POLAR BEAR ELECTRONIC DETERRENT AND DETECTION SYSTEMS

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Abstract: The responses of free-ranging polar bears (*Ursus maritimus*) to acoustic and electrified-fence repellents, and to trip-wire and proximity detection systems, were evaluated in a 4-year study. Natural and synthesized acoustic repellents deterred 69% ($N = 71$) of bears who attempted to enter a test perimeter. Position of speakers, sound amplitude, and the timing of presentations are important factors in the effectiveness of acoustic repellents. A 20-kV electrified fence repelled 35% ($N = 52$), and a 60-kV fence repelled 33% ($N = 6$) of intruding bears. Tests on a patch of polar bear fur indicated that a nominal 200 kV is required to reliably deliver an electric shock through the highly insulating hair of this species. Tests on single, double, and triple trip-wire fences yielded a 93% ($N = 161$) success rate for detecting intruding bears. A proximity (capacitance-sensing) detection system detected 100% ($N = 13$) of bear entries, but was too sensitive to stray electrical inputs. A modified system in the 2nd season detected 63% ($N = 41$) of intrusions. Refined versions of these devices could offer significant improvements in safety for personnel who must work in close proximity to free-ranging polar bears, black bears (*U. americanus*), or grizzly bears (*U. arctos*).

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In the Canadian and American arctic, polar bears are frequently encountered by oil and geological exploration personnel, scientific personnel, and local inhabitants, often with injurious or fatal consequences (C. Jonkel, unpubl. rep., Can. Wildl. Serv., 1975; I. Stirling, unpubl. rep., Can. Wildl. Serv., 1975*a*). Increased human activity in the north has resulted from enhanced utilization of natural resources, exploration for these resources, or population increases in coastal arctic towns and villages, and has led to an increase in the numbers of these potentially dangerous encounters. Several devices have been locally promoted as suitable for scaring bears, including aerosol boat horns, the roaring of car engines, thunderflashes, teleshot flares, mace and other lachrimators, gunshots, and a wide variety of other scientifically untested devices. Unfortunately, in many instances, use of these devices in defense during a real attack leaves little time for an objective scientific analysis of the process or outcome.

This research was initiated when an employee of an ESSO Resources Canada off-shore drilling rig was killed and consumed by a subadult male polar bear on the Beaufort Sea in the Canadian arctic (I. Stirling, unpubl. rep., Can. Wildl. Serv., 1975*b*). ESSO expressed interest in evaluating the use of ultrasonic sound generators as a deterrent against polar bear intrusions.

Several researchers have experimented with the use of acoustic stimuli as repellents; Belton and Kempster (1962) used ultrasonic bat mimics to repel moths from corn fields, Dracy and Sander (unpubl. annu. rep. WC123, S. Dak. State Univ., Brookings, 1975) attempted to deter coyotes with ultrasonics, and Maclean (1974) used ultrasonics to repel rats. Biologically significant sounds (recorded rat distress sounds) were used by Sprock et al. (1967) to repel lab rats.

Initial investigation on polar bears began with an evaluation of ultrasonics of high intensity and frequency (16 kHz, 120 dB) (D.R. Wooldridge, P. Belton, and C.C. Mueller, unpubl. rep., 1976; Wooldridge and Belton 1980). These studies indicated a limited potential for effective repellency on both free-ranging and captured polar and brown bears.

Subsequently, the aggressive vocalizations of captured polar bears were recorded and electronically analyzed for spectral content and amplitude envelope (relative amplitude vs. frequency in 1/3-octave bands), and several synthesized "roars" were produced. These sounds exaggerated or clarified several components thought to be significant to polar bears, and were tested on captured and free-ranging black, grizzly, and polar bears. Several of the sounds were found to be generally effective (Wooldridge and Belton 1980).

Studies by Gilbert and Roy (1977) indicated that a combination of electrified fences and lithium chloride-treated baits could reduce black bear visits and damage to beeyards in northern Alberta. These tests utilized a standard cattle "fencer" device, delivering approximately 500 V at a frequency of 1 to 2 Hz. An involuntary tetanic muscle response is achieved at much higher frequencies (30 to 50 Hz).

Several seasons of study under typical arctic field conditions prompted research into the design of effective detection equipment which would provide advance warning of an intruding polar bear and simultaneously activate a variety of proven or test deterrent systems.

The objectives of the studies reported here were to determine the effectiveness of several natural-origin and electronically synthesized sounds as repellents, to evaluate electrified fences as an effective deterrent system, and to design and evaluate several trip-wire fences and proximity antenna designs as possible detection systems for field use.

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MATERIALS AND METHODS

Repellents: Acoustics

The electronic recording, analyzing, and synthesizing techniques employed to generate the original and synthesized polar bear aggressive sounds used in this study were outlined in a previous publication (Wooldridge and Belton, 1980). Tests were conducted at Churchill, Manitoba, an area of high polar bear concentration each fall. Bears await freeze-up of Hudson's Bay and are easily attracted to dumps, camps, and other sites of human activity. During 1976, bears were observed from a truck which was moved to various locations. Two artillery ranging towers on the coast of Hudson's Bay, about 20 km and 35 km east of Churchill, were used as bases of operation for the last 3 years of study. Test sites were positioned around these towers and, during the 2nd and 3rd seasons, sardine-mash baits were used to attract bears into the test sites.

The sound playback equipment varied with each year. In 1976 I utilized a 100-W amplifier, a cassette recorder/player, and a 1.0-m double-reflex University Sound Horn; in 1977 I used a 20-W public-address amplifier and a 0.5-m single-reflex University Sound Horn; in 1978 I used a 15-W stereo amplifier and the same speaker as in 1977. Sound levels (averaged for all types) were 120 dBA in 1976, 91 dBA in 1977, and 85 dBA in 1978 (dBA = decibels measured on the "A" scale).

During 1976, the large speaker was held out of the window of the truck or was positioned on the ground. The sound source was always distant (100m) from the bears when sounds were initiated. During 1977 and 1978, the speakers were mounted on posts at approximately 1.5 m height and within 2 m of the bait station or test site. Sounds were generated only when the bear was within 1 to 2 m of the sound.

Responses of bears were classified as: strongly repelled (an immediate and obvious rapid retreat from the site without return within 1 hour); repelled (walking retreat from the site, return within 1 hour); undecided (no apparent reaction, may walk away temporarily); no response (no apparent retreat); investigate (show some interest in the sound system); and aggression or attack (an advance on the speaker, possible attack on the speaker, or vocalization in response to the sounds). In these tests, only 3 responses were seen: strongly repelled, no response, and investigate.

In 1976, bears were allowed to feed at bait stations for several minutes before initiation of the test sounds. All test sounds developed in previous work (Wooldridge and Belton 1980) were used; sounds were played for 15 to 30 s. Bears who were subjected to the sounds and returned were not tested again until 1 hour had elapsed. In 1977 and 1978, approaching bears were allowed to feed for a minimum of 4 minutes before sounds were initiated; sounds were then run for 10 to 15 s. In 1977 and 1978 a composite of natural and synthesized sounds was used. In 1979, only synthesized sounds were used, based on their previous effectiveness. During the 1977 to 1979 studies, sounds were initiated whenever a bear returned.

Repellents: Electrified Fences

A double-wire electrified fence system was set up in 1978 at one of the coastal observation towers. The charge generator produced a variable 15– to 20–kV DC pulse at a frequency of approximately 2 Hz. Preliminary tests indicated that the 20–kV level was more effective than the 15–kV level, and this was used in all subsequent trials. A single-strand 8 gauge tinned copper wire was supported on ceramic "egg" insulators at each post, at a height of 0.3 and 1.0 m, on a fence positioned approximately 10 m from the tower. Responses of the bears were observed from inside the tower and their behavior was classified as in the acoustic repellent study. The system was deactivated each night (to allow recharging of the battery system) and the wires were let down to prevent damage.

In 1979 the charge generator was redesigned to provide a 60–kV square-wave DC pulse at a frequency of 40 Hz. This frequency was chosen as that most likely to cause muscle tetany. A 4-wire fence was set up at heights of 90 cm, 60 cm, 30 cm, and ground level, with alternating "hot" and ground wires. The fence surrounded the base of the tower at an approximate distance of 10 m with support post spacing of 7 m.

Detection: Trip-Wire Systems

In 1977, 3 fenced bait sites were set up approximately 15 m from the base of the observation tower. The trip-wires were supported on 5×5-cm wooden posts, set approximately 4 m apart, supporting either a single- or double-wire system. The wire was 22-gauge, 7-strand, nylon-coated, and carried in-line E.F. Johnson jack-and-plug connectors that separated under tension. Wire heights were 15 cm (single-wire fence) and 15 and 70 cm (double-wire fence). Wires were tensioned to minimize sag over the span of each section, and wire-wrap tensioning clips were used to preload the connectors against separation under normal wire tension. Wires were supported by house electrical staples.

Observations were made from the tower or from a truck, and baits were used to attract bears into the site. A bear was considered detected if the connector disengaged. Wires were reconnected and baits replenished after each detection.

In 1978, 2 fenced sites were set up near the observation tower and both sites were surrounded by a single trip-wire at a height of 50 cm. Post size, spacing, and all tensioning and connection systems were as in 1977. All observations were made from within the tower. Both 1977 and 1978 fences utilized the fence wires as part of the electrical circuit: a disconnection of the in-line connectors would lead to disruption of an electrical circuit, signaling an intrusion.

In 1979, a double and triple trip-wire fence was set up around the base of the tower. The perimeter wires were not part of the electrical circuit but rather the 1.6-mm braided stainless-steel cables were supported on a pulley system and acted on microswitches, thus signaling the intrusion of a polar bear. Wire heights were 56 and 40 cm (double-wire system) and 46, 40, and 20 cm (triple-wire system). Wire tension was maintained by a pulley and weight system at the end of each of 2 fence sections, and post spacing was 10 m. The perimeter took the general shape of an ellipsoid to reduce lateral loading on the switches and support pulleys. No baits were used to attract the bears. Observations were made from within the tower; a detect was signalled by activation of an associated main control device.

Detection: Proximity Antennas

A battery-operated proximity detection system was set up in 1977 near the base of the observation tower. The antenna wire, at a height of 1.5 m, was supported on 3 5×5-cm posts, spaced in a triangular layout, 22 m on a side. The detector operated by amplifying small changes in the field charge on the antenna which occurred when a bear moved nearby. Baits were used to attract bears, and a detect was recorded if the electronic counter in the tower was activated during an intrusion.

In 1978, the detector circuitry was modified to average and filter out overcounts, which occurred in 1977. Antenna span was 12 m on a 4-sided layout. Wire height was 1.3 m. As in 1977, a detect was signalled by an electronic counter in the observation tower.

RESULTS

Acoustic Repellents

The responses of 71 free-ranging polar bears to acoustic repellents are summarized in Table 1. A total of 74 bears were tested for their responses to acoustic repellents. The behavior of 51 bears described as *strongly repelled* was typified by a rapid and immediate retreat away from the sound source, with continued running from the general area, for distances of 200 to 1000 m. Eight bears were classed as giving *no* apparent *response* to the sounds. These animals either continued entering the site or walked around it. Fifteen bears were classified as *investigating* the sound source. This behavior was typified by slow approaches, sniffing and pawing the speaker, and rubbing against the speaker support post.

Electric-shock Repellents

A total of 58 free-ranging bears were tested for their responses to the 20-kV, 2-Hz and 60-kV, 40Hz electrified fences. Stongly repelled bears, 34 in 1978 and 2 in 1979, reacted by immediately pulling away from the wire and running away from the study area. In 1978, 13 bears apparently received a shock (they sniffed or touched the wire and immediately recoiled) but were not repelled from the site. Further, 7 of the bears attempted to enter the site immediately (within 2 minutes) after the first attempt. Of these, 5 were able to enter despite the fence system. I subsequently tested a patch of dry polar bear fur and found that a nominal 200 kV was necessary to reliably arc through the 6 cm average fur depth. The part of the bear's body which made contact with the fence varied in most approaches, although it was most often the head, nose, ears, or shoulder which made first contact.

Trip-wire Detection Systems

The single and double trip-wire fence systems detected all 42 entries in 1977, and 36 of the 42 entries (86%) in 1978. Both the single- and double-wire fences required reconnection and repair after each entry had pulled apart the in-line plug and jack, and did not separate at all in 6 instances, accounting for the 6 undetected entries. In 1979, the double-wire microswitch system detected 36 of 41 entries (88%) and the triple-wire microswitch system, 36 of 36 entries. The cable and microswitch system required occasional resetting of the switches but proved to be very rugged and reliable despite cold weather conditions. Bears activated all systems by stepping down on the wires or by pushing through them as they entered the site. The triple-wire microswitch system provided too many obstacles for bears to enter undetected; this system detected all entries and required no maintenance over the study period.

Table 1. Responses of free-ranging polar bears to acoustic and electric-shock repellents, Churchill, Manitoba, 1976–79.

			Response of bears					
		Total number	Strongly repelled		No response		Investigated	
Year	Type of system	tested	No.	%	No.	%	No.	%
Acoustic repellents[a]								
1976	Natural, 120 dB	15	12	80	3	20		
1977	Nat.-Syn., 91 dB	9	9	100				
1978	Nat.-Syn., 85 dB	21	8	38	4	19	9	43
1979	Syn., 90 dB	29	22	75	1	3	6	22
Totals		74	51	69	8	11	15	20
Electric-shock repellents								
1978	20 kV, 2 Hz	52	34	65	18[b]	35[b]		
1979	60 kV, 40 Hz	6	2	33	4[c]	67[c]		
Totals		58	36	62	22	38		

[a] Broadcast sounds were natural bear vocalizations in 1976, composite natural and synthesized sounds in 1977 and 1978, and synthesized sounds in 1979; for further details see Wooldridge and Belton 1980.

[b] Of the 18 bears showing no response, 13 received shocks; 7 of these tried re-entering the fence within 2 minutes.

[c] The 4 bears showing no response did not apparently receive a shock.

Proximity Detector System

The proximity detector antenna was tested in prototype form in 1977. It detected all 13 entries during the tests. It also overcounted, being affected by various electrical field transients from the aurora borealis, electrical storms, and other, unexplained phenomena. In 1978, I modified the system with a filtering and averaging circuit, and found that the device detected only 26 out of 41 intrusions: the circuitry was filtering and averaging out the electrical charge variations associated with the intrusion of bears as well as the undesired electrified charges.

DISCUSSION

The results of this 4-year study indicate that acoustic repellents and electrified fences can repel polar bears, and that a trip-wire detection system can be relied on to provide a high level of security for arctic activity sites.

Studies with various acoustic repellents (Maclean 1974; Stewart 1974; Dracy and Sander, unpubl. annu. rep. WC123, S. Dak. State Univ., Brookings, 1975; Wooldridge, Belton, and

Mueller, unpubl. rep., 1976) have raised the question of habituation to the repellent stimulus. Exposure to an irritating or painful sound source does not necessarily result in a strong repellent response after many experiences. The timing and presentations of these aggressive sounds are therefore significant factors in their success. The combined effects of the presentation of a high-amplitude sound (possibly at the pain or discomfort threshold) plus a biologically significant message to an animal naturally conditioned to respect and react to territorial threats may act to reduce the possibility of habituation. Additionally, the system may be of greatest utility in situations involving a naive, curious and possibly hesitant bear, where the primary intent is to scare the animal away and reroute it around the camp. A bear which is accustomed to human activity or one which has been actively chased, trapped, or otherwise handled or harassed is less likely to respond as desired to such a repellent system.

Nominal requirements for effective use of acoustic repellents of this type are: a minimum of 100 dBA speaker output (measured 1 m from the speaker); a point source for the sound as opposed to a general, nondirected broadcast of the sound; and adequate and accessible escape routes or terrain for the target bear (it would not do to corner a nervous bear with loud aggressive sounds). Sounds should be initiated only when the bear is within approximately 100 m: too distant a sound can actually attract the bear.

Electrified fence systems seem less effective in repelling free-ranging polar bears. The presentation of a painful stimulus will repel most animals; however, the system under test was apparently incapable of delivering such a stimulus, for the following reasons. Primarily, the fur of a polar bear is a particularly good electrical insulator, especially under typical dry-air conditions prevalent in the arctic. No reliable arc through the test fur patch was generated at potentials lower than 200 kV, a difficult level to work with in the field. Secondly, frozen, dry-snow-covered ground compounds the problem of completing the shock pathway through the bear; and finally, hoar-frost on insulators allows some of the fence voltage to leak off.

Improvements in effectiveness could be achieved through the use of heavy-duty barbed fencing, itself acting as a physical barrier to entry, coupled with a 40- to 80-kV potential, applied at 40 Hz. The barbs would act as "combs" into the bear's fur. Insulators would have to be frost-protected, and small bait-scented foil strips on the fence may contribute to an effective shock delivery. A preliminary test of a scented aluminum foil "windmill" on the wire indicated that a localized attractant leading to an attempted removal by biting could greatly enhance the delivery of a shock to the bear.

The trip-wire detection system in its current state of design can be confidently relied on to provide adequate warning of a possible bear intrusion. Further development will focus on improvements in hardware and electronics, with no further need of conceptual development. A mini-system has now been developed, utilizing a pair of single 50-gauge wires as part of the circuit. This system is now in use by several exploration companies in the north and has proved itself on several occasions.

The proximity detection system was less satisfactory and its effectiveness erratic. The system is extremely sensitive to electrical transients. It may have applications in small-dimension situations, such as counting approaches to bait stations or monitoring a corridor or fence opening with a maximum 10 m width. The sensitivity of the device rises exponentially with increases in antenna length, resulting in the observed erratic counts.

Based on my findings, several recommendations can be made. Of primary importance in providing a safe environment for personnel in bear country is the provision of adequate warning that an animal is in the area. This can be reliably achieved through the deployment of an advanced trip-wire system such as I have described above. Once all personnel are safe, other actions can be taken, including the use of a nondestructive repellent system. The conditions during the encounter will determine the success of its outcome, and will (in some instances) lead to the necessary destruction of bears. A garbage-trained bear, a free-ranging bear with past experiences with humans, or a hungry dominant animal may well not respond as desired to any repellent system. On-site safety personnel should be prepared for such a possibility with a suitable backup plan.

The systems described have some application for other species of bear. In particular the electrified fence may work well on bears active in the summer (blacks or grizzlies), on moist ground and with thinner summer coats. The detection systems would work equally well for all species, and may have useful applications at pipeline construction camps or around boreal forest drilling rigs or camps.

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