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Noise and Vibration Levels in Artificial Polar Bear Dens as Related to Selected Petroleum Exploration and Developmental Activities

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ABSTRACT. The noise and vibration levels resulting from seismic testing, drilling and transport were measured in artificial polar bear dens at Prudhoe Bay, Alaska. It was concluded that the dry and wind-beaten arctic snow muffles both sound and vibrations extremely well and it seems unlikely that polar bears in their dens will be disturbed by the type of petroleum-related activities measured here, providing those activities do not take place within 100 m of the den.

Key words: *Ursus maritimus*, seismic activity, conservation

RÉSUMÉ. Dans des tanières artificielles d'ours polaires situées à Prudhoe Bay en Alaska, on a mesuré le niveau de vibrations et de bruit dus aux essais sismiques, au forage et au transport. On en conclut que la neige sèche de l'Arctique, durcie par le vent, atténue très bien sons et vibrations, et il semble peu probable que les ours polaires soient dérangés dans leurs tanières par les activités pétrolières qui ont fait l'objet de nos mesures, pourvu que ces activités n'aient pas lieu à moins de 100 m de la tanière.

Mots clés: *Ursus maritimus*, activité sismique, préservation

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INTRODUCTION

Petroleum exploration and development are occurring in various locations in the Arctic, where there are important denning sites for polar bears (*Ursus maritimus*). Petroleum activities usually involve winter operations, which coincide with the period when bears use dens.

Pregnant polar bears enter dens in October or early November, where they remain continually for 5-6 months. Cubs are born in December or early January, weigh less than 1 kg at birth and are very poorly insulated (e.g., Kost'yan, 1954; Blix and Lentfer, 1979). Snow dens, in which the air temperature is maintained close to 0°C despite ambient temperatures that fall below –45°C (Blix and Lentfer, 1979), are essential for their survival at least until the end of March or early April, when they first emerge into the open (Harington, 1968; Lentfer and Hensel, 1980).

Denning polar bears are sensitive to disturbance and may abandon their dens if the annoyance is prolonged (Shereshevskii and Petriaev, 1949; Belikov, 1976; Lentfer and Hensel, 1980). Activities related to petroleum exploration nevertheless may occur close to potential denning sites, even though the extent to which surface sound and vibration penetrate snow dens has not been measured. This paper reports measurements of levels of noise and vibration inside artificial snow dens from seismic testing, drilling and transport.

METHODS

Study Area

The study was carried out between 30 March and 5 April near Prudhoe Bay, Alaska (Fig. 1). Snow at Prudhoe Bay is usually hard packed and has a low water content as a result of the low ambient temperatures, low humidity and strong winds that persist throughout winter (Blix and Lentfer, 1979).

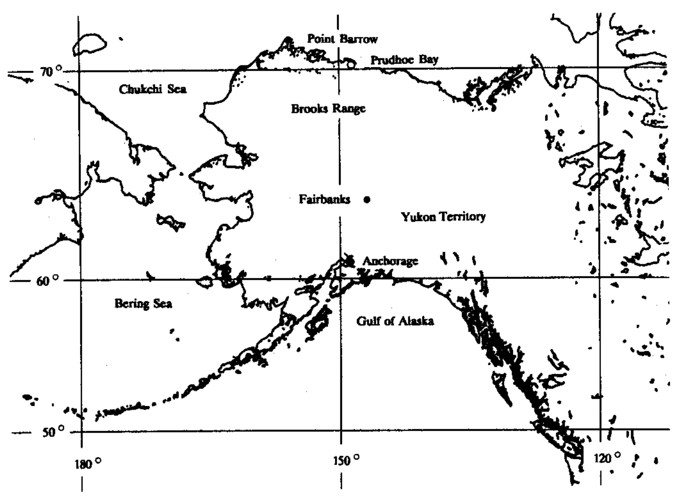

FIG. 1. Map of Alaska showing the location of the study area at Prudhoe Bay.

Dens

Artificial dens of typical size and design (Fig. 2) were dug in the snow at typical sites (Harington, 1968; Larsen, 1975). A microphone (Fig. 2: site 1) and an accelerometer were placed in each den; the accelerometer (Fig. 2: site 2) froze to the floor of the den almost immediately. In one case, a second accelerometer (Fig. 2: site 3) was fastened with a standard fastening bolt to an iron rod that had previously been driven into the tundra under the den and frozen into position with water.

Leads from these instruments were passed out through the den opening to recorders in a warm tent, truck or helicopter. The den's entrance was then filled with snow. Ambient temperatures varied between –25 and –36°C, often with wind speeds of up to 15 $m \cdot s^{-1}$, and, consequently, this snow was consolidated very quickly.

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Since polar bears are also known to den on sea ice (Lentfer, 1975), one additional series of measurements was made with an accelerometer frozen 1) onto sea ice and 2) onto a 60 cm deep snowdrift on sea ice.

Instruments

The following recording devices were used: 1) Two Bruel and Kjær Pulse Precision Sound Level Meters, Type 2204, with Condenser Microphone Cartridge, Type 4145, and 10 m extension cable, for measurements of noise. 2) Two Bruel and Kjær Vibration Meters, Type 2511, with accelerometers, two of Type 4370 and two of Type 8306, for measurements of vibrations. 3) Bruel and Kjær Four Channel Tape Recorder, Type 7005, with two channel compander unit ZM 0054 and FM unit ZM 0053, which made it possible to simultaneously record noise and/or vibration on three channels and dictate information on the fourth. 4) Three Bruel and Kjær Level Recorders, Type 2306, for simultaneous strip chart recording of noise and vibration.

Sound level meters were calibrated before and after each measurement using a Bruel and Kjær Acoustic Calibrator, Type 4230. The accelerometers (i.e., the vibration sensors) were both calibrated and matched to a particular vibration meter before departure for Prudhoe Bay at the Centre for Industrial Research at Oslo, Norway, and were calibrated electronically before and after each measurement. These calibrations were carried out using a Bruel and Kjær Vibration Exciter, Type 4809, and a Bruel and Kjær Reference Normal Accelerometer, Type 8305S, coupled to a Bruel and Kjær Conditioning Amplifier, Type 2626.

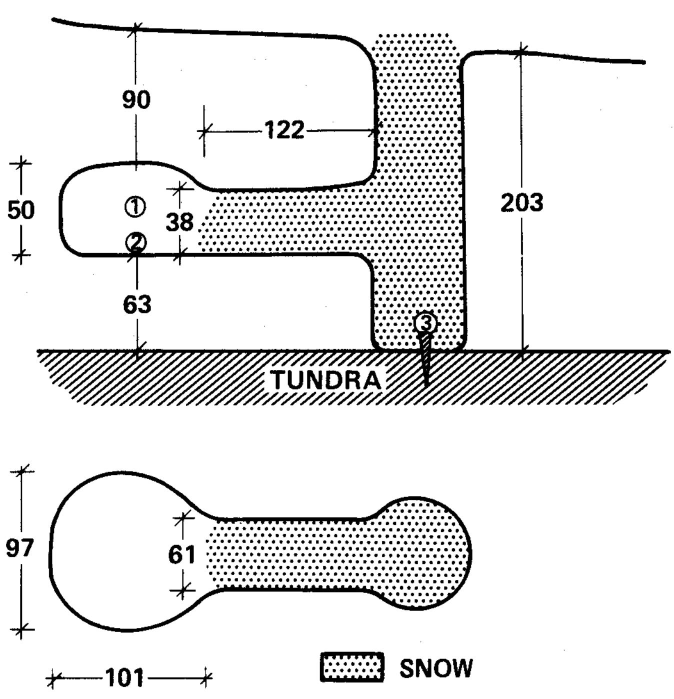

FIG. 2. Standard (artificial) polar bear den, instrumented with a microphone (1) and one accelerometer attached to the floor of the den (2) and to the frozen tundra underneath the den (3). Seen in cross section from the side (above) and from above (below). After instrumentation of the den the entrance was filled with snow ("SNOW") 24 h before any recordings were made. Measurements in cm.

Source of Noise and Vibration in Seismic Testing

The terrain at Prudhoe Bay is relatively flat, and terrestrial seismic exploration is normally carried out using so-called vibrators. These consist of a tracked vehicle equipped with a steel plate (2 m^2 and 12.700 kg weight), which hammers the ground (snow) at, in this case, a frequency of 20-30 Hz (peak power) for 5 s (Fig. 3). The vehicle advances 15 m along a previously defined line between tests and is thus capable of "blasting" once every 20 s. Four Vibroseis® (Geophysical Prospecting System) Model TK-2 vibrators were used during this study. All four vehicles were active simultaneously, with a combined transferred energy of approximately 244 000 J in a procession stretching over 50 m (Fig. 3).

Seismic Tests on Land (1): A standard polar bear den (Fig. 2) was dug 65 m from a seismic transect. Noise levels in the den (Fig. 2: site 1) and vibrations on the snow floor (Fig. 2: site 2) and in the tundra under the den (Fig. 2: site 3) were recorded. Measurements were made continually while the vibrators advanced toward and passed the den. In this way it was possible to relate both parameters to the distance between the den and the site of vibrations. In addition, above-ground noise levels were measured 3 m from all four active Vibroseis®.

Seismic Tests on Land (2): A standard polar bear den (Fig. 2) was dug in a new locality that permitted recording at a minimum distance of approximately 18 m from the seismic transect. Both noise (Fig. 2: site 1) and vibration (Fig. 2: site 2) levels in the den were recorded.

Seismic Tests on Sea Ice: A considerable amount of seismic testing is carried out on sea ice. Ice is extensively, though not completely, covered by snow similar to that found on land. Unfortunately, however, it was not possible to find snow deep enough to dig a standard polar bear den close to a seismic transect. Instead, vibration levels were measured at the top of a 60 cm deep snowdrift on 1.4 m thick sea ice continuous with the mainland and lying over 1.8 m of seawater.

Drilling Tower: An artificial den (Fig. 2) was dug 30 m from a drilling rig (Fig. 4) located on an offshore artificial gravel island. The island used by us had been constructed by transporting large amounts of gravel to the island site over an ice road in the winter. Again, both noise and vibration levels in the den were recorded.

Helicopter Noise: The drilling tower den (above) was also used for measuring noise and vibration levels resulting from the take-off of a helicopter (Bell UH-1B) 3 m from the den. Noise and vibration levels were also measured above the ground, 3 m from the helicopter, in the same situation.

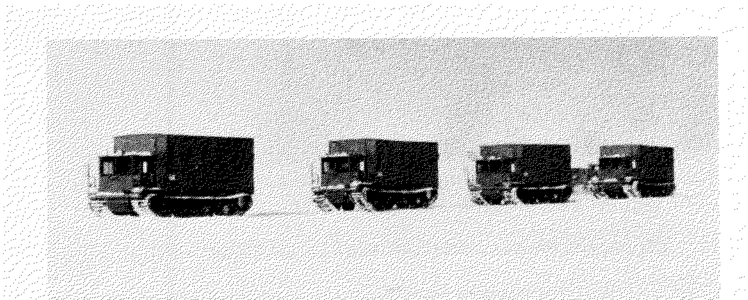

FIG. 3. The assembly of 4 Vibroseis® tracked vehicles equipped with steel plate (2 m^2 and 12.700 kg), which hammer the ground (snow) and produce "blasts" with transferred energy of approximately 244 000 J in a procession stretching over 50 m.

Road on Land: Noise and vibration levels were also recorded in an artificial den (Fig. 2) dug 65 m from a gravel road. This road, which was in a poor state of repair, was used by a variety of large vehicles (loaded weight of 80 tons) that travelled at 30-40 km·h^{-1} (Fig. 5).

Road on Sea Ice: The "ice road" from the natural "Reindeer Island" to the artificial "Seal Island" was used. Unfortunately, it was not possible to find snow deep enough to dig a standard polar bear den close to this or any other of the ice roads. Instead, vibration levels were measured on the surface of the sea ice 2 m from the road when a variety of vehicles, including those shown in Figure 5, were passing by, using an accelerometer that was frozen into position.

RESULTS

The results of the measurements of noise and vibration in artificial polar bear dens from seismic testing on land, vibration in snow from seismic testing on sea ice and noise and vibration in an artificial den adjacent to a road on land are presented in Table 1. Typical records of noise and vibration in a den during seismic testing on land are shown in Figures 6 and 7 respectively.

Measurements in an artificial den 30 m away from a drilling tower revealed noise levels (Fig. 2: site 1) of 36-42 dB (continuous) and vibration levels (Fig. 2: site 2) of 0.006-0.016 g (continuous) during active drilling, while the corresponding values were 36-42 dB (continuous) and 0.008-0.013 g (continuous) during changing of the drill shaft.

The noise (Fig. 2: site 1) and vibration level (Fig. 2: site 2) in an artificial den at 3 m distance from a helicopter during take-off was 76-78 dB (continuous) and 1.585-2.513 g (continuous) respectively. The noise level above ground (in air) at 3 m distance from the helicopter was 114-116 dB (continuous).

The vibration level (above ground, directly on sea ice) adjacent to a road on floating sea ice was not detectable before vehicles of 80 tons (Fig. 5) approached closer than 100 m. The highest value (0.510 g) was recorded with the vehicle passing only 5 m from the sensor at approximately 80 km·h^{-1}.

DISCUSSION

This study has shown that the type of snow we found in the cold, dry parts of Alaska where polar bear dens occur (Lentfer and Hensel, 1980) absorbs/muffles sound extremely well. This was particularly well illustrated in the helicopter test, where a noise level (above ground) of 115 dB was reduced to 77 dB in an artificial polar bear den covered by less than 1 m snow just 3 m away. It is important in this context to note that the decibel scale is exponential. Thus, the normal noise level in a living

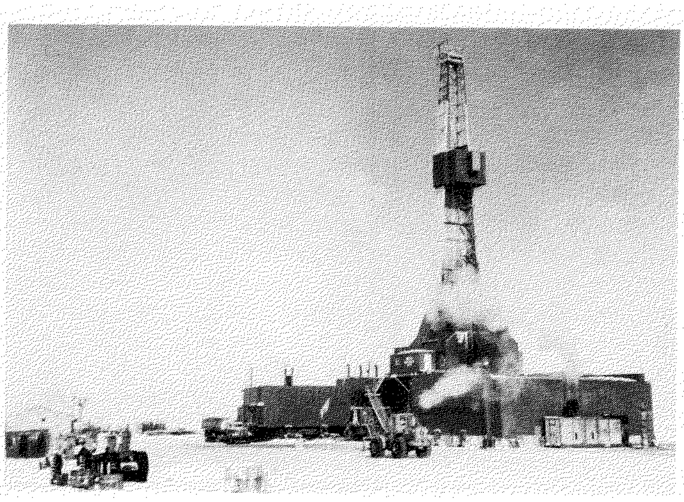

FIG. 4. Drilling tower on an artificial island off Prudhoe Bay, Alaska, used in this study.

FIG. 5. One of the heavy (loaded weight of 80 tons) vehicles running both on gravel and ice roads during the present study.

TABLE 1. Noise (measured at Fig. 2: site 1) and vibration levels (measured at Fig. 2: sites 2 and 3) in artificial polar bear dens during bursts of seismic vibrations at different distances (m) from the den on land and vibration levels on snow (measured at Fig. 2: site 2) over sea ice[1]

	Seismic on land (1)						Seismic on land (2)				Seismic on sea ice		Road on land	
	Noise, site 1		Vibration, site 2		Vibration, site 3		Noise, site 1		Vibration, site 2		Vibration, site 2		Noise, site 1	Vibration, site 2
Distance (m)	A	I	A	I	A	I	A	I	A	I	A	I		
700	—	—	*	*	*	*	—	—	*	*	0.0001	*	0-15	*
530	24-32	24-32	*	*	*	*	32-42	32-42	*	*	0.0003	*	10-20	*
300	20-30	20-30	*	*	*	*	36-46	36-46	0.004	0.003	0.0006	*	10-20	*
100	40	20-38	0.001	*	0.003	*	50	36-46	—	—	0.0030	*	15-20	*
65	70	32-48	0.001	*	0.020	0.002	58	36-46	0.010	0.003	—	*	26-30	0.001
30	—	—	—	—	—	—	68	40-48	1.000	0.390	—	*	—	—
18	—	—	—	—	—	—	78	58-60	1.000	—	0.0250	*	—	—

[1] Data are given for the active burst periods of vibration (A) and for the intervals (I) between. Noise level above ground 3 m from the four vibrators was 85-90 dB (continuous) in the intervals between vibrations, with a maximum value of 103 dB during vibrations. Data on noise (Fig. 2: site 1) and vibration (Fig. 2: site 2) in a den exposed to traffic on an adjacent road on land are also included.

All noise levels are given in dB (lin.) and all vibration levels are given in g (9.81 m·s^{-2}) — RMS. The levels presented for the farthest distance from the den are representative for background noise and vibrations.

* not detectable level.

— not measured.

room is about 40 dB, in an office 60 dB, in a city street 85 dB and close to a jet aircraft during take-off 125 dB. Other than the helicopter, the only examined activity that produced noise levels in the den exceeding 10-15 dB above background was seismic testing less than 100 m from the den.

The background noise level is strongly affected by wind. The "road on land" trial, for example, was made during a period when the air was completely still. Background noise levels varied in the range 0-15 dB. The "seismic tests on land (2)" trial, on the other hand, was conducted during windy conditions. Background levels in this case reached 50 dB, despite there being no activity or any artificial source of noise within 1 km of the test site. Thus, it is plain that a polar bear in its den will normally and quite naturally experience considerable variation in noise levels caused to a large extent by the wind.

This study has also shown that dry, cold snow absorbs vibrations very effectively. Only three trials (an 80 ton vehicle travelling at 70-80 km·h^{-1} over sea ice a few metres from the sensors, land seismic activity closer than 50 m and a take-off at 3 m) produced vibrations with an intensity exceeding 0.1 g in the den.

The biological significance of vibration cannot, however, be evaluated from g (displacement) values alone. The frequency of the vibration, too, is important. Vibrations at 0.1 g, for example, can be felt without difficulty at 10 Hz by putting a finger on, for example, an accelerometer calibration device (e.g., Bruel and Kjær, Vibration Exciter), but they are barely detectable at 30 Hz. On the other hand, vibrations at 1.0 g can be felt regardless of their frequency.

The frequency spectrum output of the Vibroseis® equipment used in Alaska is kept secret by the operators and is thus not available. However, the power output is said to be greatest at 30 Hz. This indicates that a polar bear in its den is unlikely

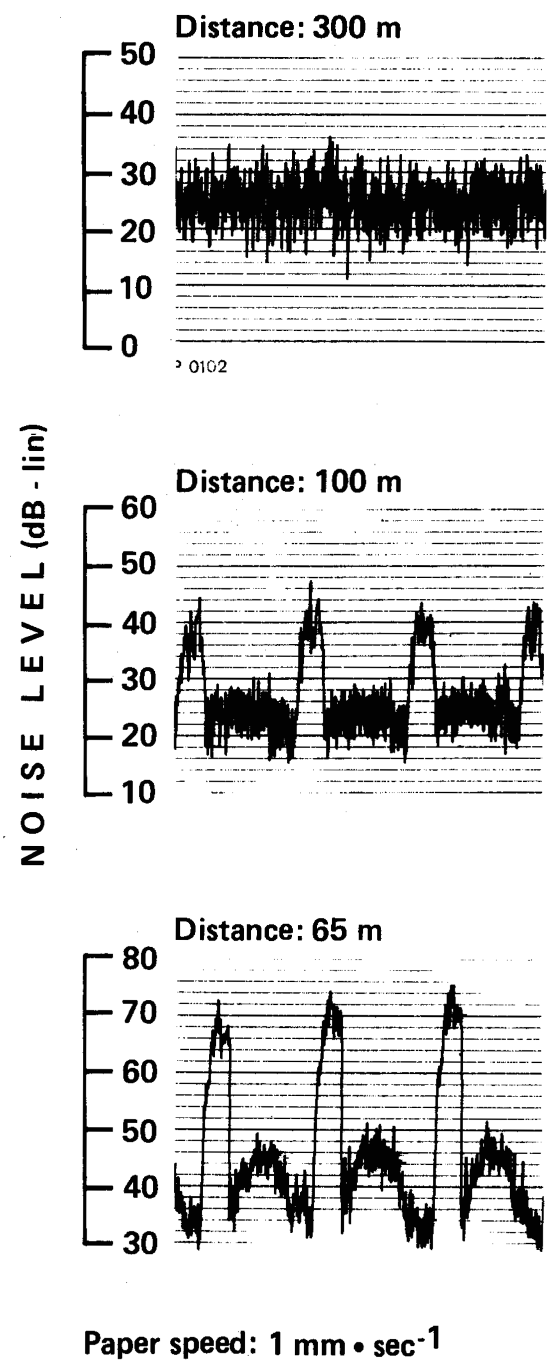

FIG. 6. Noise level (dB-lin) in standard polar bear den (Fig. 2: site 1) during a series of seismic vibrations (seismic tests on land [1]) at 300, 100 and 65 m from the den.

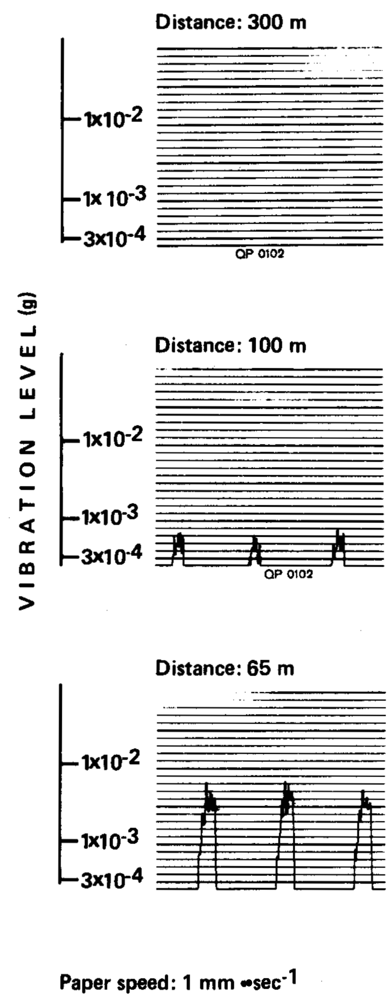

FIG. 7. Vibration levels (g) on the floor of a standard polar bear den (Fig. 2: site 2) during a series of seismic vibrations (seismic tests on land [1]) at 300, 100 and 65 m distance from the den. Measurements presented in Figures 6 and 7 were made simultaneously in the same den.

to feel man-made seismic vibrations, except when they occur very close, at least, under the circumstances experienced by us.

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