 10-min period on 23 February when

Table 3. Heart rates and collar temperatures of female grizzly bear 1086 before, during, and after seismic crews were working near its den in northwest Alaska, 1980.

Date	Type of seismic activity within 1.5 km of den	Heart rate (beats/min)				Collar temp. (C)		
		<i>N</i>	\bar{x}	SD	Range	<i>N</i>	\bar{x}	Maximum change
21 Jan	None	7	21.3	1.8	19–24	—	—	—
15 Feb	None	34	18.8	2.6	16–27	1	-18	—
23 Feb	None	209	18.6	4.4	12–47	8	-22	0
7 Mar	Drilling	87	27.8	12.3	13–60	8	-20	3
8 Mar	Drilling	15	36.6	15.6	16–64	33	-20	4
9 Mar	Shooting	143	26.5	7.6	14–47	11	-22	2
28 Mar	None	8	20.3	2.3	19–24	1	-23	—
31 Mar	None	13	18.9	3.1	13–24	3	-20	0
1 May	None	6	25.3	4.1	17–32	1	-12	—
3 May	None	260	28.7	6.0	21–62	15	-8	7
4 May	None	80	26.7	8.3	16–60	6	11	4
9 May ^a	None	4	34.5	7.1	30–45	—	—	—

^a Female emerged from den with 2 cubs-of-the-year on 12 May.

mean heart rates of 47 beats/min were recorded (Table 3). During these observations the radio collar temperature remained steady and the radio signal amplitude did not fluctuate.

Aircraft Overflights

Variations in heart rate of 2 denned bears were used as measures of responses to potential disturbance by aircraft overflights. When monitored from the air in January and March 1980, bear 1086 had a mean heart rate of 19.3 beats/min ($SD \pm 2.7$, $N = 21$; Table 4). These rates were within the same range as those observed from the ground on 23 February during undisturbed conditions ($\bar{x} = 18.6 \pm 4.4$ SD, $N = 209$; Table 3) and similar to those observed from overflights during 1–3 May (Table 4). However, on 9 May, 3 days before den emergence, heart rates during an aerial overflight rose by about 10 beats/min. One to 3 days after emergence, mean heart rates during overflights were 59 beats/min when the bear was inside the den (Table 4). These were similar to heart rates recorded during a different study under undisturbed conditions when the bear lifted its head, rose from rest, or was active (Follman, unpubl. data).

Five days after emergence on 17 May, bear 1086's heart rate was 53 beats/min as the bear ran toward its den when overflown, but its heart rate slowed to 37 beats/min after it entered the den (Table 4). On 24–26 May, heart rates were initially too fast and erratic to count when the bear was overflown near

its den, but heart rates ranging from 74 to 83 beats/min were recorded after the bear sat down and looked up at the circling airplane on 24 May (Table 4). In early June, during aerial overflights, mean heart rates of bear 1086 were more than 60 beats/min while lying, and 88 beats/min while walking, both slightly higher than mean heart rates observed during resting and active behaviors in undisturbed conditions, which were measured during a different study (Follmann, unpubl. data).

In 1981, bear 1097 also showed elevated heart rates during aircraft overflights during the 1st few days after emergence (Table 5). Heart rates recorded during midwinter flights over the den in December 1980 and early March 1981 were within the range of those obtained from the ground on 22–23 March (12–35 beats/min; Table 2). The bear emerged on 7 May and on that date and for the 2 following days its mean heart rate exceeded 61 beats/min when the aircraft flew over the den and the bear was inside. These rates were similar to heart rates recorded during a different study when the bear was observed lifting its head or rising from a resting position during undisturbed conditions and greater than mean heart rates recorded when the animal was resting (Follmann, unpubl. data). During 10–2 May, mean heart rates were lower, ranging from 19 to 46 beats/min ($\bar{x} = 29.9 \pm 7.3$ SD, $N = 17$) when the bear was inside the den and the aircraft overflew the den at elevations ranging 300–700 m above ground level.

On 26 May and 2 June, heart rates ranged from

Table 4. Heart rates of bear 1086 during aerial overflights before and after emergence from its den in northwest Alaska, 1980.

Date	N	Heart rate (beats/min)			Above ground altitude of aircraft (m)	Behavior
		\bar{x}	SD	Range		
Midwinter in den						
21 Jan	2	23.0	1.4	22–24	150	In den
28 Mar	8	20.3	2.3	19–24	500–700	In den
31 Mar	11	19.8	2.4	16–24	500–700	In den
Late spring in den						
1 May	2	17.5	0.7	17–18	150	In den
3 May	3	22.7	2.3	20–24	150	In den
9 May	4	34.5	7.1	30–45	150	In den
After emergence on 12 May						
13–15 May	6	59.3	10.0	48–70	100	In den
17 May	4	42.6	7.1	37–53	100	Run into den
24 May	4	80.8 ^a	5.1	74–83 ^a	100	Sit, look up
26 May	4	— ^a	— ^a	— ^a	100	Run
10–12 Jun	8	60.4	9.7	42–72	60–100	Lie
15 Jun	1	88.0	—	—	100	Walk

^a Minimum value because some heart rates were too fast or erratic to count.

Table 5. Heart rates of bear 1097 during aerial overflights before and after emergence from its den, northwest Alaska, 1981.

Date	N	Heart rate (beats/min)			Above ground altitude of aircraft (m)	Behavior
		\bar{x}	SD	Range		
Midwinter den						
8 Dec 80	2	12.0	0.0	12.0	—	In den
21 Mar 81						
Late spring in den						
5 May 81	3	22.3	8.7	15–32	400–800	In den
After emergence on 7 May						
7–9 May 81	15	61.7 ^a	11.7	37–81 ^a	500–700	In den
10–12 May 81	17	29.9	7.3	19–46	300–700	In den
26 May–2 Jun 81	12	46.6	5.8	41–61	650–700	Sit/nurse or walk
	10	58.3	9.5	42–75	300	Sit/nurse ^b or walk
	3	69.7	6.0	64–76	30–70	Sit/nurse ^b
Fall						
19–21 Sep 81	5	75.2	7.2	68–84	100–250	Walk/dig
	4	80.0	2.8	78–82	70	Walk/dig

^a Minimum value because some heart rates too fast or erratic to count.

^b Bear stood up on 1 occasion.

41 to 61 beats/min ($\bar{x} = 46.3 \pm 5.8$ SD, $N = 22$) when the bear was overflown by 650–700 m, and increased to 64–76 beats/min as the aircraft descended to less than 70 m. The bear responded by changing behavior (standing up) in 2 of 6 observations. The maximum increase in heart rate (22 beats/min) was not associated with any obvious behavioral changes; it was sitting nursing its cubs and did not get up. In late September 1981, heart rates observed during low overflights ranged from 68 to 82 beats/min (Table 5). The bear was walking and did not change its behavior.

DISCUSSION

In this study, variations in radio collar temperature and signal amplitude often corresponded to changes in heart rate, thus indicating that movement was accompanied by elevated heart rates. However, heart rate can vary independent of motor activity. Therefore, one cannot assume that elevated heart rate always corresponds to movement within a den. Elevated heart rates without corresponding changes in collar temperature and signal amplitude were recorded in 1 bear when seismic crews were not present on 23 February 1980.

Midwinter heart rates of 2 undisturbed denning bears with young recorded during this study were usually about 12–26 beats/min. Heart rates in both bears increased to about 30–50 beats/min for short intervals at least once or twice in a 24-hour period.

This may have been related to the presence of cubs-of-the-year in the den.

During days when seismic exploration vehicles were operating up to 0.8 km from bear 1086's den, fluctuations in collar temperature and signal amplitude were recorded, and mean heart rates appeared to be elevated, suggesting that the bear moved several times inside the den, perhaps in response to noises associated with seismic exploration activities. However, the limited number of observations and the fact that bears apparently show increased heart rates during undisturbed conditions limit the conclusions that can be drawn, especially because heart rate can vary independent of motor activity. Even if animals responded to noises associated with seismic exploration activities, effects on the bears were probably minimal. None of the radio-collared bears deserted their dens in response to seismic activities and all emerged in the spring with no observed deaths of accompanying offspring. Circumstantial evidence suggests that an unmarked bear may have deserted a den within 200 m of a seismic line; however, in another instance, a supply train came within 100 m of a dened female with 3 yearlings without causing den abandonment.

Midwinter overflights of dens in small fixed-wing aircraft did not change the heart rates of 2 female grizzly bears denning with young. About the time of emergence, both bears appeared to respond to aircraft overflights with heart rates higher than undisturbed resting heart rates, but individual differences in re-

sponse were apparent. Bear 1086 showed elevated heart rates during aircraft overflights for a longer period than did bear 1097. Bears in this study area may have been relatively insensitive to aircraft overflights as they were repeatedly located by aircraft during the years 1977–81.

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